Money growth, loan growth and consumer price inflation in the euro area: a wavelet analysis

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Abstract

Our paper studies the relationship between money growth and consumer price inflation in the euro using wavelet analysis. Wavelet analysis allows to account for variations in the money growth - inflation relationship both across the frequency spectrum and across time. Our results indicate that over the sample period 1970-2012 there was no stable significant relationship between fluctuations in money growth and consumer price inflation at low frequencies. In contrast, most of the literature, by failing to account for the effects of time variation, estimated stable long-run relationships between money growth and inflation well into the 2000s. We also analyze the relationship between loan growth and inflation in the euro area, since bank loans represent the most important counterpart to monetary developments but find no evidence for a stable relationships between loan growth and inflation at any frequency.

Keywords: money growth, loan growth, inflation, wavelet analysis

1 Introduction

A central underpinning of the Eurosystems two-pillar monetary policy strategy is a stable medium to long-run relationship between the growth rates of monetary aggregates and consumer price inflation. As argued, for example, by Drudi et al. (2010) and von Landesberger and Westermann (2010), this relationship is most clearly visibile in the comovements in low frequency components of growth rates of the broad monetary aggregate M3 and consumer price inflation in the euro area. This claim is supported by various

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empirical studies analyzing the explanatory or predictive power of low frequency components of money growth for inflation.

Our paper adds to this literature by using wavelet analysis to study the relationship between money growth and inflation in the euro area.Wavelet analysis allows to account for variability in the money growth - inflation relationship both across the frequency spectrum and across time. Thus, for a given frequency band, we can study whether comovements in money growth and inflation have become stronger or weaker through time and whether there have been changes in the lead-lag patterns between the two variables.

Our results show that in the euro area the relationship between the growth rate in M3 and consumer price inflation at low frequencies is very weak in our sample period from 1970 to 2012. At higher frequencies we find only evidence for significant covariability over short subsample periods. Estimated phase differences indicate that at these low frequencies a lead of inflation before money growth is more plausible than money growth leading inflation. Furthermore, the estimated cross-spectral gain at low frequencies which captures the long-run level relationship between money growth and inflation turns out to be relatively low after the late 1980s. In contrast, most of the empirical literature, by failing to account for the effects of time variation, presents evidence of stable long-run relationships between money growth and inflation in the euro area well into the 2000s. Various modifications, such as replacing the overall consumer price index with a version excluding food and energy prices, using a narrow monetary aggregate (M1) instead of a broad one, adjusting the money growth series for real GDP growth, and controlling for short-term interest rates leave the results qualitatively unchanged. Finally, we extend our analysis to the relationship between consumer price inflation and growth in bank lending as bank loans are the main driving force among the counterparts of monetary aggregates. Consistent with our results for money growth and inflation, we are unable to find stable relationships between these two variables at any frequencies.

The relationship between low frequency movements in money growth and inflation has been analyzed in various empirical studies. For example, Hofmann (2006) extracts the low frequency component of the growth rate of euro area M3 using the Hodrick-Prescott (HP) filter and shows out of sample forecasts of consumer price inflation (1999Q1-2005Q4) based on trend money growth to be superior to those based on unadjusted money growth over medium and long forecast horizons. However, the quality of these forecast deteriorates after 2003. Neumann and Greiber (2004) derive a measure of core money growth for the euro area based on HP filtered growth rates of M3 adjusted for the trend growth of real output. Estimates for the sample period 1980Q3 - 2004Q2 show a robust one-to-one relationship between their core money growth measure and HICP inflation. For higher frequency components of money growth they find no evidence of a significant relation to consumer price inflation. Similarly, Carstensen (2007) shows that low frequency components of M3 growth provide good predictions for HICP inflation for forecast horizons of eight to twelve quarters. Regressing the low frequency component of consumer price inflation on the low frequency component of M3 growth yields a coefficient not significantly different from one. However, using a rolling sample, he finds that the explanatory power of the regression tends to deteriorate after 2004. According to Gerlach (2004), based on the sample period 1971Q1-2003Q3, for the euro area smoothed money growth (exponential filter) has predictive content for consumer price inflation one quarter ahead. Assenmacher-Wesche and Gerlach (2007) extend this approach by regressing HICP inflation on low frequency components of M3 growth and obtain a regression coefficient insignificantly different from one for the sample period 1970Q1-2004Q4. Haug and Dewald (2004) analyse the correlation structure between low frequency components of money growth and consumer price inflation or GDP deflator inflation for a large set of countries. They find high cross-correlation coefficients for most of the countries with trend money growth leading trend inflation for a subset of countries while for most other countries the strongest correlation between both series is contemporaneous.

These results are derived from extracting low frequency or trend components from money growth in order to explain inflation and use conventional regression techniques. An alternative approach is the application of spectral analysis to investigate comovements in money growth and inflation: Jaeger (2003) studies the relationship between the growth rate of broad monetary aggregates and consumer price inflation for various later EMU countries over the time period from 1981-98. The cross-spectral coherency of these two variables turns out to be highest for low frequencies, independent from the actual level of inflation. Similar results for a set of industrialized countries are presented by Haug and Dewald (2004). Assenmacher-Wesche and Gerlach (2007) use band spectrum regressions to estimate the effects of low frequency movements in the growth rate of euro area M3 on consumer price inflation for the period from 1970-2004. For frequencies with periods exceeding two years the coefficient on money growth is not significantly different from one while it is much smaller if higher frequency components are included.

Benati (2009) uses a very extensive dataset of 40 countries (including the euro area) with some time series going back into the 19th century. For each individual country he estimates the spectral coherency of money growth and inflation at frequency zero, i.e. for permanent innovations, and the cross spectral gain for periods of 30 years and longer. For most of the countries the cross-spectral coherency at frequency zero is close to one while the spectral gain is significantly less than one. This implies, that while innovations in money growth account for almost all of the long-run variance of inflation, there is no one-to-one relationship between these two variables. Benati tries to incorporate time-variation in the money growth-inflation relationship by using rolling windows of 25 years and shows that the cross spectral gain varies strongly through time for most of the countries and often is much less than one, while the cross spectral coherency tends to remain very stable and close to one. His interpretation of these results is that, in times of low inflation, the money growth-inflation relationship is obscured by velocity shocks and that the relationship is only uncovered in these rare episodes in which surges in inflation and money growth occur. While Benati (2009) accounts for time-variation in a relatively crude way by performing spectral analyses on a moving window of observations, Sargent and Surico (2011) present evidence for time-variation in the money growth-inflation relationship in the U.S. using time-varying vector autoregressions and show the cross spectral gain at frequency zero to have moved far below one after the early 1980s.

Most closely related to our paper is the study by Rua (2012) who uses wavelet analyses to investigate the relationship between euro area M3 growth and HICP inflation based on monthly data from 1970 to 2007. He finds significant cross-spectral coherencies at low frequencies (periods of 12 to 16 years) throughout his sample period with evidence for a weakening of this relationship after 2000. In contrast to our study, Rua does not use the official euro area inflation data but relies for most of his sample on self-constructed data which leads to much different results compared to using the official HICP series. Apart from using the official series for consumer prices our study extends his analysis by investigating the effects of various corrections to the inflation and money growth series, such as correcting money growth for real output growth as in Assenmacher-Wesche and Gerlach (2007) and in Teles and Uhlig (2010) as shifts in trend output growth might obscure the money growth - inflation relationship. Furthermore, we also study the relationship between loan growth and inflation as loan growth is the most important stable driving force of long-run monetary expansion.

The paper proceeds as follows: Section 2 gives a brief introduction to wavelet analysis. Section 3 presents the results and Section 4 concludes.

2 Wavelet analysis

2.1 Idea

Frequency methods provide tools for time series analysis from an alternative perspective to those in the time domain.[1] Comovements of time series can be analyzed in the frequency domain using the cross spectrum or coherency

[1] Since both approaches can be mapped into each other, analysis in the frequency domain should be thought of as providing information complementary to that from time domain methods.

which allows to differentiate between time series components at various frequencies.

Similar to the calculation of an individual time series' spectrum by using the estimated parameters of an ARMA model (frequency decomposition of state space representation), coherency between two time series at various frequencies can be calculated by using VAR parameters (Croux et al., 2001). This approach can be extended to calculating time-varying coherency by using time-varying VAR parameters.[2]

Wavelet analysis is a tool for analyzing time variation in the importance of various scales in the coherence of time series. In contrast to Fourier analysis, it provides the possibility of uncovering transient relations in the data (Aguiar-Conraria et al., 2008). As wavelets have only finite support ("small wave" compared with a sine function which can be interpreted as a "big wave"), they are ideally suited to locally approximating variables in time or space (Crowley et al., 2006). Furthermore, wavelet methods are non-parametric and therefore more robust, e.g. with respect to specification issues and non-linearities. In what follows we will provide a brief introduction to the tools of wavelet analysis.

The starting point is a so-called mother wavelet ψ. By scaling and translation a variety of wavelets can be generated.

$$\psi_{\tau,s}(t) = \frac{1}{\sqrt{|s|}}\psi\left(\frac{t-\tau}{s}\right), \tag{1}$$

where s is a scaling or dilation factor which controls the width of the wavelet. $1/\sqrt{|s|}$ guarantees the preservation of energy, i.e. $||\psi_{\tau,s}|| = |\psi|$. τ is a translation parameter controlling the location of the wavelet. The function ψ has to fullfil some requirements in order to have properties of wavelets (Percival and Walden, 2002): the integral of $\psi(u)$ is zero, i.e.over time ψ has to be below and above zero

$$\int_{-\infty}^{\infty} \psi(u)\, du = 0.$$

An admissibility condition is a sufficient decay

There are various types of wavelet transforms. The discrete time transform (DWT) gives a parsimonious representation of the data through noise reduction and information compression (Bruzda, 2011) and generates orthogonal components. Its major weakness is related to subsample division since it deals with a specific selection of scales, so-called dyadic scales: $s_i = 2^i$, $i = 1, 2, ..., T/2$, where T is the number of observations.

The maximal-overlap DWT gives up the orthogonality requirement and considers all time units, but only dyadic frequency bands (Bruzda, 2011; Crowley et al., 2006). Thus, compared to the DWT it provides increased

[2]For an application see Sargent and Surico (2011).

resolution but at coarser scales and can be applied to data sets of any size. It is based on the intuition of moving a wavelet function along a series. However, its disadvantage is that it oversamples the data.

2.2 Continuous wavelet transform

The continuous wavelet transform (CWT) is an exploratory data analysis tool. As it is two-dimensional but depending on a one-dimensional signal, it contains a lot of redundancy. When moving into larger scales there is little difference in CWT between adjacent scales and there are slow variations across time at any fixed large scale.

2.2.1 The univariate case

The CWT, $W_x(\tau, s)$, is obtained by projecting $x(t)$ onto the family $\{\psi_{\tau,s}\}$[3]

$$\begin{aligned} W_x(\tau, s) &= \langle x, \psi_{\tau,s} \rangle \\ &= \int_{-\infty}^{\infty} x(t) \frac{1}{\sqrt{|s|}} \psi^* \left(\frac{t-\tau}{s} \right) dt, \end{aligned} \tag{2}$$

where * denotes the complex conjugate. The CWT may also be represented in the frequency domain as

$$W_x(\tau, s) = \frac{\sqrt{|s|}}{2\pi} \int_{-\infty}^{\infty} \psi^*(s\omega) X(\omega) e^{i\omega\tau} d\omega,$$

where $X(\omega)$ denotes the Fourier transform of $x(t)$, defined as

$$X(\omega) = \int_{-\infty}^{\infty} x(t) e^{-i\omega t} dt,$$

and ω is the angular frequency.

There exists a variety of different wavelet functions. In the empirical section of this paper the so-called Morlet wavelet is used.

$$\psi_{\omega_0}(t) = \pi^{-\frac{1}{4}} e^{i\omega_0 t} e^{-\frac{t^2}{2}}, \tag{3}$$

where $\omega_0 = 6$. This specific choice for the parameter ω yields a simple relation between scales and frequencies, $f \approx \frac{1}{s}$. The Morlet wavelet is complex valued allowing for an analysis of phase differences, i.e. lead-lag structures.

The wavelet power spectrum is defined as

$$WPS_x(\tau, s) = |W_x(\tau, s)|^2. \tag{4}$$

[3]This section draws on Aguiar-Conraria and Soares (2011).

In the case of a complex-valued wavelet, the corresponding wavelet transform is also complex–valued. It can be decomposed into a real part, the amplitude, $|W_x(\tau, s)|$, and its imaginary part, the phase, $|W_x(\tau, s)|\ e^{i\phi_x(\tau,s)}$. The phase-angle $\phi_x(\tau, s)$ can be obtained by

$$\phi_x(\tau, s) = \arctan\left(\frac{\Im\{W_x(\tau, s)\}}{\Re\{W_x(\tau, s)\}}\right), \tag{5}$$

where $\Im$ denotes the imaginary part and $\Re$ the real part. The use of complex wavelets is necessary in order to retrieve phase information.

2.2.2 The bivariate case

The cross wavelet transform is defined as

$$W_{xy} = W_x W_y^*, \tag{6}$$

where * denotes the complex conjugate.

The cross wavelet power spectrum is defined as

$$|W_{xy}|.$$

Wavelet coherency between two time series x and y can be interpreted as local correlation and is defined as

$$R_{xy}(s) = \frac{\left|S\left(s^{-1}W_{xy}(s)\right)\right|}{\sqrt{S\left(s^{-1}|W_x|\right)}\sqrt{S\left(s^{-1}|W_y|\right)}}, \tag{7}$$

where S is a smoothing operator with respect to time and scale.

The wavelet phase difference can be computed via

$$\phi_{x,y}(s, \tau) = \tan^{-1}\left(\frac{\Im\{W_{xy}(\tau, s)\}}{\Re\{W_{xy}(\tau, s)\}}\right), \tag{8}$$

i.e. the phase angle provides information about the lead-lag relationship of the series. If $\phi_{x,y}(s, \tau) = 0$, the series x and y move together at the specified frequencies. If $\phi_{x,y}(s, \tau) \in \left(0, \frac{\pi}{2}\right)$, series x leads y. If $\phi_{x,y}(s, \tau) \in \left(-\frac{\pi}{2}, 0\right)$, y leads x.[4] The time lag between both series can be calculated as

$$\Delta T(s, \tau) = \frac{\phi_{x,y}(s, \tau)}{2\pi f(\tau)}. \tag{9}$$

[4] Although the economic interpretation of the lead-lag pattern is not as clear cut. See Section 3, footnote 10.

2.2.3 The multivariate case

This is an extension from the bivariate to the multivariate case. The correlation of the variables of interest x and y with other variables is taken into account when calculating coherency and phase differences.

The squared multiple wavelet coherency between series x_1 and all other series x_2, ..., x_p is defined as

$$R^2_{1(23...p)} = R^2_{1(q)} = 1 - \frac{L^d}{S_{11} L^d_{11}} \tag{10}$$

where L is the $p \times p$ matrix of all smoothed cross-wavelet spectra S_{ij}.

$$L = \begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1p} \\ S_{21} & S_{22} & \cdots & S_{2p} \\ \vdots & \vdots & & \vdots \\ S_{p1} & S_{p2} & \cdots & S_{pp} \end{bmatrix}$$

L^d_{ij} is the cofactor of the element (i, j) of matrix L.

$$L^d_{ij} = (-1)^{(i+j)} \det L^j_i,$$

where L^j_i represents the sub-matrix obtained from L by deleting the ith row and the jth column and $L^d = \det L$.

The complex partial wavelet coherency of x_1 and x_j $(2 \leq j \leq p)$ is given by

$$\rho_{1j.q_j} = -\frac{L^d_{j1}}{\sqrt{L^d_{11} L^d_{jj}}}. \tag{11}$$

3 Empirical results

We use quarterly data for the monetary aggregates M3 and M1, loans to the private sector, and for the Harmonized Index of Consumer Prices (HICP) in the euro area over the sample period 1970Q1 to 2012Q4.[5] For later adjustments of the monetary aggregates (see below) we use euro area real GDP and a euro area short-term interest rate. For the short-term rate we utilize data from the area wide model (AWM) database up to 2010Q4 and the 3M euribor rate from 2011Q1 onwards. Except for the short-term rate all series were downloaded from the ECB's Statistical Data Warehouse.[6] We extend the real GDP series from the SDW which begins in 1980Q1 backwards to 1970Q1 using growth rates for real GDP from the AWM database. For the monetary and credit aggregates we used series of notional stocks which

[5] The series are standardised before the wavelet analysis is applied.

