Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Department Socioeconomics

Money Growth and Inflation: evidence from a Markov Switching Bayesian VAR

Gianni Amisano

Roberta Colavecchio

DEP (Socioeconomics) Discussion Papers
Macroeconomics and Finance Series
4/2013

Hamburg, 2013

Money Growth and Inflation: evidence from a Markov Switching Bayesian VAR*

Gianni Amisano†
DG Research, European Central Bank and University of Brescia, Italy
Roberta Colavecchio‡
Hamburg University

May 2013

Abstract

We contribute to the empirical debate on the role of money in monetary policy by analysing the features of the relationship between money growth and inflation in a Bayesian Markov Switching framework for a set of four countries, the US, the UK, the Euro area and Japan, over an estimation period spanning from 1960 to 2012. We find that the relationship between money growth and inflation appears to be nonlinear, as our estimation results identify multiple inflation regimes displaying clear and diversified features; moreover, as part of the model ´s information set, money growth plays a determinant role in the allocation of regimes. We show that observing monetary developments does (slightly) improve the signal of entering a high inflation regime but the influence of money on such signal seems to be relevant mainly in the 70s and the early 80s, i.e. in periods featuring exceptionally high rates of inflation. Our evidence confirms that the relationship between money and inflation appears to be relatively weak during periods featuring low and stable inflation.

Keywords: Money growth, inflation regimes, Markov Switching model, Bayesian inference.
JEL classification: C11, C53, E31

1 Introduction

Many central banks consider the the developments of monetary aggregates a relevant factor in their decision-making process. For example, the two pillar strategy of the European Central Bank (ECB)

*We would like to thank Ulrich Fritsche for helpful comments and suggestions. The opinions expressed are personal and should not be attributed to the European Central Bank.

†European Central Bank, DG Research, Kaiserstrasse 29, D-60311, Frankfurt am Main, Germany. E-mail: gianni.amisano@ecb.int, amisano@eco.unibs.it.
‡Corresponding author, University Hamburg, Faculty Economics and Social Sciences, Department Socioeconomics, Welckerstr. 8, D-20354, Hamburg, Germany; E-mail: roberta.colavecchio@wiso.uni-hamburg.de.

assignes to monetary analysis the role of cross-checking tool with respect to the the short to medium-term guidelines for monetary policy drawn from the economic analysis. This approach rests on the well documented historical evidence that money growth and inflation are closely related in the medium- to long- run (ECB, 2004), regularity that has been found to hold across a wide range of countries and across diverse time spans. As a matter of fact, the ECB is not the only central bank to monitor monetary developments. In particular, the Swiss National Bank attaches considerable weight to monetary variables in analysing and forecasting inflation, the Bank of England opens its quarterly Inflation Report with the assessment of the development of money supply, while the central banks of Sweden, New Zealand and Australia regularly discuss money and credit aggregates in their quarterly Monetary Policy Reports. The Bank of Japan "two perspectives" approach to monetary policy bears some similarities with the ECB's “two pillar” strategy[1], but the former does not provide an explicit role for the money stock in its conduct of monetary policy, as well as the US Fed does not put any noticeable weight on the money supply, and indeed has stopped publishing M3 (but continues to publish M2) (OECD 2007).

The debate about the importance of monetary variables for policy making is a long-standing and inconclusive one, both from a theoretical and from an empirical point of view. A number of cross-country studies claim that money may provide relevant information for future inflation developments while others cast doubt on the presence of a reliable link between the two variables and provide evidence that over the last two decades the relationship between money growth and inflation has weakened as well as it has the predictive power of money growth for future inflation. One explanation for the heterogeneity in results might be the failure in addressing the non-linearities embedded in the relationship between money and inflation throughout different sample periods. Our analysis tackles this very issue and contributes to the empirical debate on the role of money in monetary policy by analysing the features of the relationship between money growth and inflation in a Bayesian Markov Switching framework. In particular, we employ a Bayesian vector autoregressive (BVAR) model which allows regime switches to a set of four countries: the US, the UK, the Euro area and Japan. We find that the relationship between money growth and inflation appears to be nonlinear, as our estimation results identify multiple inflation regimes displaying clear and diversified features; moreover, as part of the model´s information set, money growth plays a determinant role in the allocation of regimes. On the other hand, coming to the assessment of the predictive content of the monetary indicator for future inflation, our preliminary results are not as clear-cut. Descriptive evidence based on simple correlation analysis highlighted a positive relationship between the probability of accelerating inflation and (lagged) money growth. In order to evaluate the time-dimension of the predictive content of the monetary indicator we also run counterfactual exercise. The aim of the exercise is

