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Inflation and core money growth in the euro area

Manfred J.M. Neumann
(University of Bonn)

Claus Greiber
(Deutsche Bundesbank)

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Deutsche Bundesbank, Wilhelm-Epstein-Strasse 14, 60431 Frankfurt am Main,
Postfach 10 06 02, 60006 Frankfurt am Main

Tel +49 69 9566-1
Telex within Germany 41227, telex from abroad 414431, fax +49 69 5601071

Please address all orders in writing to: Deutsche Bundesbank,
Press and Public Relations Division, at the above address or via fax No +49 69 9566-3077

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Abstract:

This paper studies the importance of money for inflation in the euro area. An inflation equation is derived from a small model that combines the supply and demand for money with a Phillips curve and the assumption that inflation expectations develop adaptively. The model's solution attributes an impact on inflation not to actual money growth but to its core component. The core component is defined as the long-lasting, low-frequency component of nominal money growth in excess of real money demand. Using quarterly euro area data from the 1980-2004 period we apply different filters (Hodrick-Prescott, Baxter-King, wavelets) as empirical measures of core money. The estimation results uniformly indicate that inflation and core money growth are closely linked, exhibiting a one–to-one relationship in the long-run. Higher-frequency money growth, in contrast, contributes nil to the explanation of actual inflation. As a stylised fact regarding frequency domain properties, cycles of money growth below eight years are found to be insignificant for inflation.

Keywords: ECB; inflation; quantity theory; frequency analysis; Hodrick-Prescott filter; band pass filter; wavelets

JEL-Classification: E31, E42, E52, E58

Non Technical Summary

In this paper we analyse the role of money growth as a carrier of information about inflation in the euro area. The study is motivated by the recent literature on the importance of monetary aggregates for monetary policy as well as the discussion on the strategy of the ECB.

In a theoretical model a standard Phillips curve is combined with an adaptive process describing inflation expectations. Additionally, a link between inflation expectations and the growth of the money stock is provided. The approach resembles the quantity theory of money in the sense that there exists a one-to-one long-run relation between "core money" growth and inflation. Core money growth is defined as the excess of permanent nominal money growth over permanent real money demand growth; the latter is equal to permanent output growth adjusted for the long-run income elasticity of money demand. A key characteristic of the core money concept is that short-run fluctuations of money growth, generated by the accommodation of money demand shocks, are eliminated as they do not invoke inflation.

The empirical performance of the core money model is tested for inflation defined as the quarterly growth of HICP using data for the euro area. An innovative aspect of our econometric strategy is to explain inflation by using symmetric filters in order to measure the permanent components of money and real growth. The filters allow for investigating which frequencies of money and output growth are relevant for explaining inflation and this way assessing how "long" the long-run relation between money and inflation is in the frequency domain. The quantity theory postulate of a stable long-run link between inflation and low-frequency money growth for the euro area is clearly supported. This relation appears to rest on relatively long lasting cycles of monetary growth. Short to medium-term fluctuations of money growth with cycles of up to about eight years are found to be insignificant for inflation. This result does not have any implications for the time lags between money growth and price changes. The lag between core money and inflation is rather short.

Hence, as in a number of empirical and theoretical studies, it is confirmed that money in the euro area has an extra informational value with respect to inflation beyond interest

rates or indicators of real activity. In sum, the evidence presented in this paper lends support to the ECB's view on the importance of M3 growth for inflation.

Nicht technische Zusammenfassung

In diesem Artikel untersuchen wir die Rolle des Geldmengenwachstums als Indikator für die Inflationsentwicklung im Euro-Raum. Die Studie ist durch die jüngste Literatur über die Bedeutung von monetären Aggregaten für die Geldpolitik sowie die Diskussion über die Strategie der EZB motiviert.

In einem theoretischen Modell wird eine herkömmliche Phillips-Kurve mit einem adaptiven Inflationserwartungsprozess verknüpft. Zusätzlich wird eine Verbindung zwischen Inflationserwartungen und Geldmengenwachstum modelliert. Der Ansatz ist quantitätstheoretisch im Sinne einer langfristigen eins zu eins Beziehung zwischen der Kernkomponente des Geldmengenwachstums, „Core Money“, und der Inflationsentwicklung. Core Money ist definiert als der Überschuss der permanenten Komponente des nominalen Geldmengenwachstums über die permanente Komponente der realen Geldnachfrageentwicklung; letztere entspricht dem mit der Einkommenselastizität der Geldnachfrage gewichteten, permanenten realen BIP-Wachstum. Eine zentrale Eigenschaft des Core Money Ansatzes besteht darin, dass kurzfristige, durch die Akkomodierung von Geldnachfrageschocks bedingte Schwankungen der Geldmenge ausgeblendet werden, weil sie die Inflationsrate nicht beeinflussen.

Im empirischen Teil wird das Core Money Modell für die Inflationsrate - definiert als vierteljährliche Zuwachsrate des HVPI - im Euro-Raum überprüft. Einen innovativen Aspekt des ökonometrischen Ansatzes bildet dabei die Verwendung symmetrischer Filter. Sie dienen dazu, die permanenten Komponenten von Geldmengen- und realem Wachstum zu erfassen anstatt die sehr volatilen tatsächlichen Beobachtungen zu verwenden. Dies ermöglicht es festzustellen, welche Frequenzen von Geldmengen- und BIP-Wachstum inflationsrelevant sind oder - anders ausgedrückt - einzuschätzen, wie „lang“ die langfristige Beziehung zwischen Geldmengenentwicklung und Inflation aus Sichtweise der Frequenzanalyse ist. Das Postulat der Quantitätstheorie einer stabilen langfristigen Beziehung zwischen Inflation und niederfrequentem Geldmengenwachstum wird eindeutig unterstützt. Diese Beziehung scheint auf relativ langfristigen Zyklen des Geldmengenwachstums zu beruhen. Kurz- bis mittelfristige Schwankungen des Geldmengenwachstums mit einem Zyklus von bis zu etwa acht Jahren stellen sich

als nicht signifikant für die Inflationsentwicklung heraus. Dieses Resultat lässt keine Schlüsse im Hinblick auf eine zeitliche Verzögerung zwischen Geldmengenwachstum und Preisänderungen zu. Die Verzögerung zwischen Core Money und Inflation ist eher kurz.

Somit wird, wie auch in anderen empirischen und theoretischen Studien, bestätigt, dass Geld einen zusätzlichen Informationsgehalt bezüglich der Inflation aufweist, welcher über den von Zinssätzen und realen Indikatoren hinausgeht. Insgesamt unterstützt die in diesem Papier dargestellte Evidenz, die Einschätzung der EZB bezüglich der Bedeutung des M3-Wachstums für die Inflationsentwicklung.

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1 Introduction

When the European Central Bank (ECB) assumed responsibility for monetary policy for the euro area, it announced a two-pillar framework for assessing the risks to price stability and for communicating the Bank's evaluation to the public (ECB, 1999). Pillar one was designed to organise the analysis of money and credit aggregates and to emphasise the medium-term orientation of the ECB's monetary policy by announcing a reference value for the medium-term growth of the broad money stock M3. Pillar two, in contrast, was intended to focus on the short-term risks to price stability by studying the developments in the real and financial sectors of the economy. In 2003 the ECB reviewed the usefulness of the two-pillar framework. While it confirmed the approach of keeping separate the two complimentary types of analysis, it introduced subtle changes. Besides renaming the pillars as "monetary analysis" and "economic analysis", the ECB reversed the order of presentation in its public communication: the economic analysis is to be presented first, the monetary analysis thereafter. The rearrangement is supposed to indicate "that monetary analysis mainly serves as a means of cross-checking, from a medium to long-term perspective, the short to medium-term indications coming from economic analysis" (ECB (2003a), p. 87).