[6] http://sdw.ecb.europa.eu/

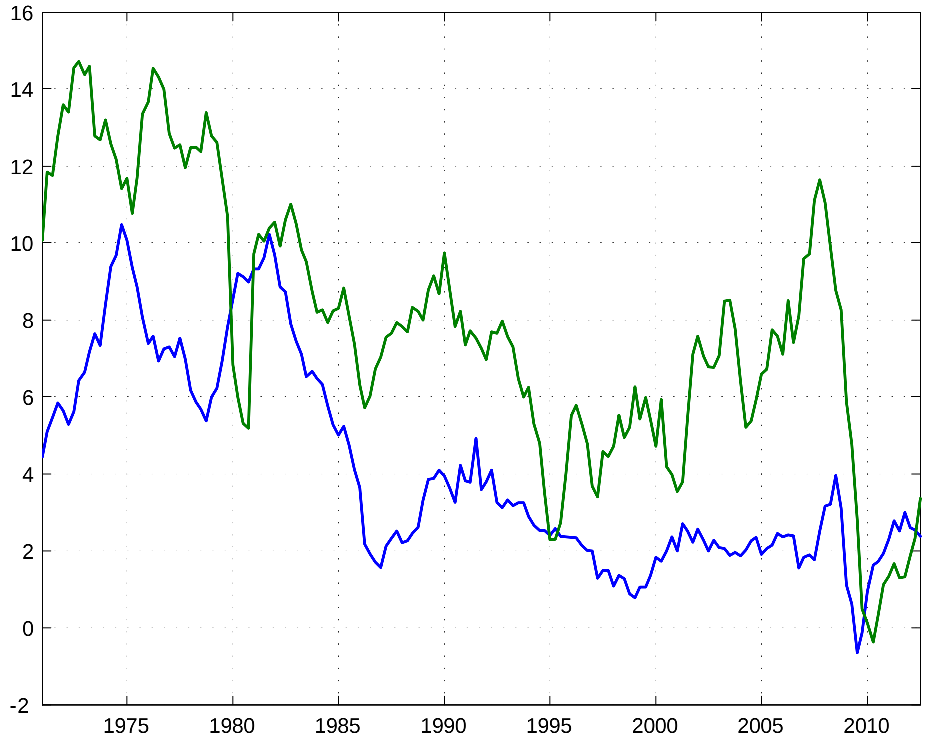

Figure 1: Annual growth rates (percent) of M3 (green) and HICP (blue) in the euro area.

are constructed from transaction-based flow data and are adjusted for non-transaction related changes such as statistical reclassifications, revaluations etc.[7]

We start by estimating the wavelet coherency between the annual growth rate of euro area M3 and the annual inflation rate of the euro area HICP.[8] Figure 1 displays the annual growth rate of euro area M3 and annual HICP inflation while Figure 2 shows the wavelet coherency of both series across time (horizontal axis) and frequencies/periods (in years) (vertical axis). The coherency is increasing from the blue to the red colored areas and the grey (black) lines indicate coherency significantly different from zero at the 10%-

[7] For details, see the technical notes to the European Central Bank's Monthly Bulletin.

[8] All estimations were performed using the AST-toolbox for MATLAB by Aguiar-Conraria and Soares. https://sites.google.com/site/aguiarconraria/joanasoares-wavelets/

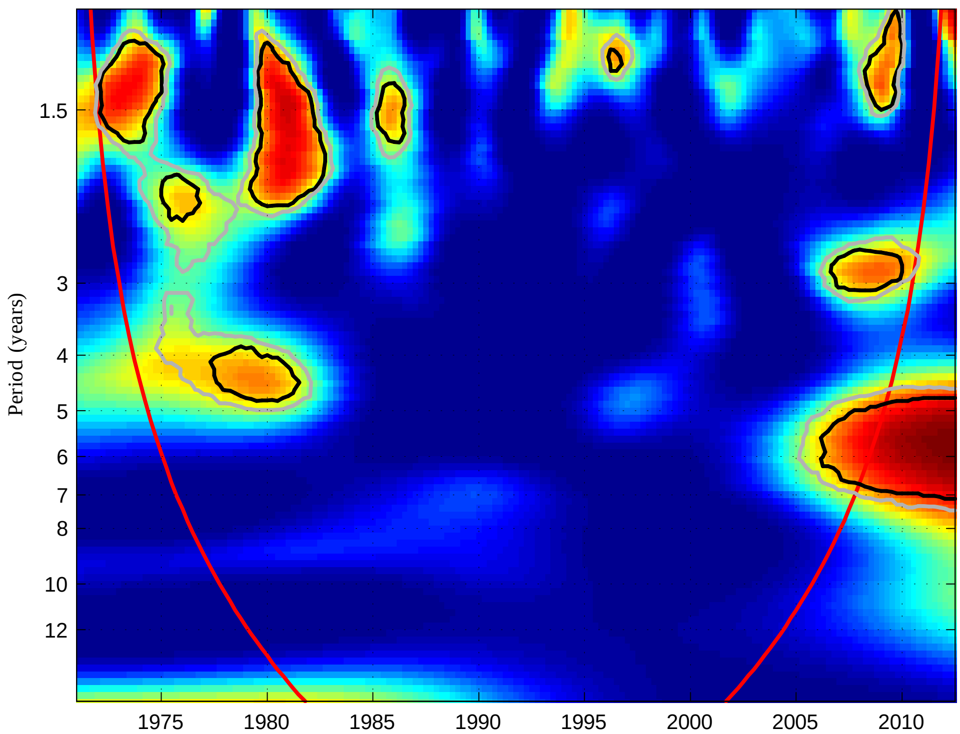

Figure 2: Wavelet coherency of annual growth rate of M3 and HICP inflation.

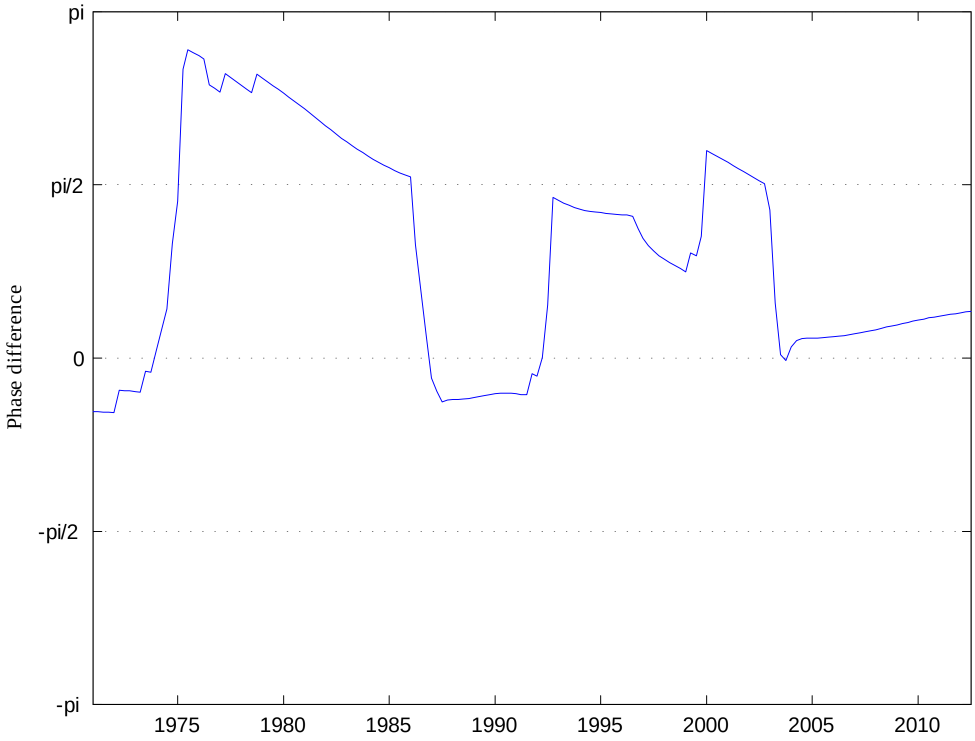

Figure 3: Phase difference of HICP inflation and annual growth rate of M3 - periods of 3-7 years

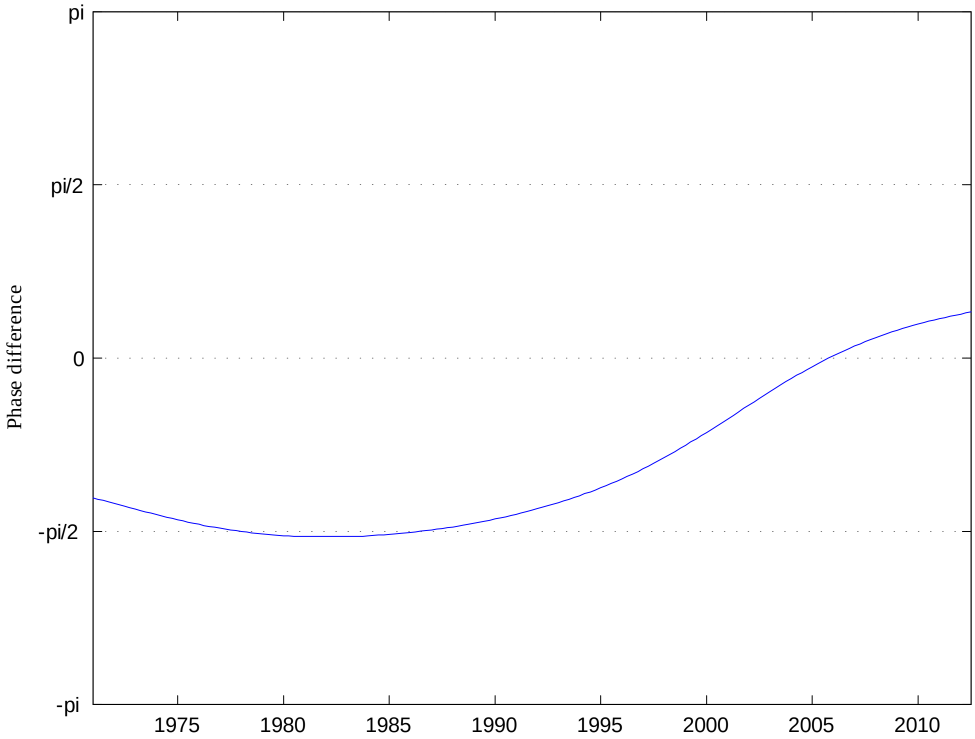

Figure 4: Phase difference of HICP inflation and annual growth rate of M3 - periods of 12-16 years

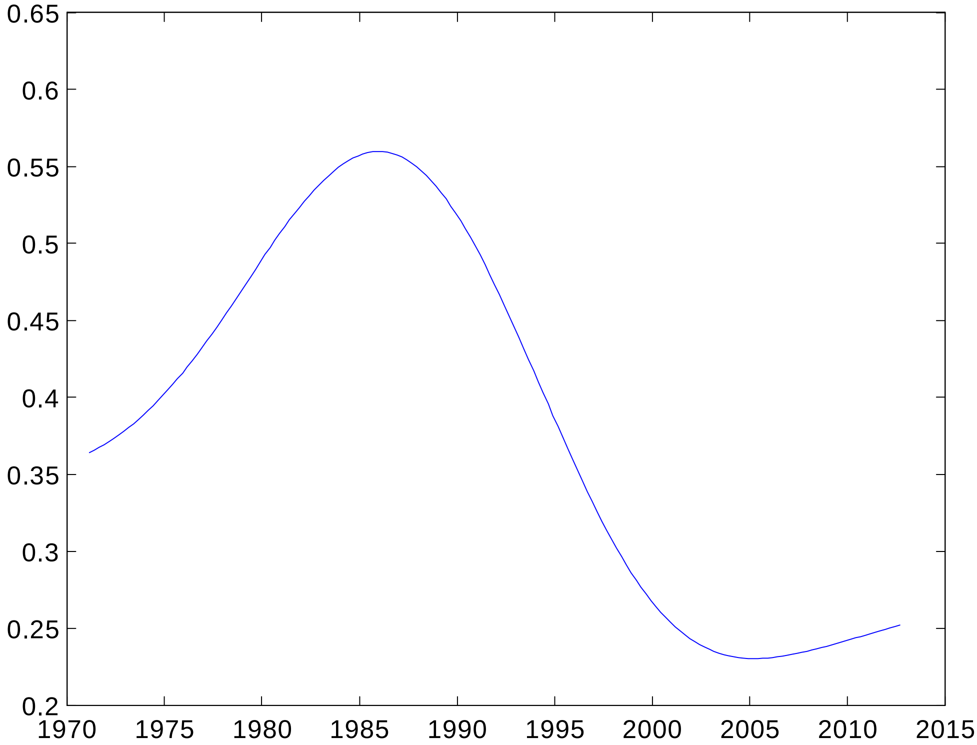

Figure 5: Cross-spectral gain of of annual growth rate of M3 and HICP inflation, periods of 12-16 years.

(5%-) level.[9] Note that only estimates between the curved red bands should be interpreted, however, since the estimates beyond these bands, closer to the outer edges, are based on relatively few observations.[10] Figure 2 shows that we estimate only few significant coherencies between money growth and inflation. Significant comovements between these two variables occured for periods about three to seven years after 2005 and at frequencies with periods between four and five years from the late 1970s to the early 1980s. Other significant coherencies are estimated for only very brief time periods (and at high frequencies) or are not contained within the interpretable region.

The lead-lag structure between the two series can be analyzed for selected frequency bands by estimating the phase difference (8).[11] Figures 3 and 4 display the estimated phase differences for movements with periods of 3-7 years, which covers the significantly estimated coherencies at medium frequencies in Figure 2, and with periods of 12-16 years, i.e. long run fluctuations for which we did not find significant coherencies The phase difference for the medium frequencies is very volatile. Over the periods for which we estimate signficant coherencies (approx. 1975-1983 and after 2005) the phase differences translate roughly into time lags of inflation relative to money growth of about 3.5 years and 4.75 years, respectively or into time lags of money growth relative to inflation of 1.5 and 0.25 years, respectively [12] On the other hand, for the frequency spectrum with periods of 12-16 years an average phase difference of slightly above $-\frac{\pi}{2}$ up to the mid 1990s

[9]The relative differences in coherencies at various scales and locations are graphically enhanced in the figures so that only significant values are displayed in red. As a consequence estimated coherency can be quite substantial but never significant within the blue areas.

[10]If there is only an insufficient number of past or future observations available to estimate the wavelet power spectra and the wavelet cross spectrum for a given point in time the algorithm extends the sample backwards or forward by "reflecting" the first/last observations. The red bars indicate the time periods in which the results are affected by this procedure.

The region of usable estimates becomes smaller for lower frequencies as the flexible determination of the observation window length that enters the wavelet transform implies broader windows and, hence, the use of more observations for extracting lower frequency components.

[11]The phase difference indicates with reference to the unit circle how far series x is leading series y. It describes how far series x leads series y along the circumference of the unit circle. A problem in the interpretation of the phase difference arises because along the unit circle any given lead of variable x before variable y can also be interpreted as a lead of variable y (money growth) for variable x (inflation). For example, assume a phase difference of $\frac{\pi}{2}$, i.e. series x is at its high point on the unit circle while series y is at zero. This relationship could either be viewed as x leading y by $\frac{\pi}{2}$or as as series x leading y $\frac{3\pi}{2}$.

[12]For the 3-7 years frequency band with an average period of 5 years an average phase difference of about $\frac{2\pi}{3}$between 1975 and the mid 1980s implies approximately a time lag of money growth after inflation of $\frac{5}{2\pi}\frac{2\pi}{3} = \frac{5}{3}$years or a time lag of inflation after money growth, i.e. a load of money growth of about $5 - \frac{5}{3}$years. An average phase difference after 2005 of $\frac{\pi}{8}$translates into a time lag of money growth after inflation of $\frac{5\pi}{2}\frac{\pi}{8} = \frac{5}{16}$years or a lag of inflation after money growth of $5 - \frac{5}{16}$ years.

implies a lead of money growth before inflation of approximately 3.5 years, a lead similar to the one estimated for the higher frequency band. Our results show that, at least at low frequencies money growth indeed appears to lead inflation but that the comovements in the low frequency band do not appear to be statistically significant.