[1] The second perspective of the BoJ´s monetary policy strategy "is examining, in a longer term, various risks that are most relevant to the conduct of monetary policy aimed at achieving sustainable growth under price stability." (Bank of Japan (2013), The "Price Stability Target" under the Framework for the Conduct of Monetary Policy).

to compare the signal of entering a "high-inflation" regime provided by the BVAR model on the basis of two different information sets: the observed data for both inflation and money growth in one case, a "modified" money growth series in the other. The "modification" simply consists in keeping money growth constant over the 2-3 years before an inflationary burst. The conclusion we draw is twofold. First, observing the monetary developments does, to a certain extent, contribute to improve the signal of entering a high inflation regime. In particular, the signal delivered by the model incorporating actual money data does anticipate the burst of the inflationary episode, i.e. the probabilities of entering the high inflation regime start to increase before the inflationary episodes, rather than in proximity of it, as it is the case when the monetary indicator is kept constant. Second, despite the rather diversified inflation experiences featured by the analysed countries, the inclusion of the monetary indicator seems to have a relevant influence on the signal of inflationary risk mainly in the first part of the sample, i.e. the 70s and the early 80s.

Nonetheless, it is important to bear in mind that the conclusions we reach in this study are are based on a rather simplified baseline specification of the model which, on one hand, calls for further analysis but at the same time constitutes encouraging ground to pursue further model extensions. In particular, we are currently working on a more general version of the abovementioned MS BVAR where a monetary indicator enters as conditioning variable in the transition probability function. In other words, the state transition probabilities, instead of being fixed as assumed in the current study, will be allowed to vary over time according to a (probit) function of the monetary indicator.

The remainder of the paper is structured as follows. Section (2) provides a brief review of recent empirical studies addressing issues related to our research question. Section (3) describes the econometric model together with a few remarks on our approach to estimation. Section (4) presents the dataset while Section (5) summarizes the results. Section (6) concludes, highlighting the avenues for ongoing and future research. In the Appendix we describe the data sources.

2 Literature Review

The quantity theory of money, the one-to-one relationship between long run inflation and long-run monetary growth, has been widely documented in the macroeconomic literature, at least since the contributions of Friedman (1956) and Lucas (1980), and empirical evidence has been provided for a wide range of countries and across diverse time spans. At the beginning of the 2000s, a number of studies suggested that money growth had leading indicator properties with respect to future inflation. In the last decade featuring relatively low and stable inflation both policy institutions and academics have failed to find a reliable predictor for inflation and a popular assumption in monetary economics has been to abstract from the presence of money supply. The premise was that the relationship between money growth and inflation seemed to have weakened.as well as its predictive power for future inflation.developments. Along this line are the contributions of Stock and Watson (2007), who claimed that US inflation had become so hard to forecast that it is difficult to improve upon the projections of a naive random walk, and Lenza (2006) for the euro area. More recently, Teles and Uhlig (2010) further validate that for the period since 1990 generalized inflation targeting at low inflation rates has made it more difficult to establish the long run relationship between monetary growth and inflation.

Sargent and Surico (2011) estimate a DSGE model and find that what hinders the quantity theory from functioning is a monetary policy rule that responds to inflationary pressure aggressively enough to prevent the emergence of persistent movements in money growth. The historical evaluation of US inflation forecasts across monetary regimes carried out by D´Agostino and Surico (2011) reaches similar conclusions: the authors show that money growth had marginal predictive power for inflation only during times in which, according to the narrative account of the U.S. monetary history, the monetary authorities did not succeed in establishing a clear nominal anchor or a credible commitment to fight inflation.