This reorganisation of the ECB's framework can be interpreted as signalling a gradual move towards giving more importance to the short-run events in the real sector and less importance to the medium to long-run consequences of the ECB's supply of money. If so, the move met the uneasiness among some ECB-watchers with a central bank that, in their view, "stubbornly" appears to believe that money growth is the most prominent information variable for inflation and underpins this by keeping separate the analysis of money and credit. For example, Gali et al. (2004) argue that money growth may or may not be a useful input to short and long-term forecasts of inflation but that this does not justify an extra role for money in the analysis. While the argument has some merits, it seems that additional aspects need to be considered when a choice has to

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[*] We would like to thank Julian Reischle, Peter Tillmann, Michael Scharnagl, Karl-Heinz Tödter and Jens Weidmann for valuable comments.

be made between the ECB’s communication strategy and a more unified approach. It is not our intention, however, to take up this discussion.

In this paper we focus on the role of money growth as a carrier of information about inflation. The study is motivated by the apparent tendency among economists and bankers to ease money out of the picture (King (2002)). Of course, a parsimonious macroeconomic model, combining aggregate supply and demand with an interest rate rule, can do without invoking the variable “money”. But this three-equations-model by no means implies that the standard quantity theory is invalid (McCallum (2001), Nelson (2003), von Hagen (2004)) or that monetary aggregates are useless indicators in practice (King (2002), Leeper and Roush (2003)).

In fact, in a number of recent empirical studies, it has been confirmed for the euro area that money has an extra informational value with respect to inflation beyond interest rates or indicators of real activity. Nicoletti Altimari (2001) finds that money and credit aggregates contain information that is useful in forecasting medium-term and low-frequency trends in inflation. Trecroci and Vega (2002) as well as Gerlach and Svensson (2003) estimate inflation equations where the real money gap, the difference between actual and long-run equilibrium real balances, has predictive power for future inflation.[1] However, Gerlach and Svensson also find that the output gap is at least as informative. Moreover, they reject the Eurosystem’s money growth indicator as it appears to carry “no or very little” information about future inflation (Gerlach and Svensson, 2003, p. 1669). In contrast, Neumann (2003) assumes that money growth affects inflation through inflation expectations and finds that inflation is quite well explained by a measure of the low-frequency component of lagged money growth. Finally, Gerlach (2004) studying the expectational link concludes that money growth contains information about future inflation that is not embedded in the current rate of inflation or the output gap.

Following this strand of literature this study seeks to clarify the empirical strength of the short- and long-term link between money and inflation in the euro area. Regarding methodological issues the paper adds to the literature by systematically

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[1] Jansen (2004) re-estimates the inflation equation of Gerlach and Svensson (2003) with a broader information set and finds that it does not perform worse in forecasting than the ECB’s area-wide model.

exploring the role of different frequency ranges of money growth and trying to assess how "long" the long-run is. As a major result we establish a stable long-run link between inflation and low-frequency money growth for the euro area.

The structure of the paper is the following. In section 2 we present a model of inflation in which the main link from money to inflation is modelled through an inflation expectations process. An important property of this process is that the perceived core growth rate of money is crucial for the expectation formation (Neumann (2003)). In section 3 the model is estimated and tested for the sample period 1980-2004 using euro area data. The theoretical concept of core money growth is empirically approximated by low-frequency filters. To check for the robustness of the results, different filter techniques are explored. Moreover, the frequency range of the link between money growth and inflation is investigated. All results point to the same conclusion: M3 growth is an important carrier of information on inflation in the euro area. Section 4 concludes.

2 A Monetary Model of Inflation

A straightforward model of inflation can be developed by combining a standard Phillips curve with a suitable explanation of expected inflation (Neumann (2003)). To make the model a monetary one, we establish a link between inflation expectations and the growth of the money stock by invoking the quantity theory of money.

Consider a Phillips curve:

$$(1) \qquad \pi_{t+1} = \pi^{e}_{t+1,t} + \beta(y_t - \bar{y}_t) + \varepsilon_{t+1},$$

where π_{t+1} denotes the inflation rate, $\pi^{e}_{t+1,t}$ the expected rate given period t information, y_t the log of output, hence $y_t - \bar{y}_t$ the output gap, defined as the percentage deviation of output from its trend and ε_{t+1} a white-noise shock. The Phillips curve (1) provides two potential channels for money to generate inflation. One is inflation expectations, the other is the output gap. The first channel is the dominant one, linking actual inflation with perceived money growth. The second channel, the output gap, may also play a role by transmitting nominal money shocks as well as real demand shocks but it does not affect the inflation trend since the gap is zero on average. In this paper we concentrate on the role of expected money driving inflation expectations, hence put the focus on the first channel. Thus we treat the output gap as a predetermined variable with respect to inflation.

Following Gerlach and Svensson (2003) the expected rate of inflation is modelled adaptively. They assume that the expected future inflation rate depends on the policy makers' targeted rate of inflation and on the observed deviation of actual inflation from this target. In contrast, we introduce the concept of a "core rate of inflation" and postulate that the expected rate of inflation is related to the the perceived core rate of inflation as well as to the actual inflation rate. The core rate of inflation is a theoretical construct which abstracts from transient noise.[2] It can be defined as the rate of price change that prevails in long-run equilibrium in the absence of transitory shocks to aggregate demand and supply as well as money demand and supply. While the core rate may reflect the monetary authorities' official inflation objective or target, this will not generally be the case given that most central banks try to achieve conflicting goals. To be sure, our theoretical construct of a core rate does not coincide with the statistical ad-hoc measure used by central banks in which the rate of change of the consumer price index is adjusted for the contribution of the prices of energy and unprocessed food.

The inflation expectation for period t+1 is modelled as follows, whereas $\overline{\pi}_t$ denotes the core rate of inflation:

$$\pi^e_{t+1} = \overline{\pi}_t + (1-\alpha)(\pi_t - \overline{\pi}_t), \qquad \text{where } 1 > \alpha \geq 0, \tag{2}$$

or equivalently as

$$\pi^e_{t+1} = \alpha\overline{\pi}_t + (1-\alpha)\pi_t\ . \tag{2a}$$

Thus, the rate of inflation expected for period *t+1* equals the perceived core rate of period *t* plus a fraction of the transitional inflation observed in period *t*.

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[2] See Eckstein (1981) who introduced the idea of core inflation. To quote: "The core rate of inflation can be viewed as the rate that would occur on the economy's long-term growth path, provided the path were free of shocks, and the state of demand were neutral in the sense that markets were in long-run equilibrium." (p. 8). Similarly, Collard and Dellas (2004) differentiate cyclical from "core" developments in the change of actual inflation.

We model the core rate of inflation to be determined by the long-run equilibrium in the money market. To this end we decompose a demand function for (the log of) the real money stock into a long-run and a short-run component:

(3) $$m_{r,t} = m^{l}_{r,t} + m^{s}_{r,t}$$

with:

(3.a) $$m^{l}_{r,t} = \lambda \bar{y}_t - \gamma(\bar{r}^{l} - \bar{r}^{s}),$$

(3.b) $$m^{s}_{r,t} = \lambda_s(y_t - \bar{y}_t) - \gamma_s(i^{l}_t - i^{s}_t) + \nu_t .$$

Following Brand and Cassola (2000) and Gerlach and Svensson (2003), we assume that the opportunity cost of holding money is given by the spread between the long- and the short-term interest rate. The long-run component of money demand (3.a) collects the agents' responses to the perceived medium-term trend of real income $\bar{y}$ given the spread between the perceived long-run equilibrium real rates of interest $(\bar{r}^{l} - \bar{r}^{s})$ which are taken to be constant here. Note that the inflation expectations embodied in nominal interest rates do not show up in the long-run component of money demand because they are equal.[3] Given that the trend income changes rather slowly, so does the long-run component of the demand for money. The short-run component of money demand (3.b), in contrast, is likely to be much more volatile due to stochastic money demand shocks ν_t as well as transitional fluctuations in real income $(y_t - \bar{y}_t)$ and the nominal interest rate differential $(i^{l}_t - i^{s}_t)$. Note that the response coefficients in the transitional component are assumed to differ from the respective coefficients of the long-run component. To be sure, empirically this may but has not to be the case.