Our results presented so far are in strong contrast to those in Rua (2012) who estimates significant coherencies at low frequencies (periods of 12 years and more) for euro area M3 growth and inflation throughout the whole sample period. These results are driven by the different inflation data, since Rua uses the officially published HICP only after 1991 and a HICP series constructed by himself from weighted national CPI data for the time before. By contrast, we use the officially published series throughout. This results in the annual inflation rate used by Rua being higher and more volatile than the official series, especially in the 1970s and early 1980s, which causes him to estimate significant wavelet coherencies for a much longer time span.[13]

Cross-spectral coherency is a measure of the extent of covariability in the fluctuations of both time series, comparable to the R^2 in a regression analysis. The relative size of the comovements, comparable to a regression coefficient is measured by the cross-spectral gain. The estimated gain at low frequencies captures the long-run level relationship between money growth and inflation and can be interpreted as a regression coefficient in a regression of the low frequency component of inflation on the low frequency component of money growth as in Lucas (1980). An estimated gain of one would imply a quantity theoretic relationship, i.e. that inflation and money growth move one to one. In wavelet analysis the length of the sample period limits the frequency spectrum that can be analysed, as estimation for lower frequencies requires more and more data. Here, we choose to approximate low frequencies by periods between twelve and sixteen years.[14] The estimated gain in Figure 5 starts around 0.45 in the early 1980s, rises to about 0.55 in 1985 and then declines to about 0.25 in the early 2000s.[15] This indicates that the long-run relationship between the levels of money growth and inflation was quite strong until the end of the Great Inflation and became much less pronounced afterwards Using a time-varying VAR for the U.S. Sargent and Surico (2011) estimate cross spectral gains between money

[13]Since the wavelet coherency is based on observations from (endogenously determined) windows a stronger correlation during the 1970s and 1980s will to some extent also affect coherency into more recent years.

[14]Estimating the gain at frequency zero would, in fact, require an infinitely long sample period. Parametric methods can be used to estimate cross spectra at low frequency even on finite data sets as they allow to "extrapolate" the relationships between the variables to frequencies not actually contained in the data.

See, for example, Sargent and Surico (2011) who estimate a time-varying VAR and derive the cross-spectral gain at frequency zero from the estimated VAR coefficients.

[15]Note that only the time period falling in the region between the red lines displayed in Figure 2 should be interpreted.

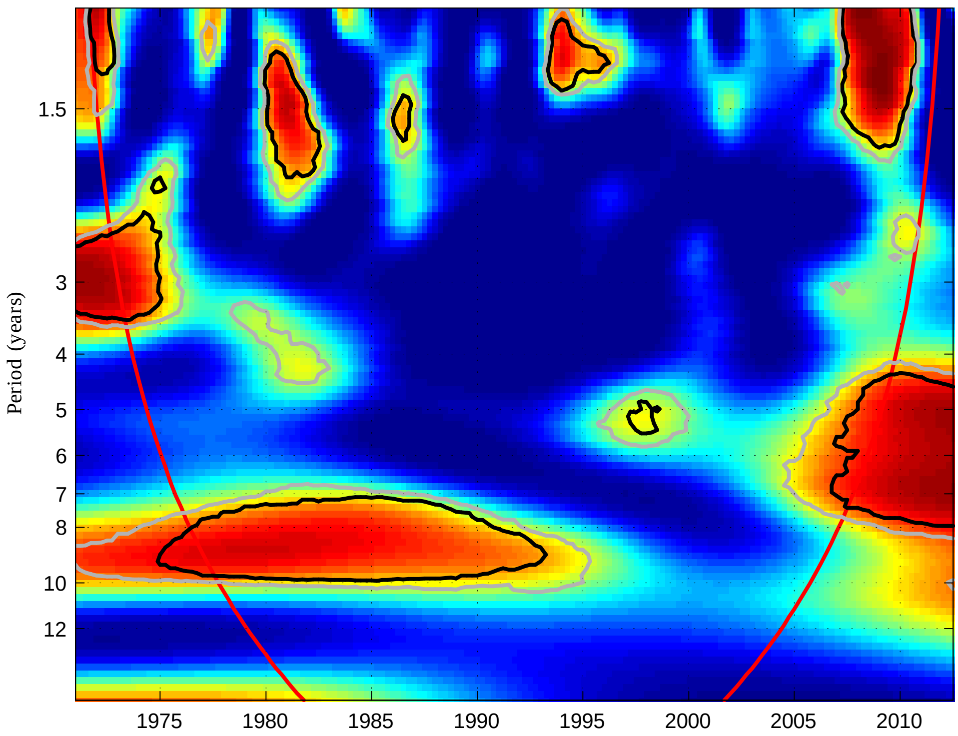

Figure 6: Wavelet cohereny of annual growth rate of M3 (adjusted for real GDP growth) and HICP inflation

growth (M2) and inflation (measure by the growth in the GDP deflator). Their results indicate that the cross-spectral gain at frequency zero is not significantly different from one in the 1970s but declines significantly below one after 1980 with point estimates around 0.25. While our peak estimate occurs somewhat later (around 1985) and is below their peak estimate in the late 1970s[16] our estimate of much lower cross spectral gains in the following period are similar to theirs. Sargent and Surico attribute the strong decline in the cross spectral gain at frequency zero to a more aggressive monetary policy reaction function which implies a shift in the cross spectral gain towards zero. Based on a DSGE model they show that a cross spectral gain at low frequencies around one results from the central bank allowing persistent innovations in money by reacting to weakly to inflationary pressures. In contrast, a monetary policy reaction function in which the central bank responds aggressively to inflationary pressures leads to a gain close to zero.

[16] See Figure 5 in Sargent and Surico (2013).

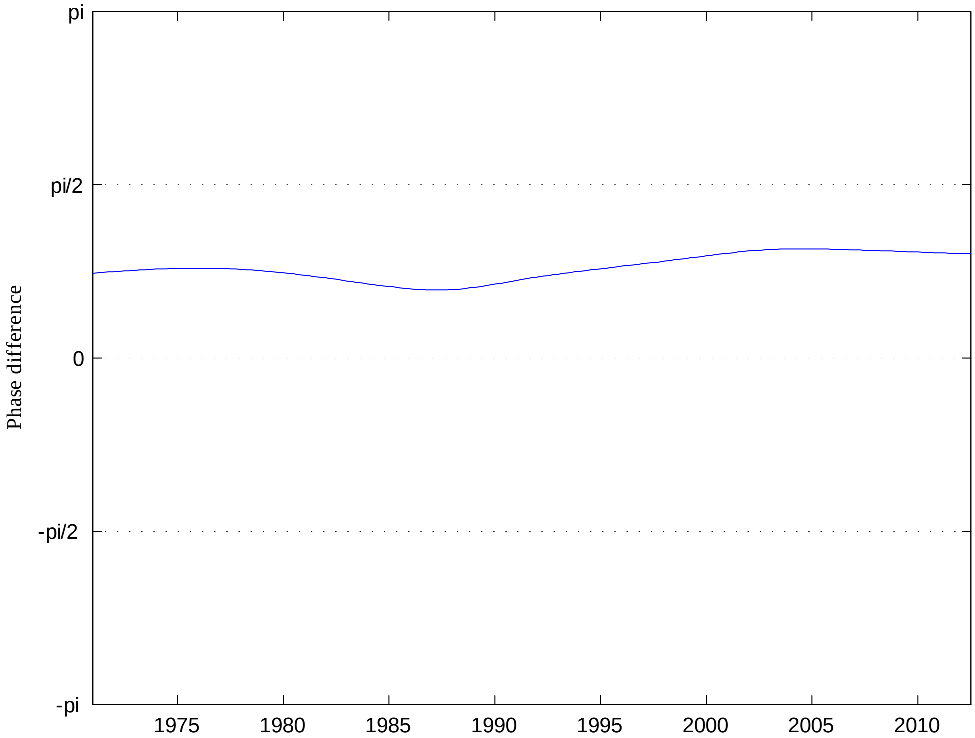

Figure 7: Phase difference of HICP inflation and annual growth rate of M3 (adjusted for real GDP growth) - periods of 6-10 years

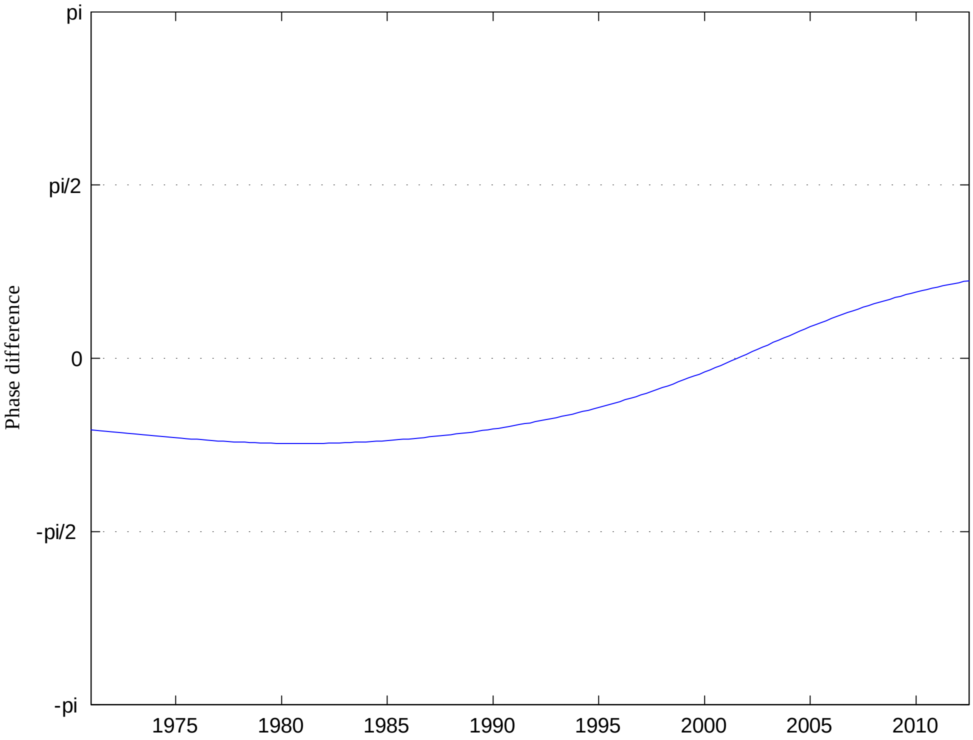

Figure 8: Phase difference of HICP inflation and annual growth rate of M3 (adjusted for real GDP growth) - periods of 12-16 years

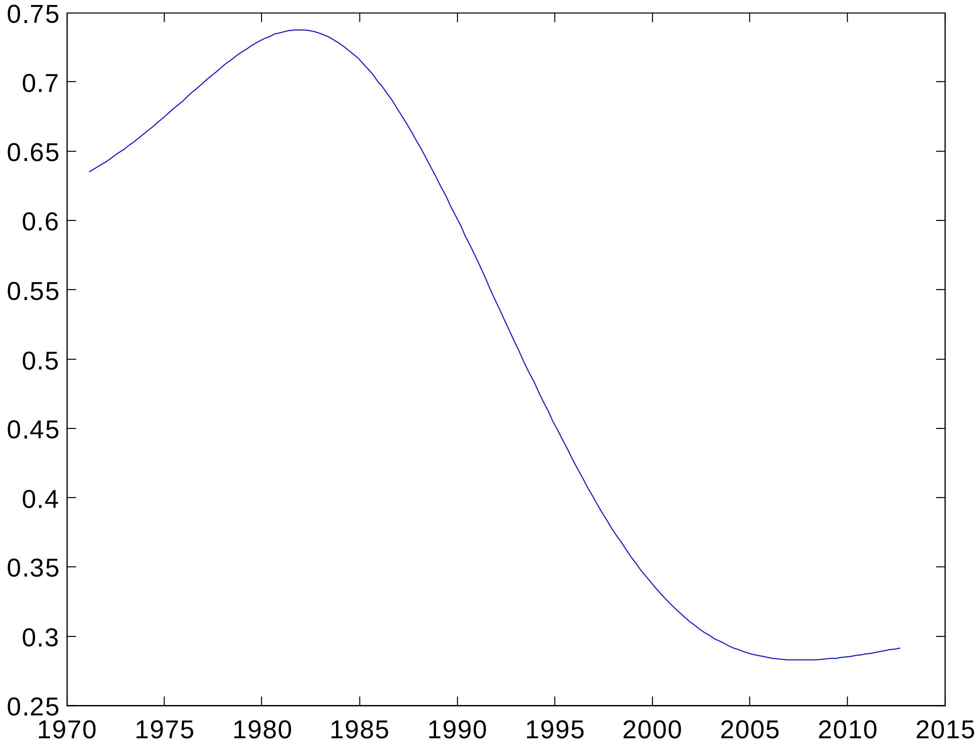

Figure 9: Cross-spectral gain of of annual growth rate of M3 (adjusted for real GDP growth) and HICP inflation, periods of 12-16 years.

As a first robustness check Figure 6 presents wavelet coherencies for M3 growth and HICP inflation where the growth rate of M3 has been adjusted for real GDP growth.[17] If money growth were strongly affected by real GDP growth this effect could obscure the money growth - inflation relationship. Compared to Figure 2 the results become somewhat stronger with significant coherency for fluctuations with periods of seven to ten years from the mid 1970s to the mid 1990s. The phase differences in Figures 7 and 8 indicate that for the frequency band where we estimate significant coherencies up into the mid 1990s (periods of 6-10 years) adjusted M3 growth leads inflation by about seven years or inflation leads money growth by about one year the latter interpretation seems to be more plausble since the money growth lead appears to be rather long. At the very low frequency band (Figure 8, periods of 12-16 years) adjusted money growth seems to lead inflation up into the mid 1990s with a lead of about 1.5 to 1.75 years which is shorter than for unadjusted M3. Note however, that for these frequencies the estimated coherency again turned out to be insignificant. Concerning the long-run relationship between money growth and inflation, the estimated cross-spectral gain at low frequencies (periods between 12 and 16 years) peaks in the early 1980s at around 0.75 and then declines to about 0.3 in the early 2000s (Figure 9). Compared to the results for unadjusted M3 growth the estimated M3 gain is higher for M3 growth adjusted for real GDP growth and peaks earlier. The overall qualitative result remains unchanged, however.

As another robustness exercise, we control for the impact of short-term interest rates on both money growth and inflation by computing for both series the partial wavelet coherency conditional on the change of the short-term interest rate. Euro area interest rates have been following a falling trend since the early 1980s (Figure 10) and may have led to low frequency increases in money demand due to lower opportunity costs. As this increase in money demand need not be inflationary it might obscure the estimated relationship between money growth and inflation.[18] Comparing Figures 2 and 11 conditioning on changes in the short-term interest rate does not lead to higher coherency of money growth and inflation at low frequencies. Using both adjustments i.e. adjusting M3 growth for real GDP growth and conditioning on changes in short-term interest rates leads to very similar

[17] See, for example, Assenmacher-Wesche and Gerlach, 2007; Teles and Uhlig, 2010; Amisano and Fagan, 2010. To construct the adjusted money growth rate, we subtract the annual growth rate of real GDP from the annual growth rate of M3.

[18] The partial wavelet coherency controls for the effect of interest rate changes on both inflation and money growth. For this reason this conditioning would not allow us to detect comovements between these two variables which are correlated with changes in the short-term interest rate. For example, if a reduction in interest rate leads to inflation as well as to an increase in money growth this comovement between money growth and inflation would not show up in our estimates. Adjusting only money growth for inflation would require an estimate of the interest rate elasticity of money demand at the relevant frequencies.