The analysis of De Santis (2012) challenges this view by showing that quantity theory still holds also in countries featuring low inflation rates. In particular, by modeling the equilibrium in the money market jointly in the US and euro area, the author argues that the long run relationship between money and prices can indeed be established if domestic and cross-border portfolio shifts are considered.

The leading indicator properties of money are the object of the contribution of D'Agostino and Surico (2009), who claim that money growht still contains useful information to predict US future inflation, but the information content is embodied in measures of global liquidity. In the same direction points the outcome of the analysis of Kaufmann and Kugler (2008). Also Berger and Österholm (2008a, 2008b) and Berger and Stavrev (2012) confirm that money growth can help improve forecasting models of both the Euro area and US inflation in a Bayesian VAR framework, but they also warn that the size of the improvement is relatively small and differs amongst time samples. Finally, Amisano and Fagan (2013) develop a money-based early warning indicator for shifts in inflation regimes. Their results support the view that money growth provides timely warning signals of transitions between inflation regimes.

3 The econometric model

We estimate a bivariate vector autoregressive model with regime shifts (MS-VAR) where $\mathbf{y}_{it}$ is a 2-dimensional vector of endogenous variables and s_t is a dichotomous unobserved discrete variable which affects both the level (intercept) and the volatilities (covariance matrix) of the variables in the

VAR:

$$\mathbf{y}_t = \mathbf{c}_{\mathbf{s}_t} + \mathbf{A}(L)\mathbf{y}_t + \Sigma_{\mathbf{s}_t}\mathbf{v}_t, \tag{1}$$

$$\mathbf{v}_t \backsim N(0, \mathbf{I}_N), \tag{2}$$

$$s_t = 1, 2, ..., S \tag{3}$$

We also assume that the evolution of the latent variable driving the regime changes, s_t, is governed by a first-order Markov chain with constant transition probabilities collected in the $(S \times S)$ transition probability matrix, $\mathbf{P}$:

$$pr(s_t = j|s_{t-1} = i) = p_{ij}, \tag{4}$$

$$\mathbf{P} = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1S} \\ p_{21} & p_{22} & \cdots & p_{2S} \\ \vdots & \vdots & \cdots & \vdots \\ p_{1S} & p_{2S} & \cdots & p_{SS} \end{bmatrix} \tag{5}$$

In this paper, we adopt a Bayesian approach to estimation, which allows to obtain a joint posterior distribution for the parameters and the latent variables. Simulation-based Bayesian methods are well suited to estimate Markov Switching models (see, for example, Kim and Nelson (1999), Amisano and Giacomini (2007) and Geweke and Amisano (2011)), whose irregular likelihood surface is not easily amenable to numerical maximization. In particular, we apply a Gibbs sampling-data augmentation MCMC scheme, a modified version of Amisano Fagan (2013), which converges to the target joint posterior distribution by sampling from the distributions of each of three blocks of parameters (i.e. the VAR parameters, $\mathbf{c}_{\mathbf{s}_t}$ and $\mathbf{A}(L)$, the shock covariance matrix parameters, $\mathbf{\Sigma}_{\mathbf{s}_t}$, and the parameters of the transition probability matrix, $\mathbf{P}$) conditional on all the other blocks of variates (full conditional distributions).[2] As for the prior specification, we construct a Minnesota prior for the VAR coefficients and a Wishart prior for the inverse of $\mathbf{\Sigma}_{\mathbf{s}_t}$ in Equation (1), while for the parameters of the matrix $\mathbf{P}$ we employed a Beta (or Dirichlet prior, for $S > 2$) prior.[3]

We estimate the BVAR models with 2 and 3 regimes ($S = 2$, $S = 3$), both with lag length set to 2 and 4 lags.[4] The results are summarized in Section (5).