Similarly, the (log of the) nominal stock supply of money can be decomposed into a permanent or trend component $\bar{m}$ and a transitory component s:

(4) $$m_t = \bar{m}_{t-1} + \Delta\bar{m}_t + s_t .$$

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[3] See Gerlach and Svenssson (2003) for a similar specification.

The permanent component of money growth $\varDelta\overline{m}$ can be thought of as describing the authorities' planned trend rate plus any systematic response to e.g. deviations of core inflation from target while the transitory component s reflects the central bank's response to temporary short-run events - for example the partial or full accommodation of money demand shocks v - as well as discretionary innovations. Note that this interpretation does neither imply any specific hypothesis regarding the policy instruments like base money or a short-term interest rate nor the actual mode of implementation of monetary policy. For the purpose of this paper, it suffices to treat the nominal money stock as policy-controlled.

Based on the equilibrium of money demand (3) and money supply (4) we define the core price level as the price level that equilibrates the permanent components of supply and demand. Thus we have:

$$\overline{p}_t = \overline{m}_t - \lambda\overline{y}_t + \gamma(\overline{r}^l - \overline{r}^s), \tag{5}$$

and consequently,

$$\overline{\pi}_t = \Delta\overline{m}_t - \lambda\Delta\overline{y}_t \ . \tag{6}$$

Thus, the core rate of inflation responds one-to-one to the difference between permanent nominal money growth and the permanent component of real money demand growth. Henceforth, we call this difference *core money* growth

It is important to note that the concept of a core price level differs from what has become known as the price level *P** (Hallman, Porter and Small (1991)). The latter is defined as the long-run equilibrium price level consistent with the *actual* money stock m_t instead of the permanent component $\overline{m}_t$:

$$p_t^* = m_t - \lambda\overline{y}_t + \gamma(\overline{r}^l - \overline{r}^s) .$$

Using (4) and (5) yields:

$$p_t^* = \overline{p}_t + s_t .$$

Both price level definitions are long-run equilibrium concepts, the difference being that the concept of the core price level ignores the potential effects of the stochastic money supply shocks summarised by the variable s_t. This is an attractive characteristic because to the extent that short-run changes in the money stock result from the central bank's accommodation of money demand shocks they do not affect the price level.

To derive the solution for the rate of inflation, it remains to combine (1), (2) and (6). This leads to:

$$\pi_{t+1} = \alpha(\Delta\overline{m}_t - \lambda\Delta\overline{y}_t) + (1-\alpha)\pi_t + \beta(y_t - \overline{y}_t) + \varepsilon_{t+1}, \tag{7}$$

where the first expression in brackets on the r.h.s. summarises core money growth, i.e. the excess of permanent nominal money growth over permanent real money demand growth. The model's solution indicates that the long-run equilibrium impact of core money on inflation is unity. Nevertheless due to the adaptive expectation formation in the short-run core money growth affects next period's rate of inflation with a coefficient of less than unity. Thus it takes time until a change in the core rate of money growth is fully transmitted into inflation and the smaller α is, the longer it takes. Furthermore, as has been pointed out above the output gap provides a potential source of transitional inflation

3 What the Euro Area Data Tell

In this section we investigate the empirical performance of our core money model of inflation using quarterly observations for the euro area from the period 1980-2004 based on an updated version of the ECB's area wide model data set.[4] This applies with respect to real GDP-growth and the price index. In addition we employ an oil price series from the IFS and the ECB's official time series of M3. All data are seasonally adjusted. In this study inflation is measured by the rate of change of the harmonised consumer price index HICP.

An innovative aspect of our empirical modelling is to explain inflation by using symmetric filters in describing the permanent components of money and real growth

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[4] See Fagan, Henry and Mestre (2001).

instead of the noisy actual observations.[5] This has two main advantages in comparison to related approaches. First, using frequency adjustable filters instead of cointegration techniques for modelling the permanent components allows to study at which frequency the line has to be drawn between money fluctuations that are relevant for the explanation of inflation and those which are not. Hence in contrast to cointegration analysis which can describe only the one long-run relation at the "zero-frequency", filter techniques permit a more flexible and more precise empirical modelling. Second, in comparison to one-sided filters symmetric filters are not phase-shifted. For example, some authors like Cogley (2002) and Gerlach (2004) have explored simple backward-looking exponential smoothing. A drawback of such one-sided filters is that the resulting trend values depend on past data only. As a result, the estimated permanent component of a variable will move above (below) the actual values of the variable as long as the variable declines (rises). This is an undesirable feature and has Neumann (2003) led to employ the Hodrick-Prescott (HP) filter (Hodrick and Prescott (1997)).

3.1 Benchmark Estimates

We start by estimating the following inflation equation that resembles the model's solution (7):

$$\pi_t = c + \alpha_1(\Delta\overline{m}_{t-1} - \lambda\Delta\overline{y}_{t-1}) + \alpha_2(L)\pi_{t-1} + \beta y_{t-1}^{gap} + \phi\Delta p_t^{oil} + \varepsilon_t, \tag{8}$$

where

$$\alpha_2(L) = \alpha_{20} + \alpha_{21}L + \alpha_{22}L^2 + \dots + \alpha_{2k}L^k,$$

$$y_{t-1}^{gap} = y_{t-1} - \overline{y}_{t-1}.$$

In order to account for possibly richer inflation dynamics we permit lagged inflation to be modelled by a lag polynomial.[6] As a supplementary variable we add the change in

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[5] Lucas (1980) was the first to explore the relations between low-frequency components of inflation, money growth and nominal interest rates by means of graphical analysis. McCallum (1984) criticised Lucas and cautioned that the co-movements of low-frequency components do not generally reflect the long-run relationships between variables because the empirical decomposition may not map the expected-unexpected distinction. Though the argument is well taken, it does not imply that exploring the empirical role of low-frequency components is a useless exercise.

[6] In estimation, the order of the lag structure is chosen such that serial correlation of the errors is ruled out.

the world market price of oil to capture the short-run impact of a prominent exogenous determinant of domestic inflation. All variables are in logs, hence differences denote quarterly growth rates.

In this section we start modelling the permanent components of money and real growth applying the HP filter as a benchmark. The HP filter is standard in business cycle research, but has also been used for modelling inflation expectations (Orr, Edey and Kennedy (1995), Martins and Scarpetta (1999)). However, further below we also use other filters, such as exponential smoothing, wavelets and band pass filters, in order to corroborate the results.[7] Since our theoretical model is silent regarding the empirical definition of permanent components, we take a purely agnostic view.

More specifically, to compute the permanent components of M3 and real GDP growth we apply the HP filter to the first differences in logs. This is equivalent to filtering the log levels of M3 and GDP first and then computing the first differences. This is because the HP filter and the difference operator are linear transformations of the data and hence the ordering of application does not matter.

In a first step we estimate model (8) by non-linear least squares to capture potential non-linearities in the parameters. For each estimate the lag structure of the inflation rate on the r.h.s is chosen such that serial correlation of the residuals is avoided. Additionally, in order to achieve normality of the residuals, three outliers in the inflation series were corrected.[8] The results are shown in Table 1.[9] For the first

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[7] Some authors display uneasiness using filtered data in regressions. For example, using Monte Carlo studies Meyer and Winker (2004) show that regressions with HP filtered series may exhibit spuriously significant coefficients. However, this result does not hold for our approach. This is because the endogenous variable on the r.h.s. of equation (8) "prevents" the filtered trend from picking up a spurious relation with the dependent variable. Simple Monte Carlo experiments (available upon request) demonstrate that the t-statistics of a simulated setting corresponding to (8) are not biased due to using an HP filtered trend. This result seems to hold for a wide range of I(0)-variables. Moreover, even in the case of assuming I(1)-variables no spurious regression effects potentially caused by the application of a HP filter are found.