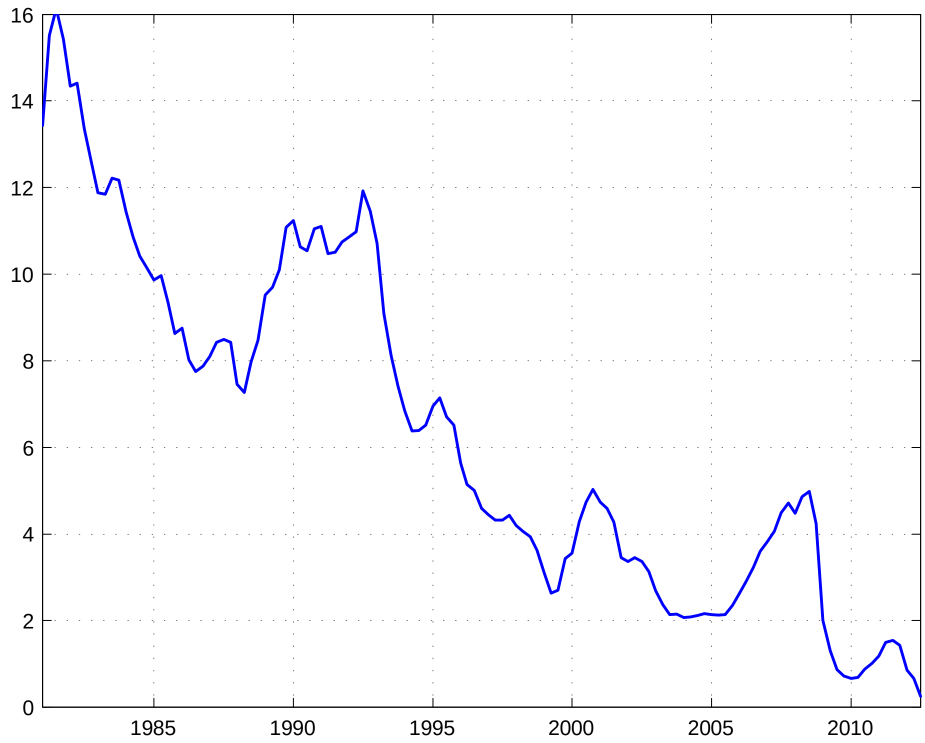

Figure 10: Euro area short-term interest rate (percent)

results (Figure 12). As a further robustness check we repeated our analysis with the HICP excluding prices for food and energy in place of the overall HICP. The results are very similar and are presented in the appendix.

In a further step, we replace the broad monetary aggregate M3 with the narrow aggregate M1. According to Figure 13 significant coherency (at the 5%-level) exists only temporarily at frequencies with periods between three and seven years and the phase differences for these frequencies are very unstable (Figure 14) Significant (at the 10%-level) coherencies are also shown for frequencies with periods of 10-12 years from 1988-93. The phase differences for the low frequency spectrum indicate for this time period a lead of M1 growth before inflation between five and six years (Figure 15). The cross-spectral gain has a similar shape to the one for M3 but is generally higher, starting out at approximately 0.6 in 1980, reaching a peak in the mid-to-late 1980s at about 0.7 and falling afterwards until about 2005 at approximately 0.15. The peak occurs about at the same time as for the unadjusted M3 growth and inflation series in Figure 5 Adjusting M1 growth

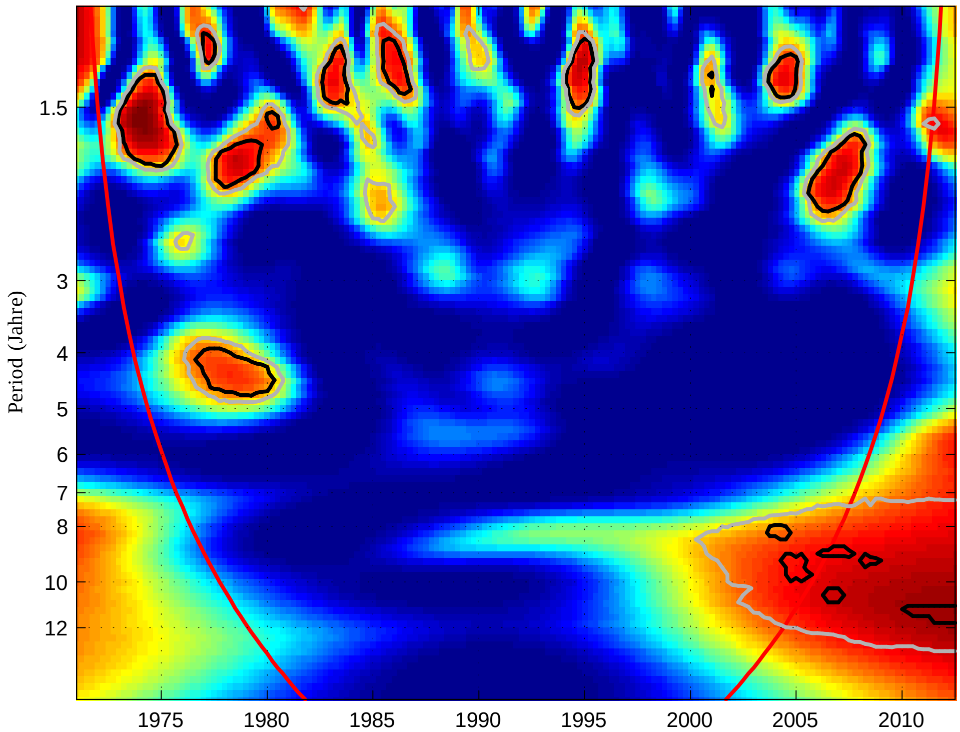

Figure 11: Partial wavelet chereny of annual growth rate of M3 and HICP inflation, conditional on change in short-term interest rates

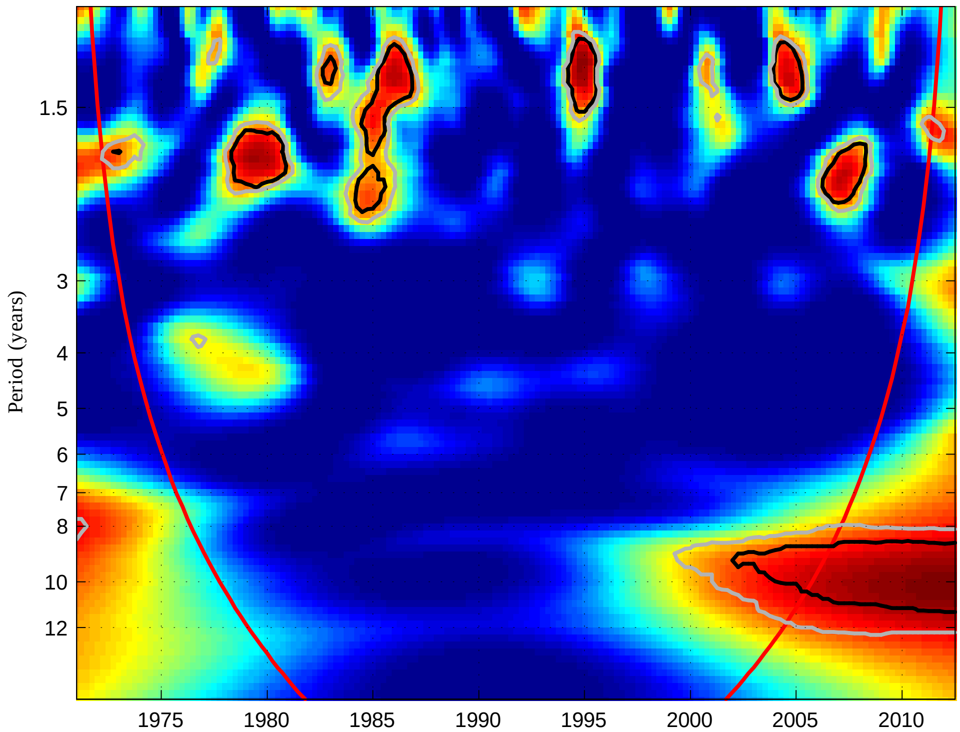

Figure 12: Partial wavelet chereny of annual growth rate of M3 (adjusted for real GDP growth) and HICP inflation, conditional on change in short-term interest rates.

for real GDP growth (Figure 17) results in signficant and stable coherency for frequencies with periods of six to 16 years until the mid 1990s and for frequencies with periods of three to seven years thereafter. For these medium frequencies the phase difference changes strongly from a lag of money growth of about half a year (or a lead of about 4.5 years) in the late 1990s to a lag of money growth of about 2 years (a lead of about three years) in the early 2000s (Figure 18). At the lower frequencies the phase difference is more stable and implies a lead of money growth before inflation of somewhat below seven years (or a lag of above four years, Figure 19). The cross-spectral gain at low frequencies turns out to be comparatively high with a peak in the mid 1980s at about two and a minimum at about 0.8 in 2005 (Figure 20). We obtain much weaker results for the partial wavelet coherency of the two series conditional on the change in the short-term interest rate (Figure 21) with only very few and short-lived significant coherencies. In contrast to M3, combining both adjustments, i.e adjusting M1 growth for real GDP growth and computing the partial wavelet coherency conditional on the change in the short-term rate leads to significant cohereny at low frequencies which break down only temporarily in the second half of the 1980s (Figure 22). The phase-differences in Figure 23, however, indicate that adjusted M1 growth is lagging inflation by more than 2 years at these frequencies as interpreting the phase difference as a lead of adjusted M1 growth before inflation would imply implausible long leads of about 11 years.

Being mostly unable to find significant correlations between money growth and inflation at the low frequency spectrum we now turn to the relation between loan growth and inflation in the euro area.[19] This analysis is based on the observation that bank lending is the most important counterpart to M3 and the major driving force in long-run changes in the broad monetary aggregate M3 in the euro area. Here, we focus on lending of MFIs (monetary financial institutions) to the private sector. The close relationship between M3 growth and loan growth is documented in Figure 25. Significant wavelet coherency (at the 10%-level) for periods between six and nine years and periods of 12 years and more indicate that the relationship between loan growth and money growth is driven mostly by low frequency components. Turning to the relationship between lending and inflation, however, similar to the results for M3, Figure 26 shows no evidence of stable coherency at low frequencies between the annual growth rates of lending to the private sector and HICP inflation. Those significant coherencies estimated for frequencies with periods of 1.5 to 4 years after 2005 are probably driven by the comovements of both series during the financial crisis.. Adjusting loan growth for real GDP growth, i.e. looking at the growth rate in the loans-to-gdp ratio does not lead to much different results (Figure 27).

[19] Time series for loans are only available back to 1980Q1.

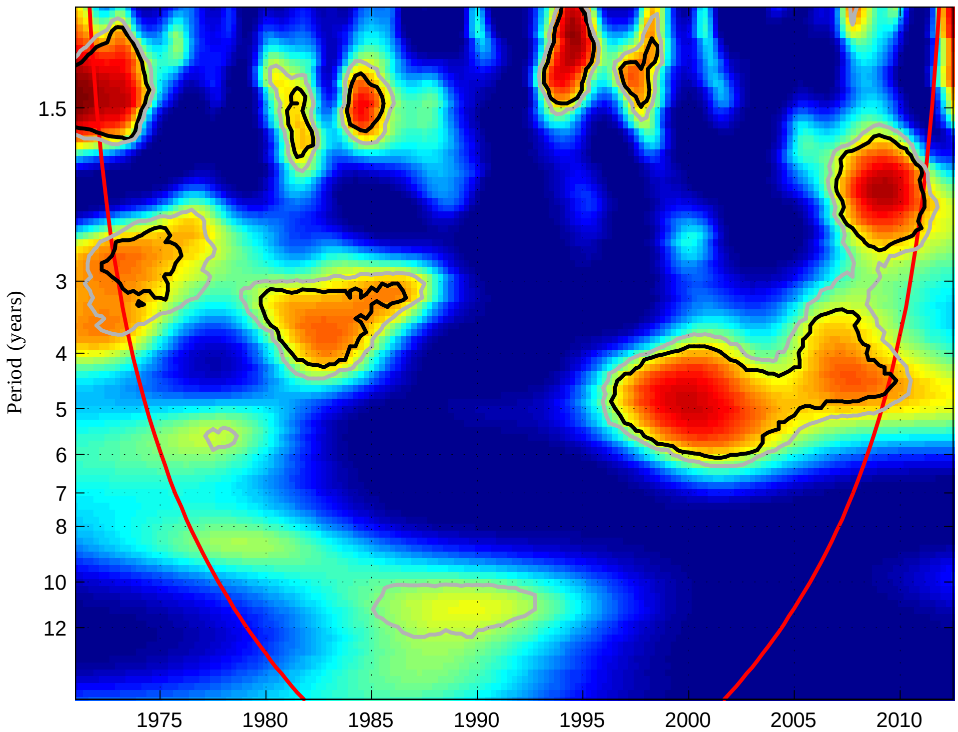

Figure 13: Wavelet chereny of annual growth rate of M1 and HICP inflation.

Figure 14: Phase difference of HICP inflation and annual growth rate of M1 - periods of 3-7 years

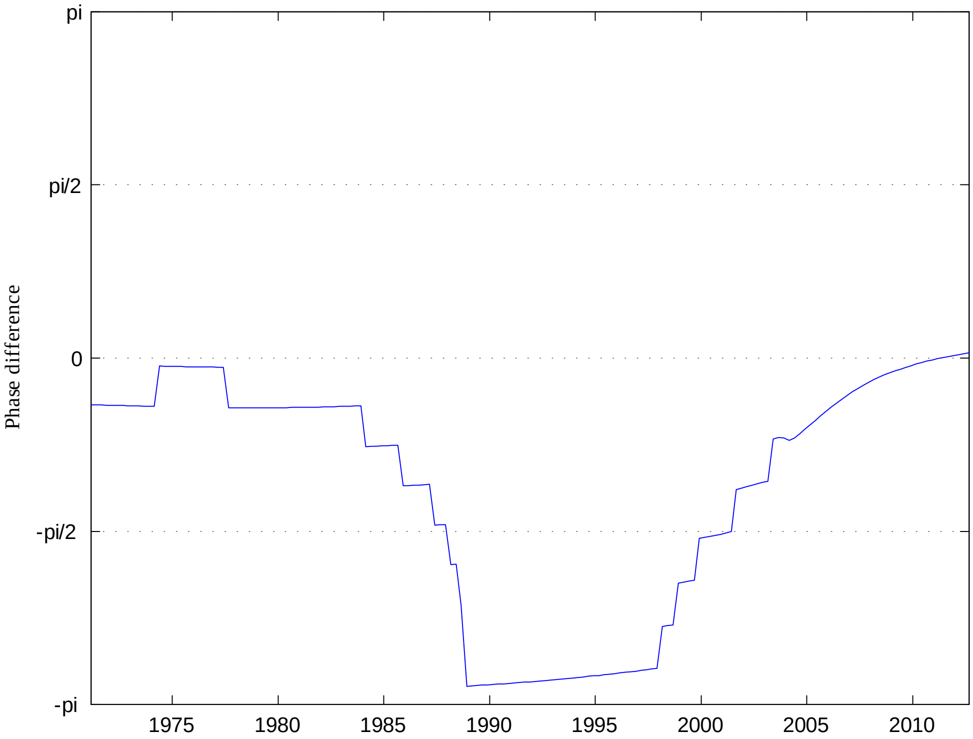

Figure 15: Phase difference of HICP inflation and annual growth rate of M1 - periods of 10-16 years

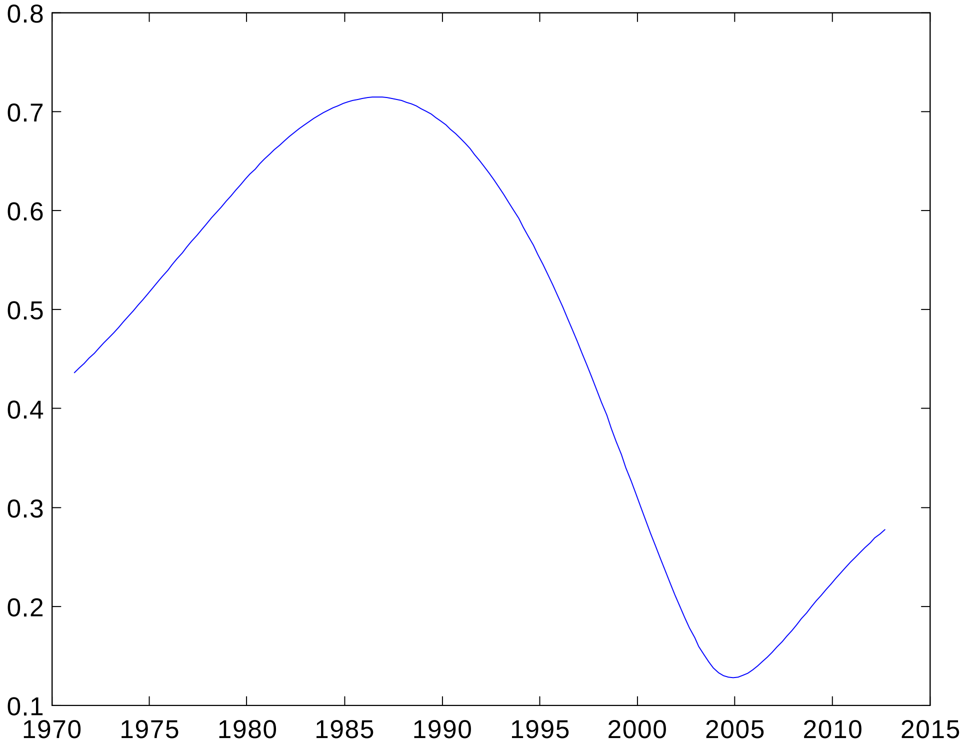

Figure 16: Cross-spectral gain of of annual growth rate of M1 and HICP inflation, periods of 12-16 years.