[2] Additional details on the implementation of the different steps of the Gibbs sampling-data augmentation algorithm are available in...forthcoming

[3] Additional details on prior specification are available in...forthcoming

[4] On the basis of VAR stationarity checks we decided to employ the VAR(4) specification for all countries, with the exception of the UK, for which we estimated a VAR(2). Robustness checks on the VAR specification included also the estimation of 2-state and 3-state univariate AR models for inflation. More thorough robustness checks, such as Bayesian Model Averaging, are to be implemented in the forthcoming version of this paper.

4 The dataset

We run our analysis for four countries, separately: US, UK, Japan and Euro area. We chose this set of countries for two reasons: first, the data are available for time spans that are long enough to allow the identification of regime changes; second, a multi-country analysis rather than a single-country one should shed light on the robustness of the results, especially considering the rather diverse inflation experiences featured by the abovementioned countries.

Our data set contains quarterly data for inflation and money growth; the series, the data sources and the sample sizes are described in greated detail in the Appendix, together with the details on the transformations applied to the data. The effective estimation samples start in 1960Q1[5] and end in 2012Q3. The upper left panels of Figures 1 to 4 display the sample behavior of the inflation and money growth series for the analyzed set of countries.

For the euro area, we fece the issue of how to construct historical backdata. For this purpose are available a number of approaches which typically involve some weighted average of the series of the historical data of the participating countries (for a review of alternative methods, see Beyer, Doornik and Hendry (2000)). However, we follow Bruggemann, Luetkepohl and Marcellino (2008) and splice German backdata onto the official euro area data published by the ECB. This method is found to lead to more accurate euro area in‡ation forecasts over the period since the start of the monetary union and finds its rationale in the idea that the ECB´s commitment to maintaining price stability closely resembles the historical policy of Bundesbank rather than a "weighted average" of the past monetary regimes in the euro area members. Thus our data for the euro area consists of official area-wide data from 1992 onwards linked to German data for the earlier period.

5 Estimation results

The results we describe in the two subsections that follow focus on the three issues. In Subsection (5.1), we first highlight the features of the inflation regimes identified by the model for each country throughout the estimation period. In particular, Tables (1) to (4) summarize the state-specific mean of inflation, the inflation shock variance as well as the ergodic probabilities and the transition matrix state persistence probabilities (i.e. the diagonal elements of the transition probability matrix). Second, we show the allocation of the inflation regimes over time, by looking at the posterior smoothed probabilities of each regime at each point in time conditioned on the whole sample, namely

$$p(s_t = i|\underline{\mathbf{y}}_T). \tag{6}$$

The upper-right and the bottom-left panels in Figures (1) to (4) provide alternative grahpical representations of the time allocation of different inflation regimes and allow a comparison with the

[5] 10 years of data are used to calibrate the priors.

empirical evidence on inflationary episodes in each country. Finally, we provide some evidence on the leading indicator properties of the monetary indicator with respect to inflation dynamics on two levels: a descriptive one, by means of simple correlation analysis, and a more forecast-oriented one, by means of a counterfactual exercise. Additional details on how these two exercises are performed are provided in Subsection (5.2) together with a summary of the results.

5.1 Inflation regime allocation

For the two Anglo-Saxon countries and for Japan the model clearly identifies three regimes. As Tables (1) to (3) show, state 1 is characterized by low inflation mean and very low volatility; state 2 displays a significantly higher inflation mean and higher volatility and state 3 features very high inflation levels and sustained volatility. The results displayed in Table (4) for the Euro Area show that a 2-state model seems to fit the data better. Estimates for mean inflation in the high inflation regimes are higher for the Anglo-Saxon countries compared with the euro area, in line with historical experience during the Great Inflation era.

The diagonal elements of the transition matrix and the ergodic probabilities indicate that for all the considered countries regime 1 is the more persistent one as well as the one where the system would find itself in the great majority of the time. The only exception is represented by the US, for which the ergodic probabilities displayed in Table (1) indicate an almost even distribution of the time allocated to each state.