[8] The outliers in the inflation series were adjusted by replacing them by the median over this observation and the three leading and lagging data points. The outlier-dates are 1981:1, 1985:3 and 2001:2. Those were caused by extraordinary developments e.g. the last one was caused by the impact of BSE and foot-and-mouth disease .

[9] Similar to other studies we treat the variables as I(0)-processes, even though formal unit root tests sometimes point to I(1). Our I(0)-approach can be interpreted as implicitly assuming a possibly breaking deterministic trend in the time series (which is described by core money). See also Jansen (2004) for a brief discussion of that view. However, spurious regression between inflation and lagged core money growth is not an issue in this context. Unit root/cointegration analysis not shown here clearly demonstrates that there exists a highly significant (cointegrated) long-run relationship between

estimation we cut the sample period at 1998:4, hence estimate the inflation equation for the pre-EMU period. As can be read from the test statistics in the lower part of the table, the regression is satisfactory because the residuals are normal and serially uncorrelated. The estimated short-run impact a_1 of core money on inflation is about 0.5 and together with the estimate for the influence of lagged inflation a_2 almost perfectly sums to one. This is formally backed by a Wald-test which shows that the restriction of a one-to-one long-run relation between core money and inflation cannot be rejected. The estimated income elasticity of long-run real money demand λ=1.58 is in line with similar results from studies of euro area money demand.[10] Those studies report estimates in the range of about 1.3 to 1.4. The small difference between these values and our estimate is probably due to the practice in money demand studies of using the GDP-deflator, whereas we focus on the consumer price index HICP. It may also be partly due to the fact that the frequency spectrum of our HP filter based core money measure differs from that of the long-run components estimated in cointegration analysis. Note that the output gap does not show up significantly. Regression (2) serves to demonstrate that omission of this variable does not change the results.[11]

In a second step we extend the sample period to 2001:4. Thus the augmented period comprises the first three years of EMU and ends before the more recent period 2002 - 04 of unusually strong money growth. The results of regression (3) in Table 1 show that the estimated coefficients do not change markedly in comparison to regressions (1) and (2). However, no structural break can be diagnosed. Thus the explanatory power of our core money model has not been impaired by the historical regime change of switching from a large number of national currencies to a new jointly controlled currency, the euro. This is a remarkable finding.

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these variables for the Euro area, with similar coefficients to the ones following in this analysis. The same holds if the HICP, M3 and real GDP are investigated using cointegration techniques. Results are available upon request.

[10] See Brand and Cassola (2000), Calza, Gerdesmeier and Levy (2001) and Bruggeman, Donati and Warne (2003).

[11] In the literature the question of significance of output gaps in empirical Phillips curves is an open issue; see e.g. Gali and Gertler (1999). Other variables measuring the marginal costs of production like unit labour costs were also tested in this context but also found to be insignificant here.

Table 1: Benchmark inflation equation

$$\pi_t = c + \alpha_1(\Delta\overline{m}_{t-1} - \lambda\Delta\overline{y}_{t-1} + \varphi \cdot D_{02-04}) + \alpha_2(L)\pi_{t-1} + \beta y^{gap}_{t-1} + \phi\Delta p^{oil}_t + \varepsilon_t$$

End of sample	1998:4 (1)	1998:4 (2)	2001:4 (3)	2004:2 (4)	2004:2 (5)
α_1	0.47* (0.1)	0.48* (0.1)	0.53* (0.1)	0.31* (0.1)	0.49* (0.11)
λ	1.58* (0.27)	1.56* (0.26)	1.51* (0.23)	1.06* (0.35)	1.48* (0.25)
$\alpha_2(L)$	0.52* (0.09)	0.52* (0.09)	0.49* (0.08)	0.71* (0.07)	0.52* (0.1)
ϕ	0.007* (0.001)	0.007* (0.001)	0.007* (0.001)	0.007* (0.001)	0.008* (0.001)
β	0.013 (0.02)	-	-	-	-
φ	-	-	-	-	- 1.97* (0.40)
R^2	0.95	0.95	0.94	0.93	0.94
JB	0.63	0.64	0.61	0.60	0.94
$LM(4)$	0.34	0.35	0.09	0.03	0.05
$White$	0.19	0.22	0.47	0.53	0.24
$Wald$	0.84	0.97	0.76	0.68	0.85

Standard errors in parenthesis; * significant at 5% level; JB - Jarque-Bera test for normality; LM(4) - test for no autocorrelation up to order 4; White - White test for heteroskedasticity; Wald – test for long-run restriction unitary elasticity of inflation to core money; estimates for constants c not shown; lag length k = 1, except for the 2004:2 regressions; estimation start 1980:3.

For the final regressions, we extend the sample period to 2004:2, the most recent observation available (see regression (4) in Table 1). While the long-run property of homogeneity of degree one remains valid, the point estimates of the short-run impact of core money growth and of the income elasticity of money demand are markedly smaller, the point estimate of the influence of lagged inflation is higher. This raises the question of whether regression (4) reflects a break-down of our core money explanation of inflation. To check on this, we try to nail down the specificity of the most recent sub-period by introducing a simple ad-hoc specification. We augment the core money variable with a dummy being one for the period 2002:1 to 2004:2 and zero elsewhere (see regression (5)). This leads to parameter estimates which do not differ from the ones in the regressions for the shorter samples, regressions (2) and (3). Thus we find that our inflation equation has not changed. Moreover, the estimated dummy coefficient of close to minus 2 can be given an intuitively appealing interpretation. It indicates that the permanent component of the money stock M3 since early 2002 has grown by about 2 percent per year in addition to what was absorbed by inflation and the normal transactions demand for money.

Concerning the implications of this core money "surplus", excessive money growth that does not translate into inflation generally signals a shifting demand for real money balances. It may well be, as the ECB has suggested,[12] that this is due to portfolio shifts from risky to liquid assets. According to this interpretation, stock markets were affected by global turbulences caused by geopolitical and economic uncertainties, and this initiated an increased demand for euro area M3. In line with that, Carstensen (2004) reports a significant impact of the increased volatility in stock markets on money demand. However, our study does not permit us to draw any conclusion as regards the nature of the process reflected by the dummy variable used in regression (5).

In sum, the estimates of our model show that the core money approach (7) is successful in describing the development of inflation in the euro area. This can also be demonstrated by a simple graph. Figure 1 shows that our HP filter based core money variable literally retraces the path of inflation in the euro area for most of the sample period. As discussed before, this does not hold for the recent sub-period 2002-04 because of shifting money demand. As can be read from the figure, the difference between the levels of actual inflation and core money growth during the latter sub-period is about 2 percentage points on average. This provides a graphical illustration of the dummy coefficient estimate in regression (5) above.