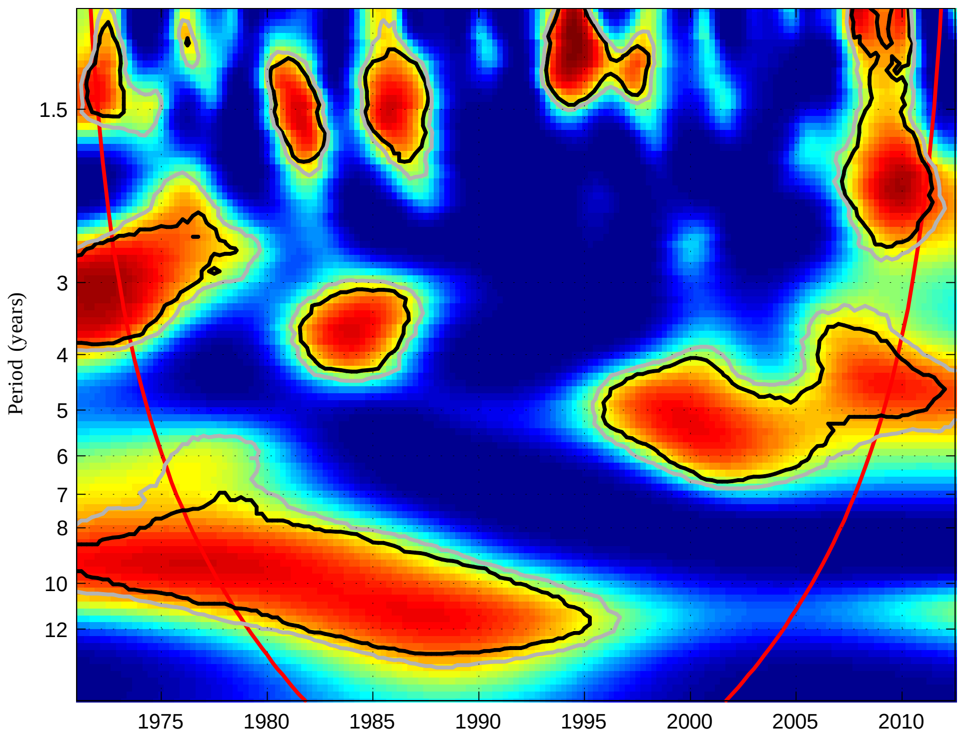

Figure 17: Wavelet chereny of annual growth rate of M1 (adjusted for real GDP growth) and HICP inflation.

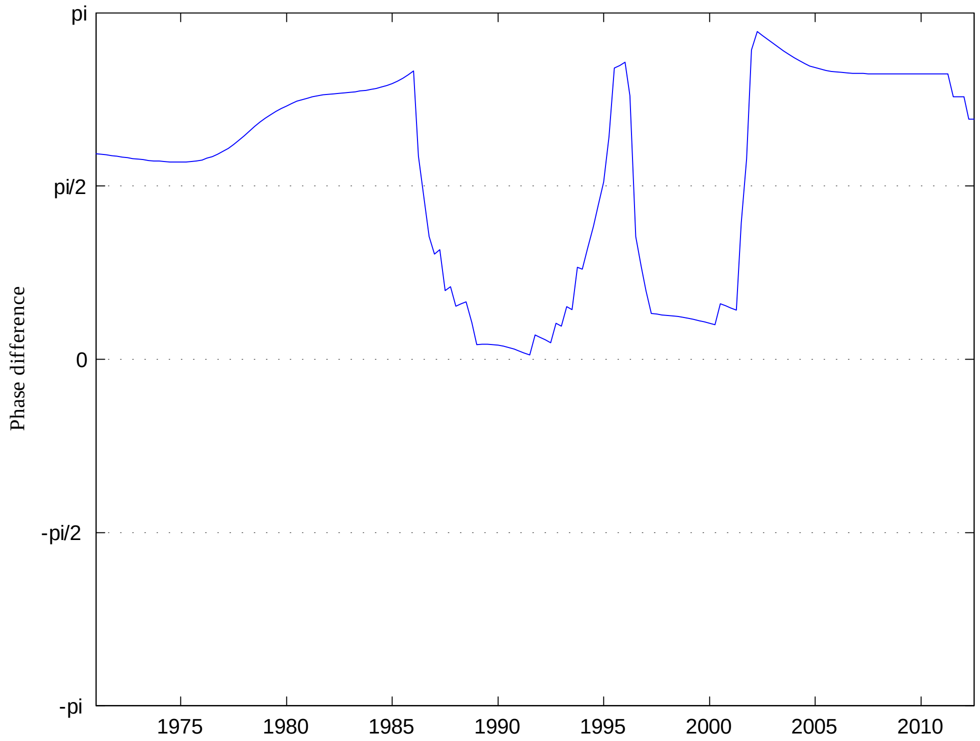

Figure 18: Phase difference of HICP inflation and annual growth rate of M1 (adjusted for real GDP growth) - periods of 3-7 years

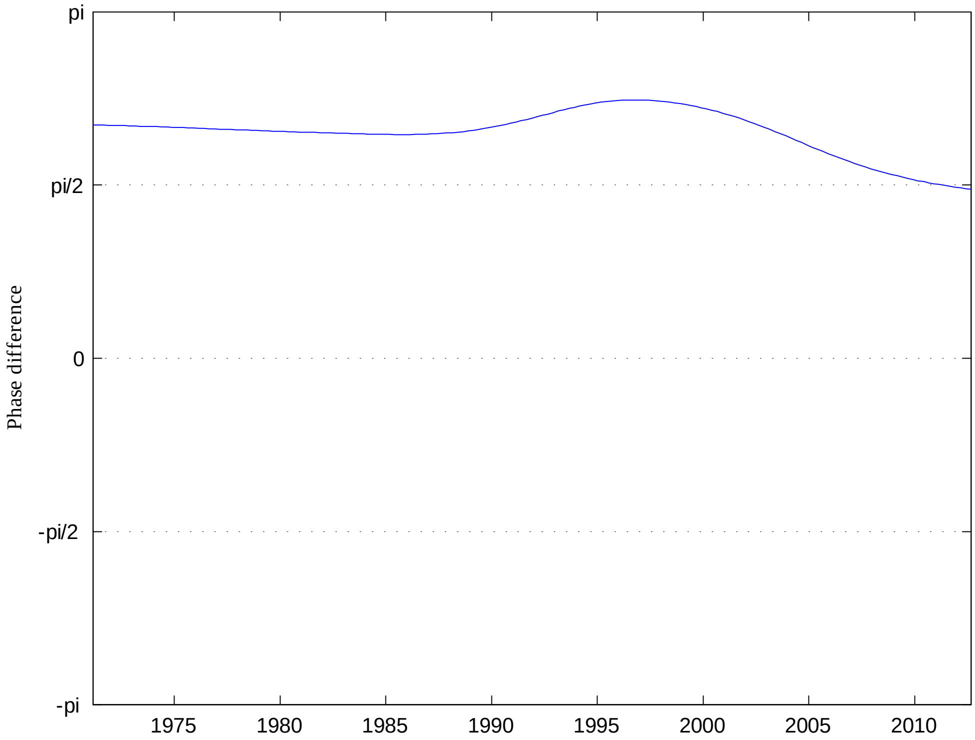

Figure 19: Phase difference of HICP inflation and annual growth rate of M1 (adjusted for real GDP growth) - periods of 6-16 years

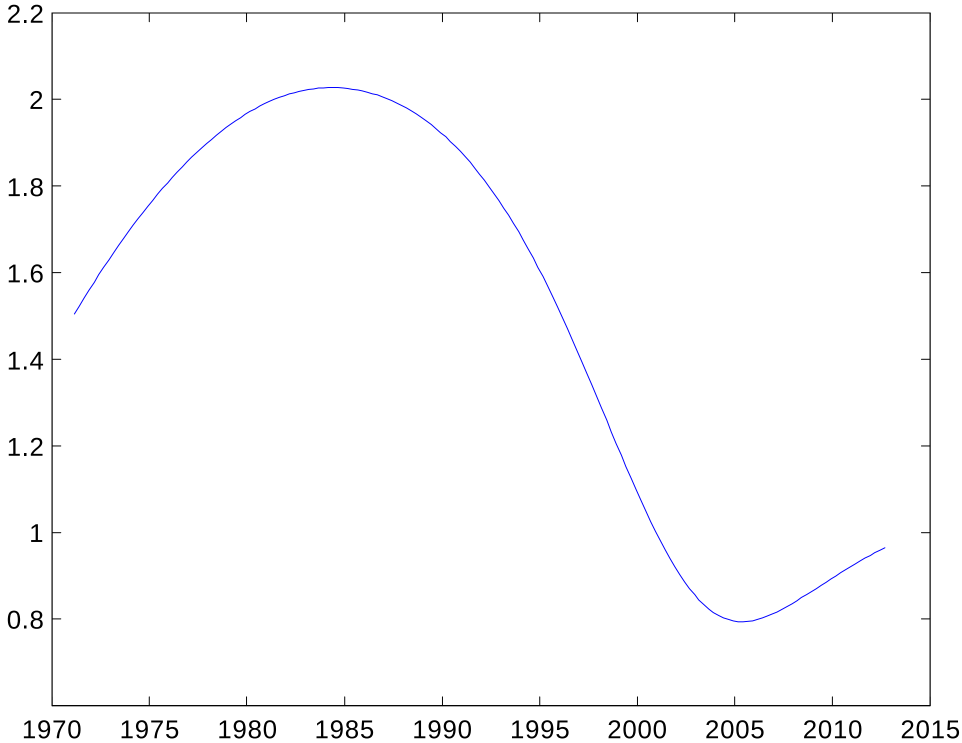

Figure 20: Cross-spectral gain of of annual growth rate of M1 (adjusted for real GDP growth) and HICP inflation, periods of 12-16 years.

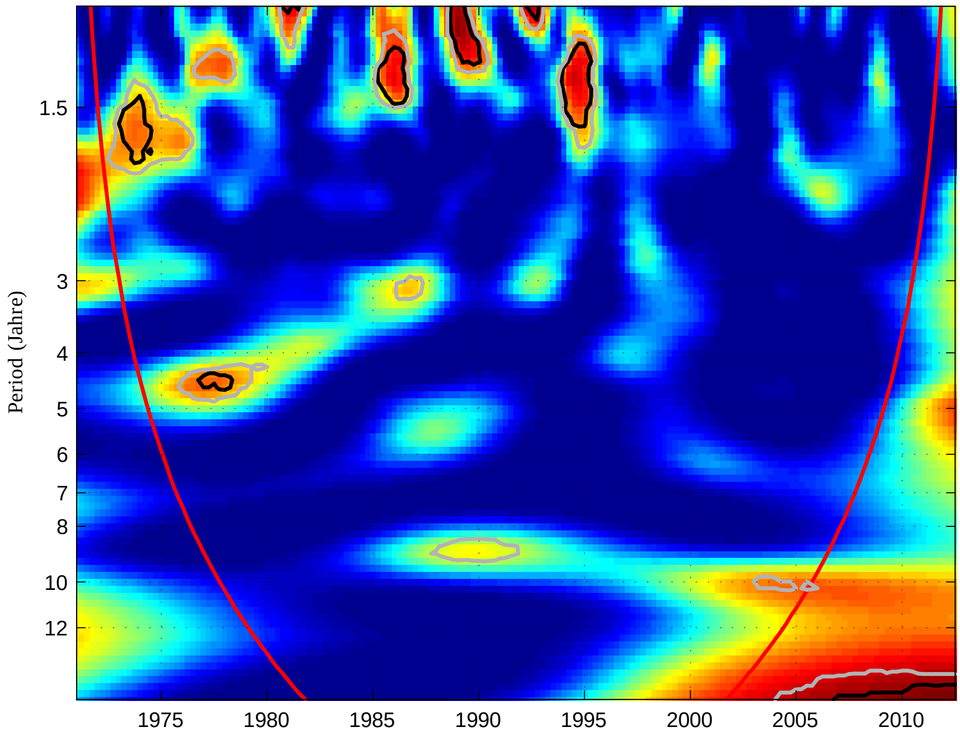

Figure 21: Wavelet cohereny of annual growth rate of M1 and HICP inflation, conditional on change in short-term interest rate.

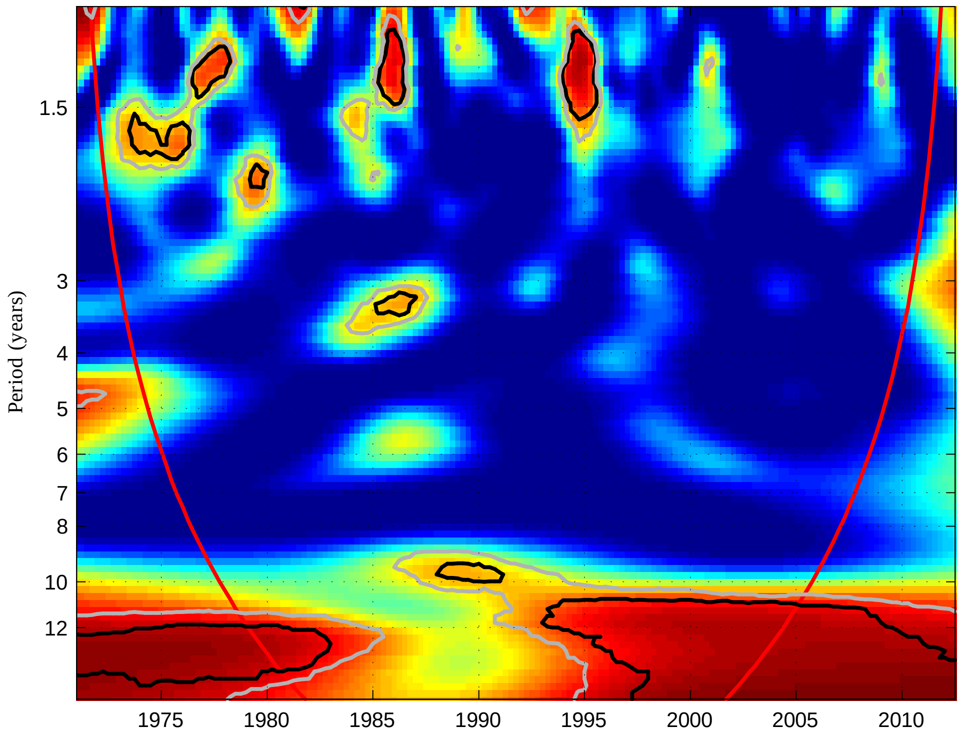

Figure 22: Wavelet cohereny of annual growth rate of M1 (adjusted for real GDP growth) and HICP inflation, conditional on change in short-term interest rate.