The regime classification is supported by the plots displaying the state allocation in Figure (1) to (3): the top-right panel plots the evolution of each country inflation series together with the episodes that the model assignes to inflationary bursts, namely periods of high inflation mean and volatility (shaded areas); the bottom-left panel depitcts the smoothed probabilities of the low inflation regime. For all countries the regime allocation turns out to be somehow in line with anecdotal evidence, validating the suitability of a Markov switching model to fit the dynamics of the inflation series.

For the US, Figure (1) shows that the model anticipates the departure from the low inflation (and low volatility) regime and clearly detects the transition to the high-level-high-volatility-of-inflation state in the early and late Seventies. Both inflationary episodes were led by an acceleration in the money growth indicator. The new increase in inflation which began in the late 80s and culminated in 1991 is also detected by the model, which displays a sharp drop in the probability of regime 1 accompanied by transitions from low to high inflation regimes. Following the 1991 spike, the estimated model highlights the prevalence of regime 1 until 2007, when the sharp acceleration of inflation coupled with major swings in money growth triggers a new regime change from low to high inflation. Finally, in 2009, following the return of the money growth indicator to pre-crisis levels, the system enters a regime-2 phase.

A 3-state model specification appears to be the appropriate one also for the UK experience. Table (2) shows that the features of the regimes identified for the UK case are very similar to those highlighted for the US. Figure (2) shows a regime allocation consistent with anecdotal evidence. In particular, the model generates a predicted regime change from low to high inflation in 1964 as a result of the sharp upswing of the adjusted money growth indicator. Moreover, it correctly signals an increase in high inflation risk at the beginning of the 1970s. In particular, Figure (2) shows that the third of the identified regimes, featuring relatively higher inflation variance and intercept, dominates the period between 1970 and 1982 while regime 1, the more persistent one (see transition probability matrix), appears to prevail in the second half of the sample. A sharp drop in the probability of regime 1 during 2007, the subsequent switch to the high inflation state and its reversal in 2010 were correctly signaled by money growth developments.

Also for the case of Japan the 3-state BVAR model provides a highly meaningful regime allocation, capable of distinguishing between periods featuring low inflation variance and levels (regime 1), and those displaying higher levels on inflation contextually to higher inflation volatility (regime 3). As displayed in the bottom right panel of Figure (3), regime 1 appears to be the most frequent one over the considered time span, with the exception of three main episodes of regime switch: one in the first half of the 70s, inflationary episode which the model classifies as regime 3, one in the early 80s and the last one at the beginning of the 90s (allocated to regime 2, featuring relatively low variance and intermediate inflation level).

Finally, for the Euro area the estimated model clearly identifies 2 states, both featuring inflation variance substantially lower in comparison with the other analyzed countries. As for the regime allocation, it has been found to be consistent with anecdotal evidence: Figure (4) displays a shift to the high inflation regime in the early 1970s and one in 1978, with the latter reversing in 1981. These transitions appear to be somehow anticipated by the developments of the money growth indicator The 1990s and 2000s feature the persistence of a low inflation regime, with the risk to price stability remaining very low until 2007. The monetary growth acceleration started in in 2005 and reversing only in the course 2008 anticipated the change of regime from low to high inflation detected by the model between 2007 and 2009.

To sum up, our estimation results show that all the analyzed countries share a rather similar inflation regime allocation, in particular in the first half of the estimation sample: the oil price shocks were correctly identified by our model as well as the price acceleration experienced in the late 70s-early 80s in the US, the UK and the Euro area. The same holds for the 2007-2009 episode, which our models also allocates to regime 3, most probably for the relatively high volatility displayed by the inflation series. This evidence suggests that the US, the UK, the Euro area and Japan would make suitable candidates for a panel. It is worth mentioning that a panel analysis of the single country money-inflation VAR model we employed in this study would help to solve issues such the low number of transitions and weak inference faced in the country-by-country analyis. Moreover, the inclusion in the panel of countries featuring episodes of deflation (e.g Japan) would bring into the model a whole new information set and allow to model deflation risks explicitly. The extension of our simple BVAR model to the panel framework is currently work in progress and will be the object of a forthcoming paper.