As a caveat, it needs to be mentioned that the recent deviation of core money growth from inflation might to some extent reflect the well known end-of-sample problem of the HP filter. As the HP filter gets more asymmetric towards the sample ends the HP trend is influenced relatively more strongly by exceptional developments at the boundary dates. Hence, at the current sample end the HP based core money growth

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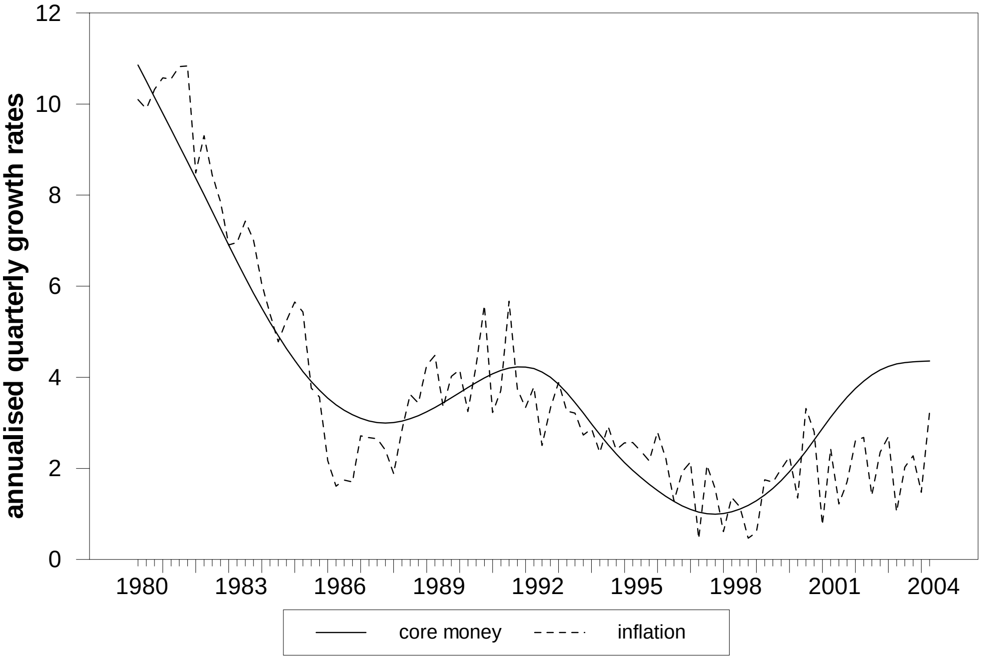
[12] See the ECB (2003b) p. 13.

trend is likely to be heavily influenced by the strong monetary growth of recent periods. Should these developments at a later date - with more observations available - be identified as rather high to medium-frequency events, the current excess in core money growth might disappear as it will be filtered out.

Figure 1: Core money and inflation (λ =1.5)



Alternatively, in the unlikely event that this development lasts for another one or two years, the simple HP filter core money measure might not be able to reliably identify the permanent component of money growth relevant for inflation. Due to the lack of recognising structural economic information, the longer this exceptional money growth persists, the more of it is mechanically attributed to core money by this simple univariate filter. This may pose a problem if, for example, a central banker tries to use the core money approach to assess inflation prospects. That would require correcting actual money growth for the impact of these portfolio shifts before applying the filter. But this would in turn require extra structural information concerning the size of conjectured portfolio shifts.

3.2 Alternative Measures of Core Money

Having established an empirical base for the core money model in the euro area, we now investigate the robustness of the HP filter based results by using other filters for computing core money measures. On the one hand, as an example of a one-sided filter we explore exponential smoothing which is used by Gerlach (2004). On the other hand, we investigate two variants of a two-sided filter: a band pass filter and a trend extraction based on wavelet analysis.

The exponential smoothing $\overline{X}_t$ is defined by:

$$\overline{X}_t = \overline{X}_{t-1} + \delta(X_{t-1} - \overline{X}_{t-1}),$$

where δ represents the smoothing parameter. Often used values are 0.15 or 0.075 which correspond to a half-life of deviations from trend of 4.6 and 9.2 periods respectively.[13] Additionally, deterministic trends could be included in the computation.

Other standard filters used in econometric analysis are the band pass filters based on Baxter and King (1999) or Christiano and Fitzgerald (2003). These filters are designed to extract certain frequency ranges from a time series. Although most prominently used to identify business cycles which are assumed to lie in a window of 1½ to 8 years they provide a versatile tool for filtering out any desired frequency range and hence can also serve to extract a long-run trend. As for our data both filters lead to very similar results, we concentrate on using the Baxter-King (henceforth BK) filter.[14] The BK filter capturing fluctuations of a variable X between an upper bound of p_{up} and a lower bound of p_{low} periods can be denoted:

$$BK(X) = BK(p_{up}, p_{low}).$$

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[13] See e.g. Cogley (2002).

[14] More specifically, this applies for the simple symmetric version of the band pass filter proposed by Christiano and Fitzgerald (2003).

Hence a trend variable $\overline{X}$ containing only cycles above 32 periods (corresponding to 8 years using quarterly data) can be constructed by: $\overline{X} = X - BK(2,32) \equiv BK^T(2,32)$.[15]

An alternative filter procedure, less often used in econometric analysis so far, is provided by wavelet analysis. Wavelets can be used to produce a unique and complete decomposition of a time series into different frequency bands.[16] In contrast to Fourier analysis the wavelet decomposition also captures time domain information and not only frequency information. Additionally, wavelets have good properties regarding their gain function. Their leakage - a measure of the difference between the gain function and a theoretical ideal band pass filter - can be adjusted to be relatively small. Moreover, the frequency bands extracted by wavelet analysis, the so-called wavelet details, are orthogonal or at least almost orthogonal, hence uncorrelated.[17] This is an interesting property as it allows us to introduce the different frequency ranges separately without creating the danger of an omitted-variable bias in a regression where only selected frequencies are analysed.

More specifically, the wavelet decomposition separates a time series into several wavelet details Δm^{WD_i} which correspond to different frequency ranges.[18] Thereby, the grid defining the borders of the frequency bands follows a series 2^i. This implies when using quarterly data that wavelet details Δm^{WD_i} contain frequency bands representing cycles between ½-1 year, 1-2 years, 2-4 years and so on. The filter quality as regards leakage or gain properties depends on the type of basic wavelet filter function employed, the so-called mother wavelet.[19] To give a graphic description of this

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[15] As the shortest identifiable cycle lasts 2 periods a $BK(2,n)$ filter always extracts the highest frequencies from a series.

[16] For an introduction to wavelet analysis for economic applications see Gencay, Selcuk and Whitcher (2002), Ramsey (2002) and Schleicher (2002).

[17] Orthogonality only holds for the genuine discrete wavelet transformation (DWT). In this paper we use a variant of wavelet decomposition, the maximum overlap discrete wavelet transformation (MODWT). It is not necessarily orthogonal by construction. However, in this study the wavelet frequency bands produced are almost uncorrelated.

[18] This decomposition is called multiresolution analysis (MRA).

[19] In this paper, Minimum Bandwidth Discrete Time mother wavelets of lengths L = 24 (MBDT(24)) are used as these approximate ideal band pass filters (see Gencay, Selcuk and Whitcher (2002)). Wavelets were computed using the “waveslim 1.3” package based on the statistical software R version 1.9.1. Both are available for free on the internet.

procedure mother wavelets work like lenses which only let pass certain frequencies. These lenses are “pulled” over the time series whereby the different observed frequencies are assigned to the corresponding sets or frequency bands, the wavelet details. Finally, the remaining lower frequencies, e.g. the difference between the actual series and the sum of the extracted wavelet details, can be “collected” in the so-called wavelet smooth $\Delta\overline{m}^{WD}$ which represents our trend variable.

In our application we assign frequencies corresponding to cycles above 8 years to the wavelet smooth.[20] To provide a graphical illustration, a wavelet decomposition of the quarterly log-change of euro area M3 is depicted in Figure 2. The first four upper rows show the higher frequency wavelet details (corresponding to the cycles ½-1 year, 1-2 years, 2-4 years and 4-8 years) and the last one at the bottom the wavelet smooth which contains the lower frequency movements.

In comparing the properties of different filters, several aspects may be noted. Generally, in contrast to the two-sided HP, BK and wavelet filters, a purely backward-looking filter like exponential smoothing relies solely on information that has accrued up to a particular point in time. This property makes backward-looking filters attractive to forecasters. However, the construction of these filters leads to a disadvantage as regards their frequency domain properties. As mentioned before, due to the purely backward-looking construction they are phase shifted, e.g. in our context movements in core money might be indicated too late.