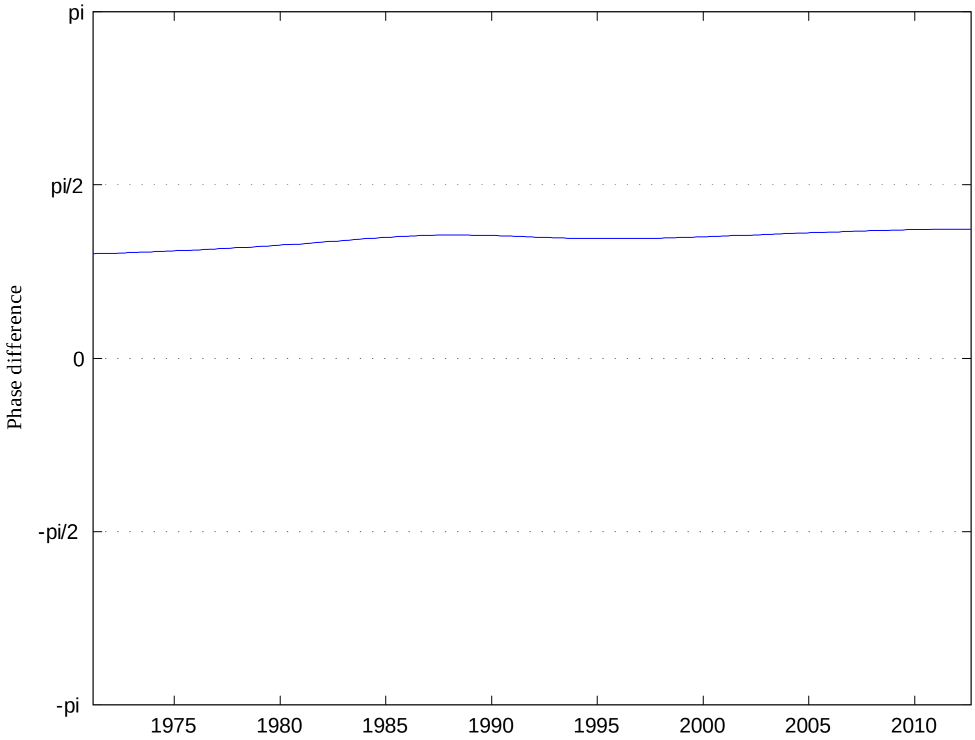

Figure 23: Phase difference of HICP inflation and annual growth rate of M1 (adjusted for real GDP growth), conditional on change in short-term interest rates - periods of 10-16 years

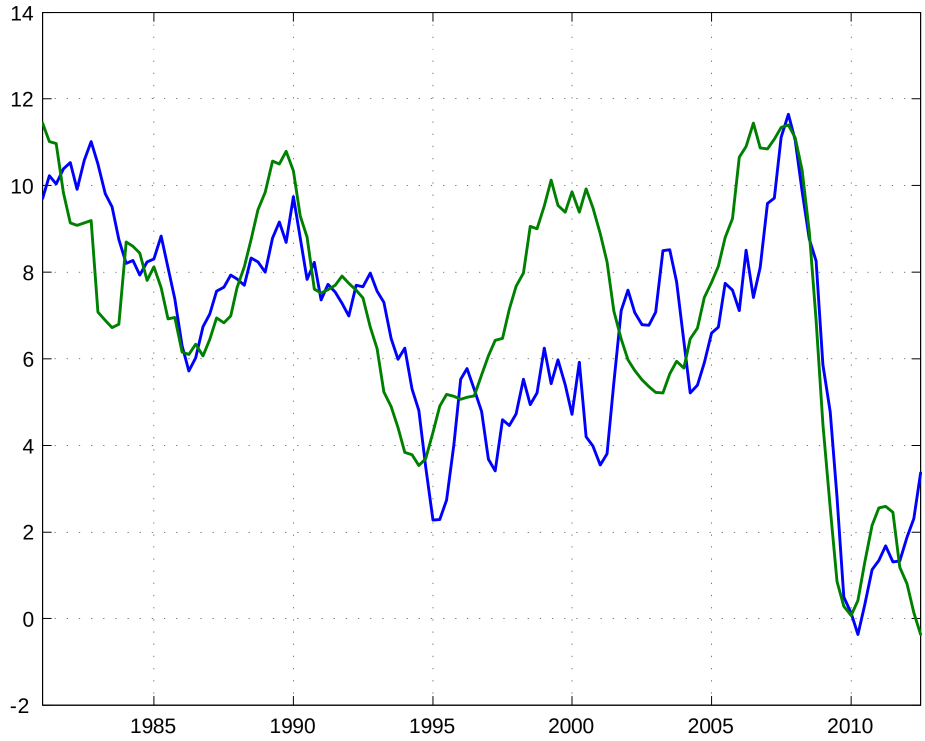

Figure 24: Annual growth rates (percent) of M3 (blue) and loans to the private sector (green).

4 Conclusions

The empirical literature surveyed in Section 1 has found evidence for a stable relationship between money growth and inflation in the euro area, in particular between the low frequency components of these time series. However, some more recent studies indicate that this relationship might have weakened through time. The results of our wavelet analysis, which accounts explicitly for time variation in the relationships of interest, indicate that there is no evidence for significiant comovements between the low frequency components in the growth rates of the monetary aggregate M3 and consumer price inflation in our sample period (1970-2012). For the frequency bands for which we find evidence for significant coherencies the phase differencea indicate either money growth leading inflation by three to seven years or lagging inflation by a quarter to 1.5 years, which seems more plausible. Replacing M3 with M1 leads to somewhat better results but does not overturn the main results. Finally, using growth rates of bank lending in place of

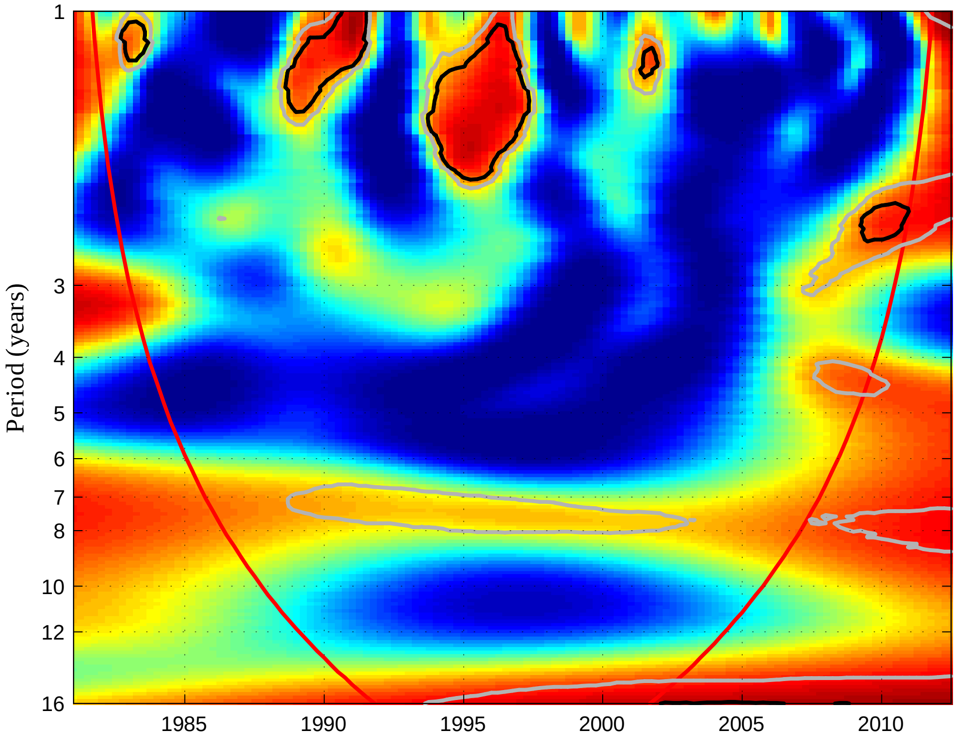

Figure 25: Wavelet coherency of annual growth rates of M3 and loans to the private sector.

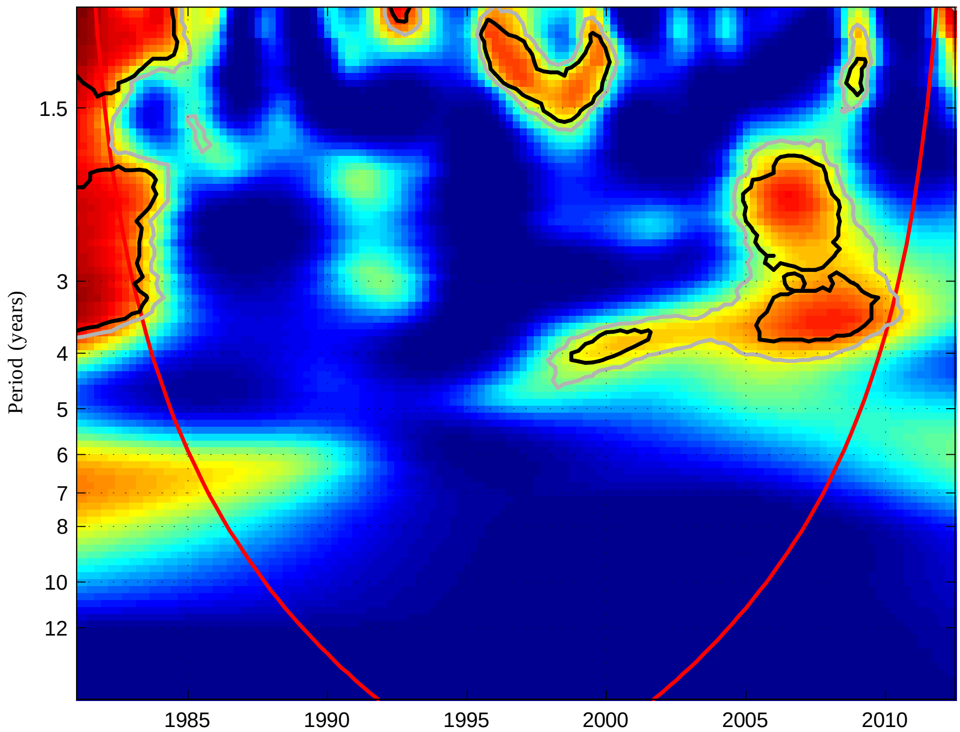

Figure 26: Wavelet cohereny of annual growth rate of loans to the private sector and HICP inflation.

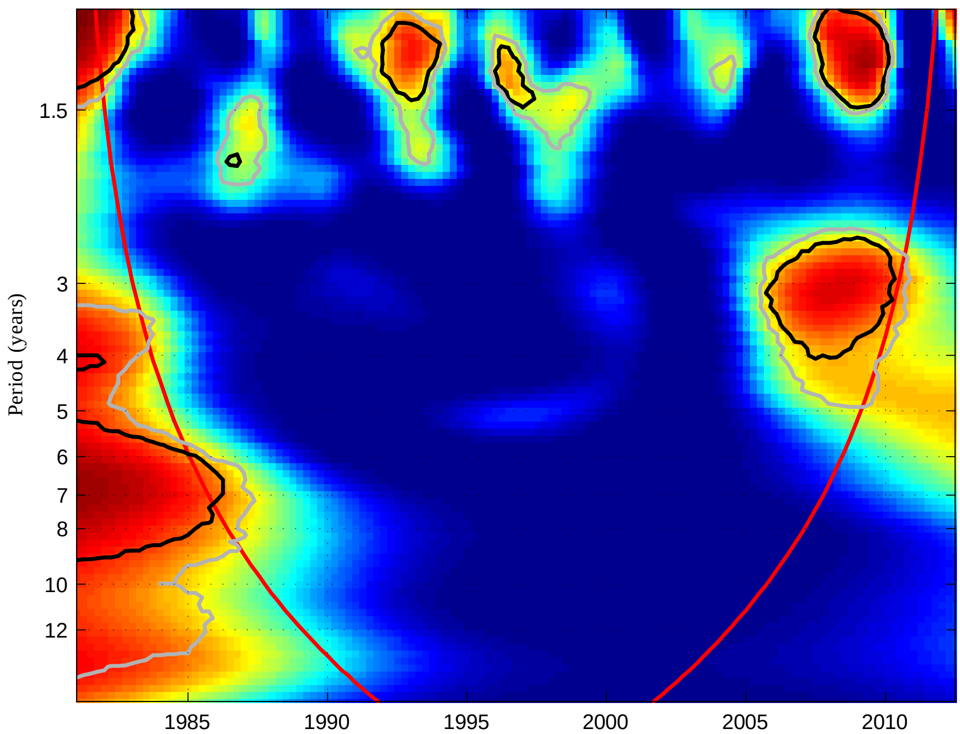

Figure 27: Wavelet chereny of annual growth rate of loans to the private sector relative to real GDP growth and HICP inflation.

money growth we find evidence for significant covariability only at higher frequencies during the financial crisis period. According to our estimates of the cross-spectral gains at low frequencies, the low frequency relationship between the levels of money growth and inflation has weakened after the 1980s as well, similar to the U.S. as shown in Sargent and Surico (2011) but somewhat later.

One possible interpretation of our results is that the relationship between money growth and inflation might be regime dependent and that strong co-movement occur temporarily, such as in the 1970s and early 1980s.. For example, De Grauwe and Polan (2005) show that money growth has only a significant effect on inflation in high inflation countries (countries with inflation rates of 10% or higher). Their interpretation is that inflation rates in low inflation countries are dominated by shocks unrelated to money growth with the velocity of circulation adjusting endogenously to inflation and output shocks. For high inflation countries, however, accelerating money growth leads to increasing inflation and increasing velocity which reinforces the inflationary process. Similarly, the results in Benati (2009) suggest that the relationship between money growth and inflation might be tighter in periods of high inflation and high money growth than in those where inflation and money growth are low. During low inflation episodes the relationship between money growth and inflation might be obscured by non-monetary shocks to inflation and shocks to the velocity of circulation. Sargent and Surico (2011) argue that monetary policy is central to understanding the shifting relationship between money growth and inflation: if monetary policy responds aggressively to inflation the relationship between money growth and inflation will break down. Structural change is another candidate explanation for the weakened money growth - inflation relationship. For example, changes in financial market might have caused monetary overhangs no longer to lead quickly to an increase in consumer prices but to unload into asset price increases first.[20]

[20] See, e.g. Adalid and Detken (2007) or Bruggemann (2007).

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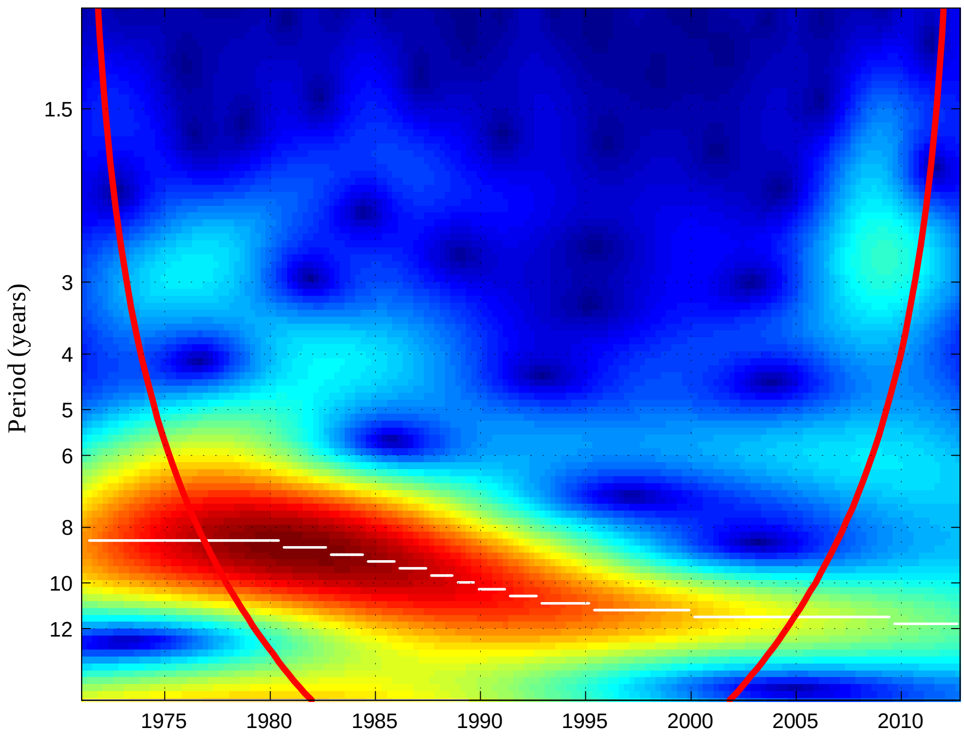

Figure 28: Wavelet power spectrum - annual HICP inflation.

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Appendix A: Wavelet power spectra

Our empirical analysis of comovements in money growth and inflation across times and frequencies rests on the assumption that the frequency components highlighted in the main text above actually are important to the behaviour of the overall time series. For this reason the following figures show the wavelet power spectra (4) for the time series with the power spectrum increasing from dark blue to dark red.

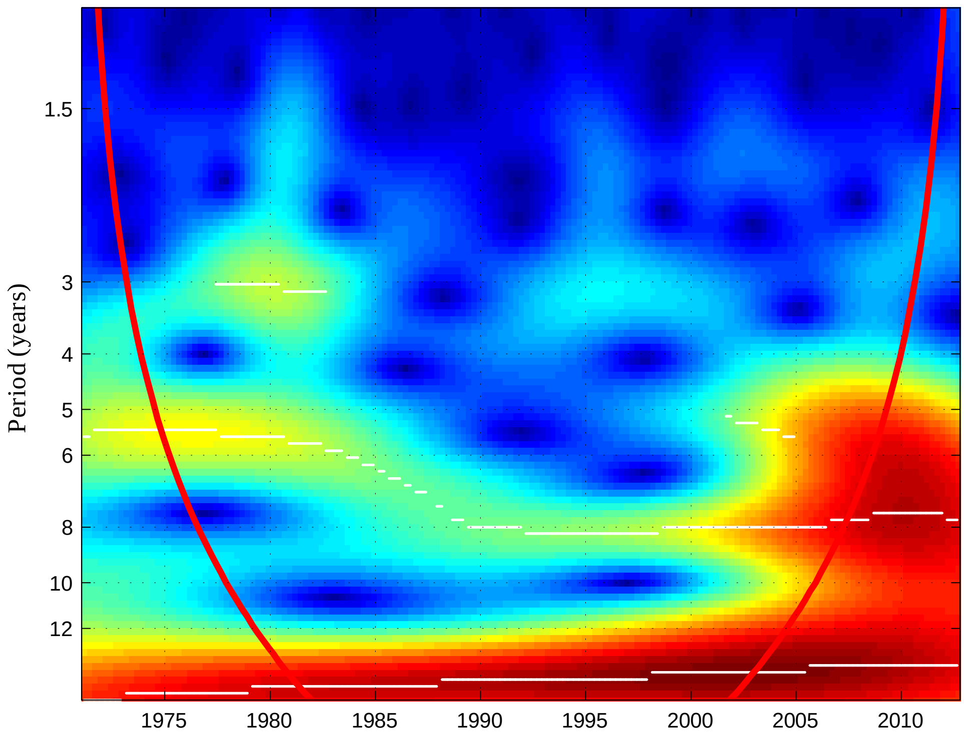

Figure 29: Wavelet power spectrum - annual growth rate of M3

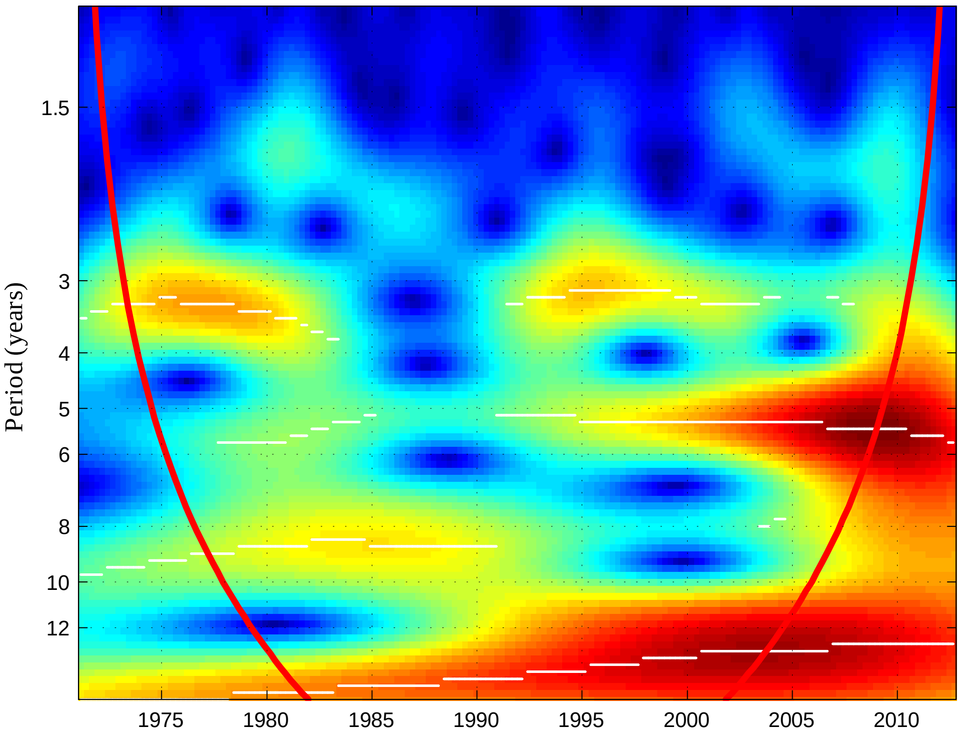

Figure 30: Wavelet power spectrum - annual growth rate of M3, adjusted for real GDP growth

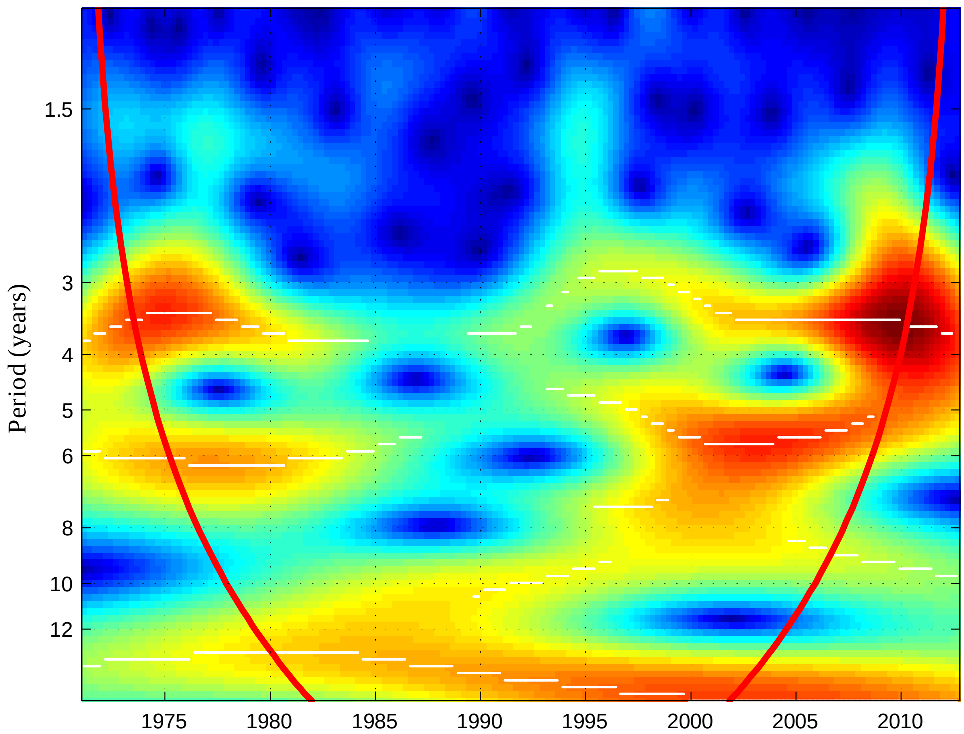

Figure 31: Wavelet power spectrum - annual growth rate of M1

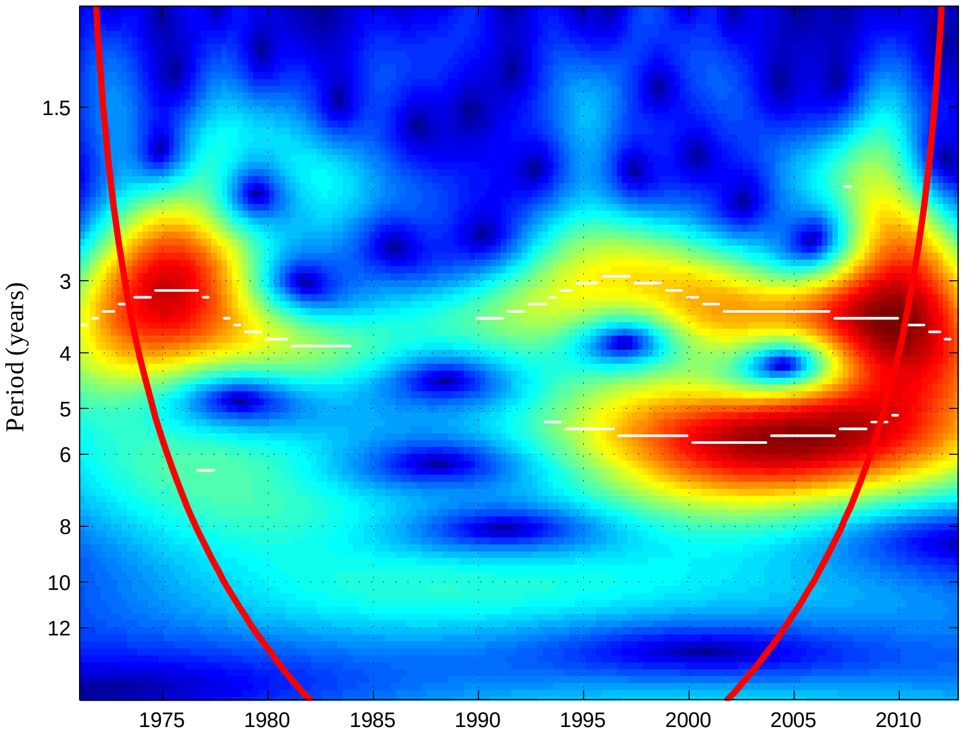

Figure 32: Wavelet power spectrum - annual growth rate of M1, adjusted for real GDP growth

For the HICP inflation rate the power spectrum (Figure 28) shows the importance of fluctuations with periods longer than six years. From the 1980s to the 1990s and later the power spectrum shifts slowly to somewhat lower frequencies. Thus, the frequency range on which the analysis for M3 in the main text is focused on exhibits high values for the inflation power spectrum except for frequencies with periods between three and seven years which are analyzed - among others - for M1 in the main text. For M3 growth the power spectrum (Figure 29) shows large values for periods longer than five (or in the mid 1990s seven years) and for periods longer than three years in the case M3 growth adjusted for real GDP growth (Figure 32) and M1 growth (Figure 31), which again covers the frequencies studied in the main text. Only for M1 growth adjusted for the growth rate of real GDP the power spectrum (Figure 32) is relatively weak at the low frequencies for which we estimate significant coherency.

Appendix B: Analysis for HICP excluding food and energy prices

Significant wavelet coherencies between annual inflation in the HICP index (excluding food and energy) and M3 growth are estimated from the mid 1990s onwards for cycles with periods between two and six years (Figure 33). For these fluctuations and time period the phase differences indicate a lead of inflation before money growth of about half a year or a lead of money growth before inflation of about 3.5 years (Figure 34). Adjusting M3 growth for real GDP growth leads to signficant wavelet coherencies at cycles with periods between two and seven years from the late 1980s onwards and at lower frequencies (fluctuations with periods between seven and ten years) up to 1995 (Figure 36). For the first frequency band the estimated phase differences show a lead of inflation before money growth of about half a year or a lead of money growth before inflation of about four years (Figure 37) while the estimated phase difference for the lower frequencies turn out to be relatively unstable (Figure 38). The estimated cross-spectral gain at low frequencies has the familiar shape (Figure 35). Conditioning on the change in the short-term interest rate does not result in signficant stable coherencies at low frequencies (Figure 40). Overall the results for the HICP (ex) are similar to the results for the overall HICP.

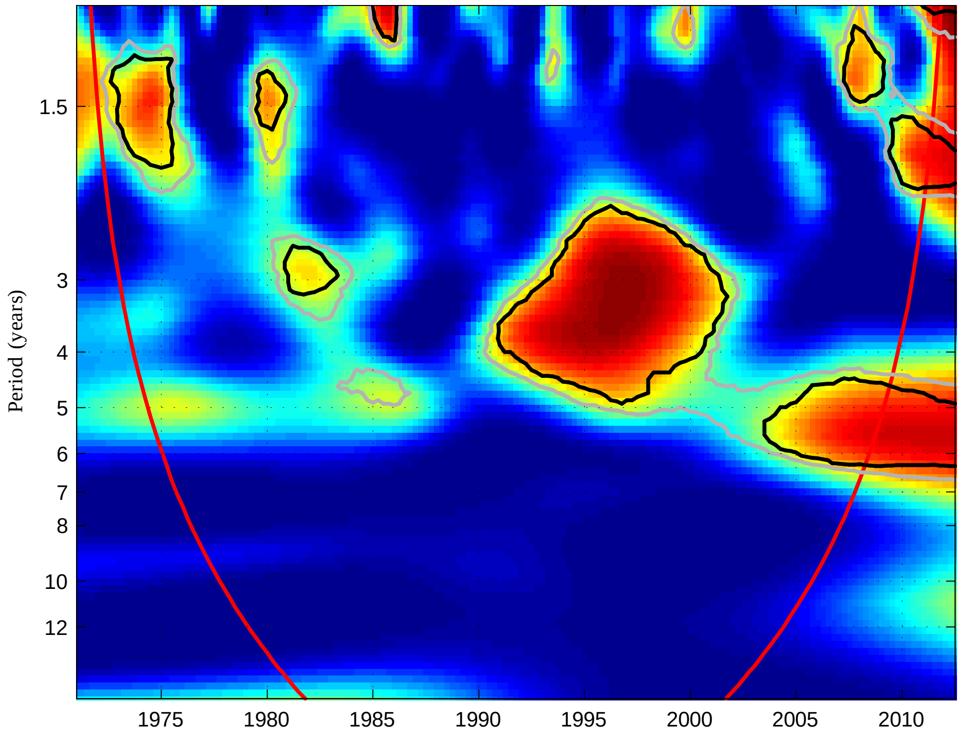

Figure 33: Wavelet chereny of annual growth rate of M3 and HICP inflation (excluding food and energy prices).