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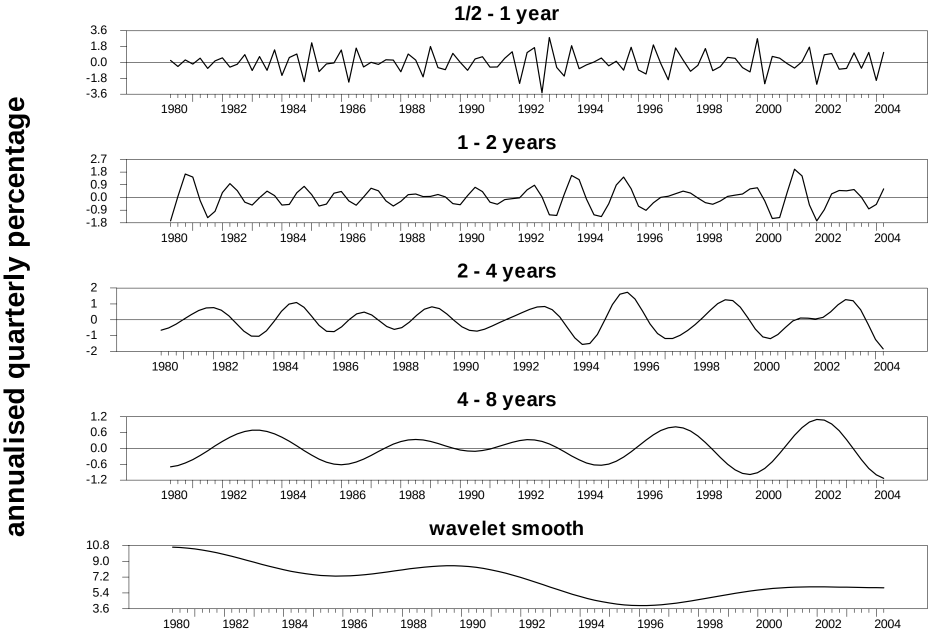
[20] This is the “smoothest” wavelet smooth we constructed concerning the limited number of observations in our sample. The next stage wavelet smooth would be a trend containing only cycles above 16 years. These very long cycles can only be identified with very long sample periods. Regarding that our data base comprises only about 24 years, it contains at most one complete cycle of those rather very low frequencies movements.

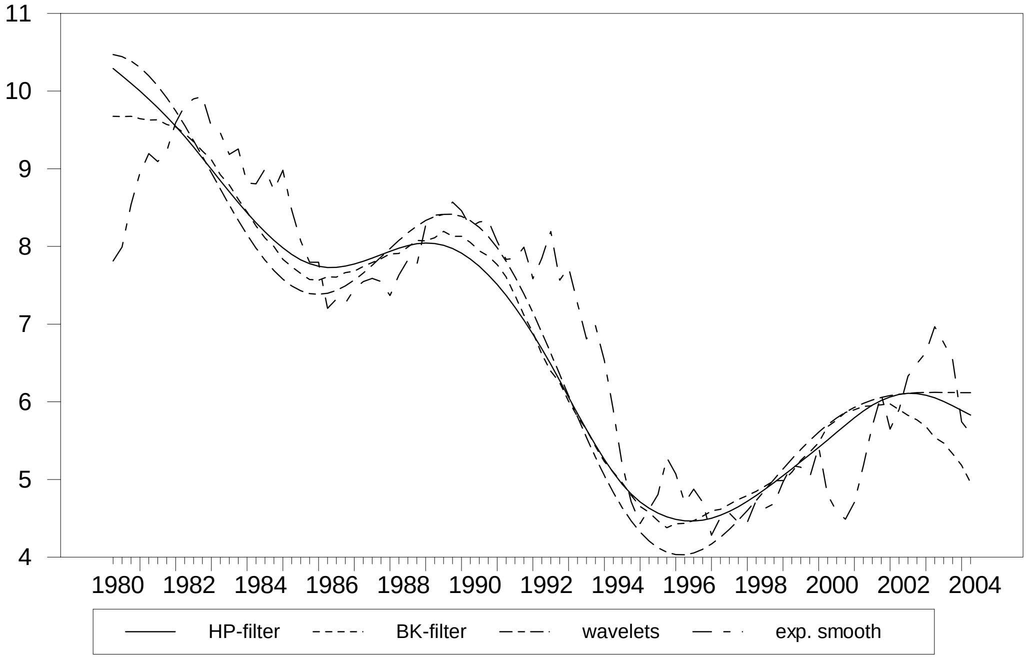
Figure 2: Wavelet decomposition of euro area M3 growth



This is demonstrated in Figure 3 where the euro area M3 growth trends based on different filters are depicted. More specifically, those are the HP(1600) filter, a BK^T(2,32) filter, the wavelet smooth described above and an exponential smooth (δ=0.15, no trends). The figure shows that the trend based on the exponential smoothing filter always lags behind the ones of the HP-, BK- and wavelet filter. Additionally, the exponential smoothing trend is coarser.

Generally, the symmetric filters are smoother and have a very similar shape. The small differences between the symmetric filters mainly result from differences as regards the reflected frequency bands. While the chosen BK and wavelet filters assign fluctuations above 8 years to the trend, the HP filter does so for cycles longer than 10 years. This explains why the HP-trend is a bit smoother than the former. Additionally, differences in the gain function properties of the filters play a role. As a consequence depending on the filter properties, in particular for cycles close to the border values of 8 or 10 years, the separation of trend from non-trend growth is more or less sharp. Nevertheless, as can be seen in Figure 3 for our data, the HP, BK and wavelet filter appear to produce similar trend values for the trend growth of euro area M3.

Figure 3: Money growth trends – alternative filters



In the next step we re-estimate inflation equation (8) using the alternative filters discussed above. Although the general patterns of the trends based on the different two-sided filters presented in Figure 3 look quite similar there are some differences among the permanent components. Hence, the following comparison based on alternative filtering procedures provides an excellent test of the robustness of our core money approach.

Table 2 presents the estimates for the different filters.[21] Regression (1) replicates the earlier estimate based on the HP filter (see regression (3) in Table 1 for comparison). The sample period is 1980:2-2001:4. As output gaps were clearly insignificant for the BK and the wavelet filter, except for the exponential smoothing, only estimations without output gaps are presented.[22] A cursory glance over the table reveals that the

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[21] The smoothing parameter for the exponential smoothing is 0.15. It corresponds to 4.6 quarters in terms of half-life of deviations from trend. For the BK filter throughout the paper the number of leads and lags was set to 12, as suggested by Baxter and King (1999). At the sample ends the series was padded using an AR(4) process.

[22] In the regressions including output gaps these were computed in standard fashion using an HP(1600)-filter. Alternatively, computing gaps using the corresponding filters did not lead to different results.

estimate which deviates the most from our HP estimate is regression (5) where the core money variable is represented by the exponential smooth. The estimated short-run impact of core money is no more than one half of the benchmark estimate and the estimated λ-parameter is markedly higher.[23] Moreover, the Wald test indicates that the long-run homogeneity restriction is rejected for this specification.