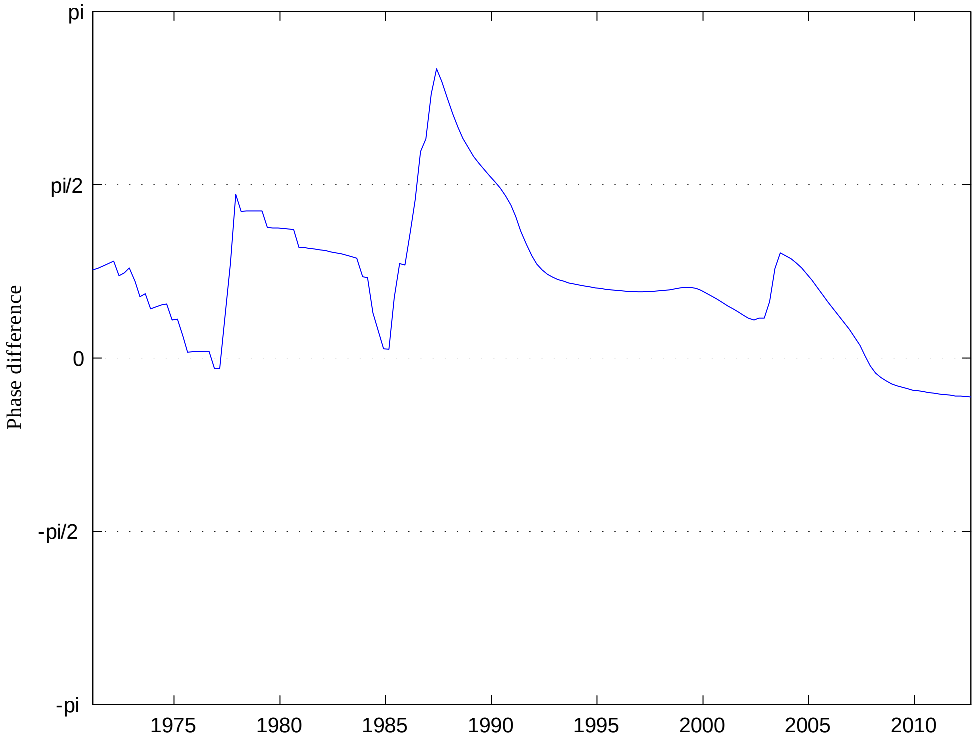

Figure 34: Phase difference of HICP inflation (excluding food and energy prices) and annual growth rate of M3 - periods of 2-6 years

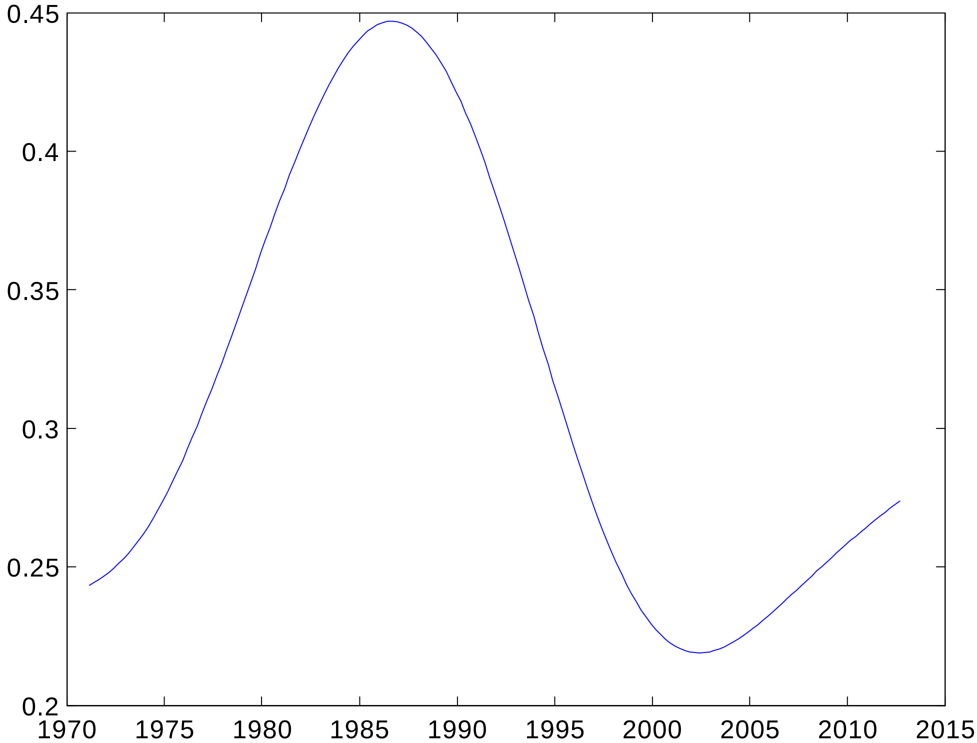

Figure 35: Cross-spectral gain of of annual growth rate of M3 and HICP inflation (excluding food and energy prices), periods of 12-16 years.

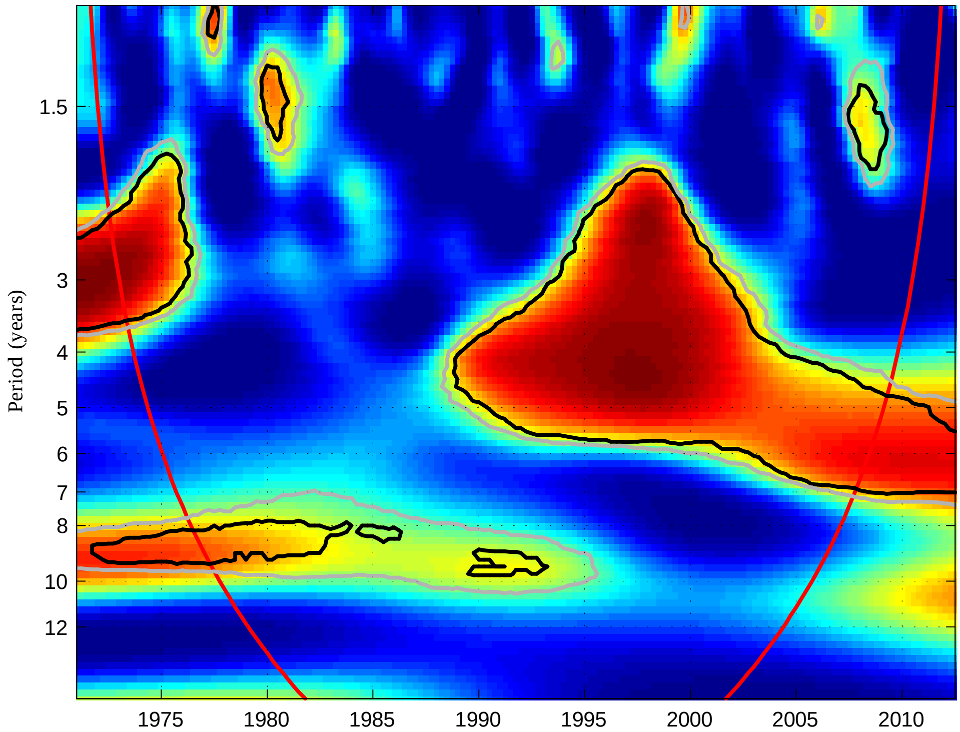

Figure 36: Wavelet cohereny of annual growth rate of M3 (adjusted for real GDP growth) and HICP inflation (excluding food and energy prices).

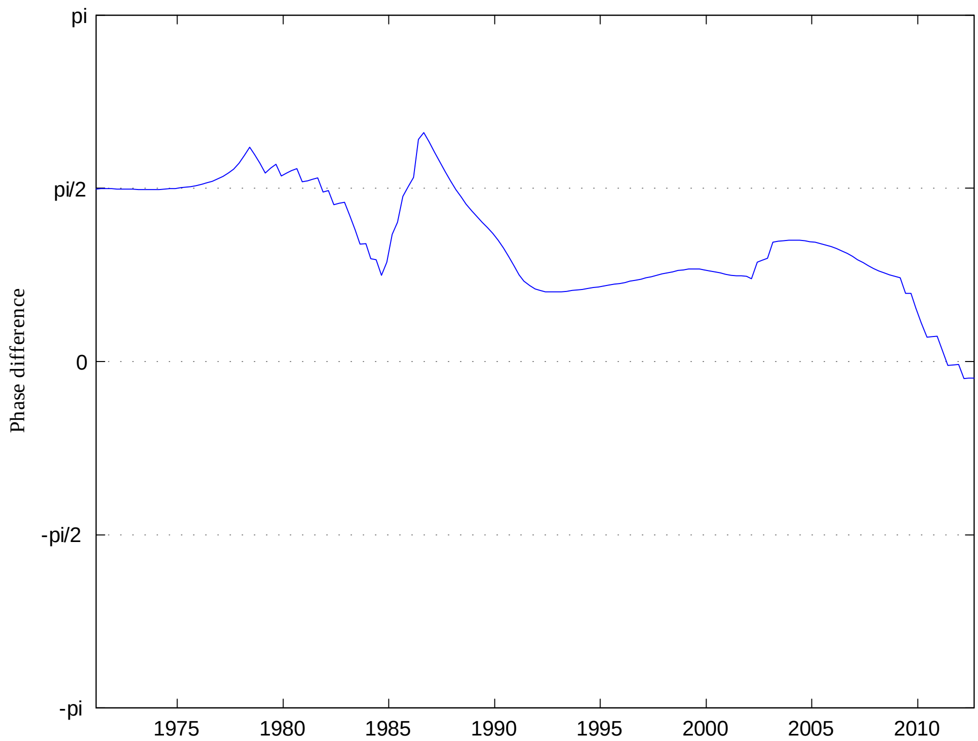

Figure 37: Phase difference of HICP inflation (excluding food and energy prices) and annual growth rate of M3 (adjusted for real GDP growth) - periods of 2-7 years

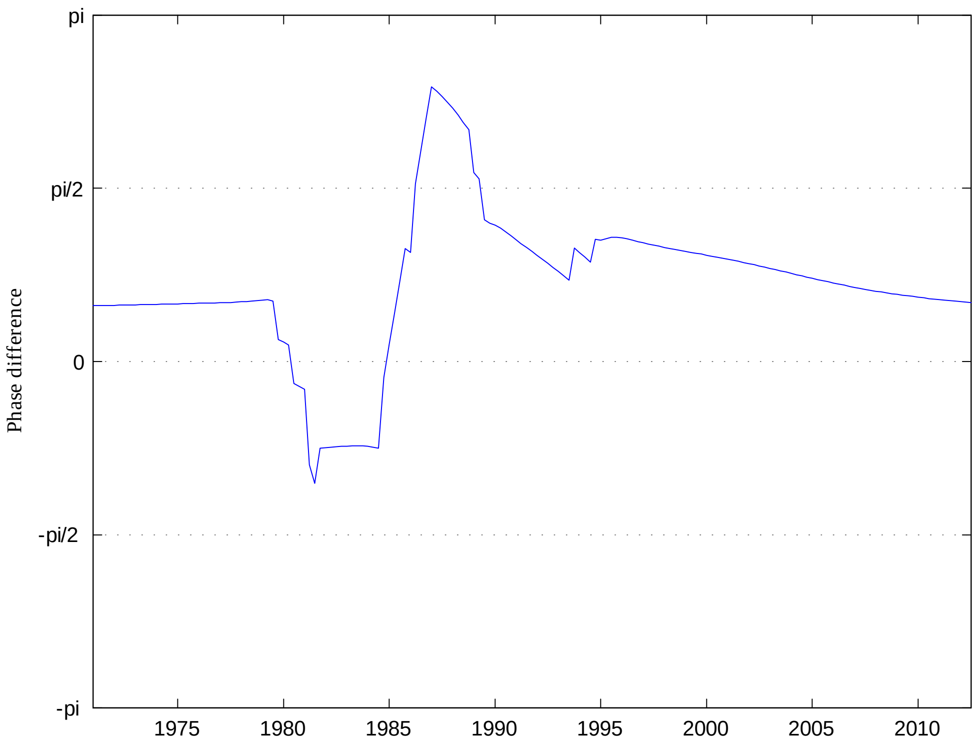

Figure 38: Phase difference of HICP inflation (excluding food and energy prices) and annual growth rate of M3 (adjusted for real GDP growth) - periods of 6-10 years

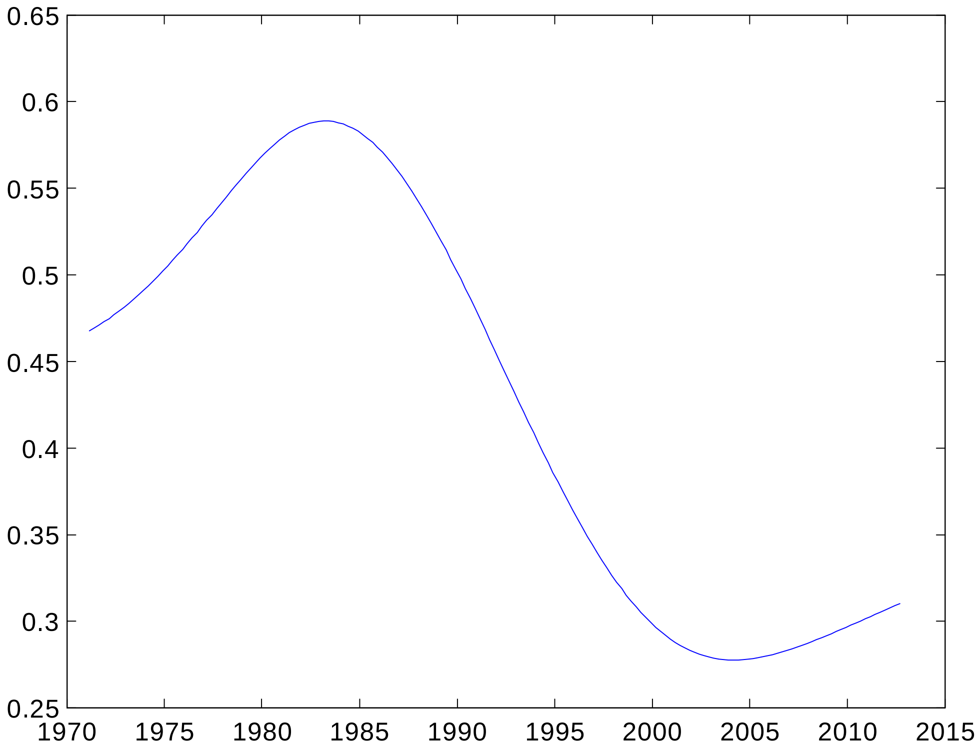

Figure 39: Cross-spectral gain of of annual growth rate of M3 (adjusted for real GDP growth) and HICP inflation (excluding food and energy prices), periods of 12-16 years.

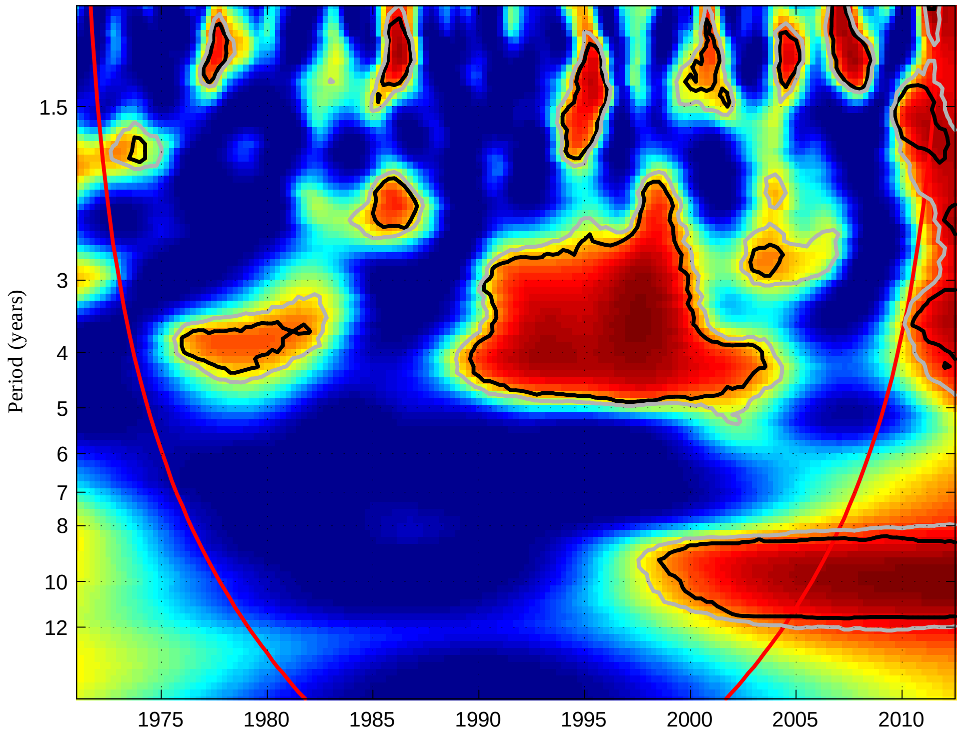

Figure 40: Wavelet cohereny of annual growth rate of M3 (adjusted for real GDP growth) and HICP inflation (excluding food and energy prices), conditional on change short-term interest rates.