Table 2: Alternative filters

$$\pi_t = c + \alpha_1(\Delta\overline{m}_{t-1} - \lambda\Delta\overline{y}_{t-1}) + \alpha_2(L)\pi_{t-1} + \beta y_{t-1}^{gap} + \phi\Delta p_t^{oil} + \varepsilon_t$$

	HP filter	BK^T(2,40)	BK^T(2,32)	Wavelets	exp. Smooth
	(1)	(2)	(3)	(4)	(5)
α_1	0.53* (0.1)	0.51* (0.1)	0.49* (0.1)	0.43* (0.09)	0.23* (0.09)
λ	1.51* (0.23)	1.58* (0.26)	1.49* (0.26)	1.27* (0.24)	1.83* (0.53)
$\alpha_2(L)$	0.49* (0.08)	0.52* (0.08)	0.53* (0.08)	0.56* (0.08)	0.66* (0.1)
ϕ	0.007* (0.001)	0.007* (0.001)	0.007* (0.001)	0.007* (0.001)	0.008* (0.001)
β	-	-	-	-	0.09* (0.04)
R^2	0.94	0.94	0.94	0.94	0.94
JB	0.61	0.65	0.61	0.49	0.63
$LM(4)$	0.09	0.09	0.10	0.05	0.10
$White$	0.47	0.51	0.36	0.37	0.15
$Wald$	0.76	0.62	0.64	0.84	0.04*

Standard errors in parenthesis; * significant 5% level; JB - Jarque-Bera test for normality; LM(4) - test for no autocorrelation up to order 4; White - White test for heteroskedasticity; Wald – test for long-run restriction unitary elasticity of inflation to core money; estimates for constants c not shown; lag length k = 1, except for exponential smooth, k=2; estimation period 1980:3-2001:4.

Of the remaining regressions, the two versions of the BK filter, one similar to the HP filter representing only cycles above 40 periods and the other corresponding to the wavelet smooth cycles above 32 periods, yield results that match the HP based estimate

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[23] Setting the δ-parameter of the exponential smoothing to 0.075, which corresponds to a half-life of 9.2 years, even led to a larger λ-estimate of about 2.7.

quite closely in every respect (see regressions (2) and (3)). They confirm that the short-run impact on inflation of core money is about 0.5 and the long-run impact not significantly different from unity (see the Wald test statistics).

Although the wavelet smooth like the $BK^T(2{,}32)$ trend principally collects all cycles above 8 years, the point estimates of the parameters are slightly different (see regression (4)). This probably is to be attributed to the gain function properties which imply slightly differing trend extractions (compare Figure 3). Nevertheless, the long-run unity restriction clearly holds and differences between the estimates are numerically small and statistically insignificant. In sum, we conclude that all of the symmetric filters explored in this section clearly underpin the empirical validity of the core money approach and provide useful measures of core money.

3.3 Do Higher Frequencies Matter?

As noted before, wavelet and band pass filter techniques permit decomposing time series into different frequency bands. In this section we use this property to investigate whether frequencies higher than the rather low ones used above to define measures of core money also carry information on inflation. To this end we compute additional wavelet details Δm^{WD_i} representing bands of higher frequencies of money growth than the ones included in the wavelet smooth $\Delta \overline{m}^{WD}$ above (see Figure 2).

As a first illustration we use the interesting feature of wavelet analysis that the computed wavelet details are (at least almost) orthogonal to each other. This permits the computation of correlations between the frequency bands of two variables. In Table 3 contemporary correlations between wavelet details for euro area quarterly growth of M3 and HICP are presented. The first row shows the correlations between the wavelet smooth of inflation $\Delta \overline{\pi}^{WD}$ and the wavelet smooth $\Delta \overline{m}^{WD}$ as well as the different wavelet details Δm^{WD_i}, i = 1 to 4. As noted before, according to the construction of the wavelet details, i represents cycles between ½-1 year, 1-2 years, 2-4 years and 4-8 years. The second row depicts the correlations of actual inflation with the money growth wavelet decompositions. Although these are only simple bivariate correlations that cannot provide a definitive answer to the question which frequencies of permanent money growth contribute to the explanation of inflation, they yield a preliminary assessment: it seems that only the long-run trends represented by the smooths matter. Except for the correlation of the wavelet details i =4 all correlations are close to zero.

Table 3: Wavelet correlations – euro area M3 growth and HICP inflation

	$\Delta\overline{m}^{WD}$	Δm^{WD_4}	Δm^{WD_3}	Δm^{WD_2}	Δm^{WD_1}
corresponding π^{WD_i}	0.84	0.31	0.10	0.02	-0.01
π	0.82	0.10	0.02	-0.02	0.00

wavelet detail numbers i = 1 to 4 corresponds to cycles between ½-1 year, 1-2 years, 2-4 years, 4-8 years; wavelet smooths comprise cycles > 8 years

As a more appropriate test we integrate the higher frequencies of money growth into the core money model. Hence we include the wavelet details of money growth Δm^{WD_i} as additional regressors in our inflation equation (8) and analyse their significance. The same applies with respect to the second variable constituting core money, the wavelet details of output growth Δy^{WD_i}.[24] Thus we have:

$$\text{(9)} \qquad \pi_t = c + \alpha_1(\Delta\overline{m}_{t-1}^{WD} - \lambda\Delta\overline{y}_{t-1}^{WD} + \rho_m \Delta m_{t-1}^{WD_i} - \rho_y \Delta y_{t-1}^{WD_i}) + \alpha_2(L)\pi_{t-1} + \phi\Delta p_t^{oil} + \varepsilon_t .$$

Note that we do not require the wavelet details to have the same impact as the wavelet smooth, i.e. we do not require $\rho_m = 1$ or $\rho_y = \lambda$. Table 4 gives the results where regression (1) is the wavelet benchmark regression (4) from Table 2.

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[24] As noted before the wavelet based frequency bands are almost orthogonal. Hence it is not necessary to include them altogether in the regression and test for a possible joint significance.

Table 4: Higher frequencies – wavelet analysis

$$\pi_t = c + \alpha_1(\Delta \bar{m}_{t-1}^{WD} - \lambda \Delta \bar{y}_{t-1}^{WD} + \rho_m \Delta m_{t-1}^{WD_i} - \rho_y \Delta y_{t-1}^{WD_i}) + \alpha_2(L)\pi_{t-1} + \phi \Delta p_t^{oil} + \varepsilon_t$$

wavelet detail	smooth only (1)	4-8 years (2)	2-4 years (3)	1-2 year (4)	½-1 year (5)
α_1	0.43* (0.09)	0.45* (0.09)	0.44* (0.09)	0.41* (0.09)	0.40* (0.09)
λ	1.27* (0.24)	1.29* (0.23)	1.28* (0.23)	1.26* (0.24)	1.26* (0.25)
$\alpha_2(L)$	0.56* (0.08)	0.54* (0.09)	0.55* (0.08)	0.58* (0.08)	0.59* (0.08)
ϕ	0.007* (0.001)	0.007* (0.001)	0.007* (0.001)	0.007* (0.001)	0.007* (0.001)
ρ_m	-	0.24 (0.36)	-0.07 (0.29)	0.23 (0.25)	0.07 (0.16)
ρ_y	-	-0.26 (0.33)	0.21 (0.30)	0.46 (0.25)	-0.33 (0.18)
R^2	0.94	0.94	0.94	0.94	0.94
JB	0.63	0.46	0.41	0.27	0.78
$LM(4)$	0.05	0.06	0.06	0.11	0.16
$White$	0.37	0.13	0.55	0.69	0.51

Standard errors in parenthesis; * significant 5% level; JB - Jarque-Bera test for normality; LM(4) - test for no autocorrelation up to order 4; White - White test for heteroskedasticity; estimates for constants c not shown; estimation period 1980:2-2001:4

The estimates uniformly show that including higher frequency bands of money and output growth does not affect the parameters in comparison to the benchmark regression based on the wavelet smooths only. All coefficients ρ_m of the higher frequencies of nominal money growth are insignificant and sometimes even bear the wrong sign. A similar result can be observed for the parameter ρ_y of higher frequencies of output growth, although in the latter case of the shorter cycle band of waves between 1-2 years the parameter comes close to significance. In sum, we find that fluctuations of money growth with cycles less than 8 years are not relevant carriers of extra information on inflation. The results support the implication of our theoretical model that transitional movements of money do not influence inflation. Remarkably, these transitional movements can last relatively long given that even the frequency band capturing fluctuations between 4 and 8 years is not significant.

In a last step we try to corroborate the result that money growth fluctuations between 4 and 8 years are not relevant for the course of inflation by conducting an additional examination applying the BK band pass filter.[25] Generally, the wavelet based results concerning the shorter-term movements could be caused by an inappropriate choice of the cycle length $b_{\Delta\overline{m}}$ separating non-inflationary from inflationary money growth. In order to check for this, we try to get a "finer" assessment of where the inflation-relevant frequency-boundary of money growth fluctuations $b_{\Delta\overline{m}}$ is located. This requires employing the BK filter. In contrast to wavelets where the frequency band grid is confined to powers of 2, the BK filter permits to extract arbitrary frequency bands.

Our strategy is to use the following slight modification of regression equation (9):

$$(10)\quad \pi_t = c + \alpha_1(\Delta\overline{m}_{t-1}^{b} - \lambda\Delta\overline{y}_{t-1} + \rho_m \Delta m_{t-1}^{m,b}) + \alpha_2(L)\pi_{t-1} + \phi\Delta p_t^{oil} + \varepsilon_t\,.$$

Here $\Delta\overline{m}^{b}$ is the long-run trend of money growth while $\Delta m^{m,b}$ represents the adjacent more "medium-term" oriented frequency band. Both depend on the border $b_{\Delta\overline{m}}$ defining the cycle length where the two bands are separated. In the following simulation we let the medium term component $\Delta m^{m,b}$ start at 4 years and end at the border $b_{\Delta\overline{m}}$ while the trend component captures all cycles above.[26] Depending on the moving border $b_{\Delta\overline{m}}$ equation (11) is then estimated recursively. The output trend growth $\Delta\overline{y}$ is held fixed throughout to contain cycles above 8 years.

In Figure 4 the relation between the estimated ρ_m parameter from this experiment and the boundary value $b_{\Delta\overline{m}}$ is shown together with its 95 percent confidence band. The boundary moves between 24 and 40 periods (corresponding to 6

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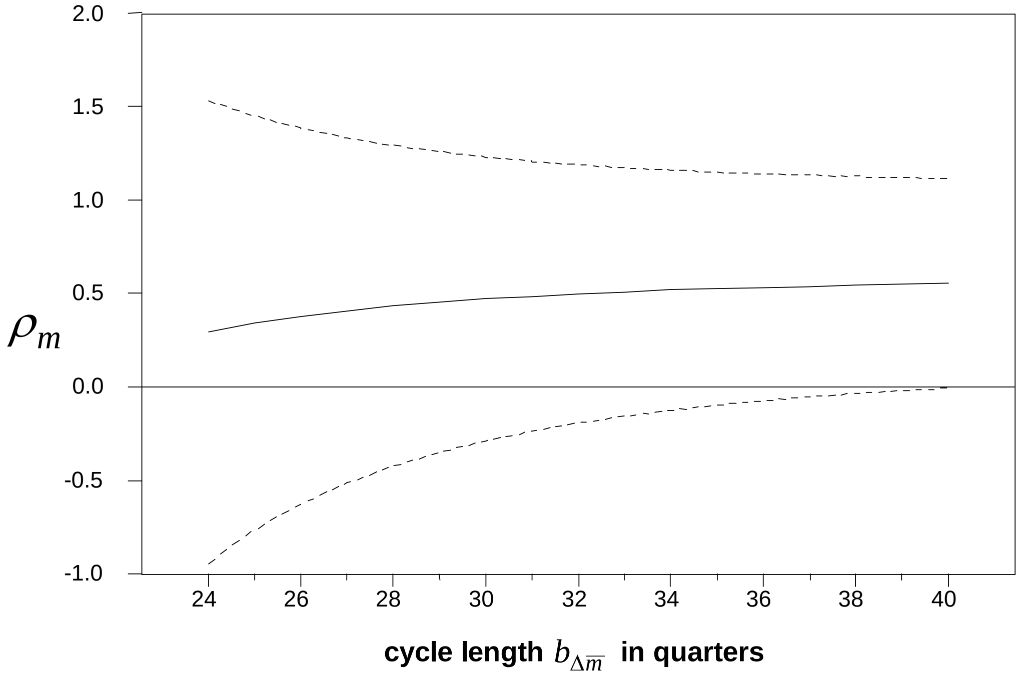
[25] As output fluctuations at fluctuations below 8 years were clearly insignificant, we concentrate now just on the role of nominal money growth. Nevertheless, it can be shown that the following results also hold if higher frequencies of output growth are included in the analysis.

[26] Hence those components are computed using the $BK(16, b_{\Delta\overline{m}})$ and $BK(2, b_{\Delta\overline{m}})$ filter respectively.

and 10 years). Although none of the ρ_m-parameter estimates is significant at the 95 percent level, it can be seen that those medium-term frequency bands with an upper bound close to 40 periods are at least almost significant. In contrast those with an upper bound below 30 to 32 periods are clearly insignificant.

Figure 4: Assessing the cycle length of inflationary money growth - estimated ρ_m depending on relative boundary $b_{\Delta\overline{m}}$



Thus we find from this experiment that the relevant boundary - in the sense that below this value money growth fluctuations do not matter for inflation - lies in a range of about 8 years. This corresponds to the assumed ranges of the filter specifications used in the sections before and hence explains their empirical success in tracking the inflation development in the euro area. To be sure, the value of 8 years can be taken as a stylised fact for the euro area but must not be interpreted as a "sharp" boundary. The properties of the filters do not permit us to precisely discriminate between the cycles for example of length 6, 8 and 10 years. Also, one cannot rule out that empirical relations change over time. Nevertheless, this simulation supports the assessment based on wavelet analysis that - in the view of the frequency domain - nominal money growth at (relatively long lasting) medium-term cycles does not necessarily affect the trend of euro area inflation.

Concerning the implications of this result for the conduct of monetary policy in the euro area, we like to emphasise that the 8-years-boundary holds for the frequency domain and certainly not for the time domain. Hence, it must not be interpreted to mean that money growth has an impact on inflation only over a horizon of eight years and above or with a very long lag. Instead, it implies that all short-run fluctuations of money growth which do not change the underlying trend - i.e. do not affect the cycles above eight years - do not have an impact on the trend of price changes. However, as regards the time dimension the relative size of the parameter estimates reveals that inflation reacts quickly to changes in trend money growth. In sum, our results support the notion that there exists a close link between money growth and inflation in the euro area.

4 Concluding Remarks

This paper provides a theoretical and empirical analysis of how inflation in the euro area is influenced by money growth. Combining the Phillips curve with money demand and supply we model inflation to be linked trough expectations to the “core money” growth. Core money growth is a long-run equilibrium concept and defined as the excess of permanent nominal money growth over permanent real money demand growth; the latter is equal to permanent output growth adjusted for the long-run income elasticity of money demand. Our concept of core money growth differs from that of the P*-approach by excluding noisy short-run fluctuations of money growth generated by the accommodation of money demand shocks. The approach resembles the quantity theory of money in that there exists a one-to-one relation between money growth and inflation. In the empirical part, core money growth is modelled by different measures of low-frequency components. Using quarterly data for the euro area, we find a very stable relationship with inflation that is robust over the measures investigated. The postulated homogeneity of degree one between money growth and inflation is clearly supported by the data. Moreover, in the view of the frequency domain the relation between money and inflation appears to rest on relatively long-lasting cycles of monetary growth. Short to medium-term fluctuations of money growth with cycles of up to about 8 years were found to be insignificant for inflation.

In sum, the evidence presented in this paper lends support to the ECB's view on the importance of M3 growth for inflation. Money exhibits a clear and stable relation with inflation, hence it can serve as an important indicator in assessing price developments in the euro area.

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