5.2 The predictive content of money

This Subsection tackles the issue of the predictive content of the monetary indicator with respect to future inflation developments. Our assessment relies on two levels of analysis: a descriptive one, by means of simple correlation analysis, and a more forecast-oriented one, by means of a counterfactual exercise.

In order to evaluate the leading properties of money growth on inflation in the contex of correlation analysis, the money growth indicator must be appropriately lagged. In addition to that, it is reasonable to employ a smoothed money growth measure to discount the temporary shocks that might affect the aggregate without bearing any implications for future inflation. The issues of the smoothing of inflation and the lagging of money in the context of the causality relationship between these two variables in the Euro area are explored in Reichlin and Lenza (2007). The authors show that the optimal predictive content of money on inflation is given between 6 and 12 quarters ahead and for a three year average of inflation.

In our study, the smoothness of the inflation data is not a concern: the model we employ is suited to assign observed inflation to different inflation regimes. On the other hand, the use of an appropriately lagged and smoothed measure of money growth matters and thus we employ a MA(q) on the monetary growth indicator and then lag it p periods. In line with the evidence provided in Amisano and Fagan (2013), we decided to use $q = 5$ and $p = 9$. The particular choice of the lag order ($p = 9$) is motivated by the fact that the unfolding of the monetary signal appears to need a few quarters to happen.

As first step of our assessment, we shed some light on the leading properties of money growth on inflation by means of simple graphical analysis. In particular, to assess whether there is any evidence that observing the adjusted monetary indicator might provide some information with respect to the dynamic of future inflation, we plot the relationship between the adjusted money growth indicator and the probability of accelerating inflation. We identify the "accelerating inflation" subsample as the set of observations featuring a current inflation higher than the last period´s 12-quarter moving average. A positive correlation between the two variables would indicate that indeed monetary growth developments provide useful information when it comes to anticipating inflationary episodes.

The scatter plots between these two variables together with the linear regression line and their correlation coefficients are displayed in the bottom right panel of Figures (1) to (4). In all the four analyzed countries, the relationship between the monetary indicator and the probability of "accelerating inflation" turns out to be positive, although the Anglo-Saxon countries feature a much lower correlation coefficients than Japan and Euro area. An interesting feature is indeed the exceptionally high correlation coefficient displayed by the Euro area.

To sum up, the graphical analysis presented here seems to validate the fact that observing the adjusted monetary indicator might provide some information with respect to the dynamic of future inflation. To delve into the issue from a forecast-oriented perspective, we then performed a counterfactual exercise by means of the so-called h-step-ahead probabilities, $\xi_{t+h|t}$, one of the byproducts of the Markov switching framework. In particular, for each t, the jth element of the $(S \times 1)$ vector $\xi_{t+h|t}$ represents the optimal forecast of how likely the process is to be in regime j in period $t+h$, given observation obtained through date t, which can be found by iterating the following equation:

$$\xi_{t+h|t} = \mathbf{P}^h \xi_{t|t} \tag{7}$$

where $\mathbf{P}$ is the $(S \times S)$ transition matrix and $\xi_{t|t}$ is the $(S \times 1)$ vector of conditional probabilities $P\left\{s_t = j|\underline{\mathbf{y}}_T, \theta\right\}$, which denote the probability that the model assigns to the possibility that the tth observation was generated by regime j.

The counterfactual exercise consists in calculating the h-step-ahead probabilities obtained with an information set which does not fully include monetary developments and to compare it with the actual one, based on the observed data. Should money growth indeed have leading indicator properties with respect to future inflation developments, this would translate into the model based on the complete information set providing a stronger and possibly more timely signal of entering a "high-inflation" regime. In order to perform such exercise we modify the actual money growth series by setting it constant over the 2-3 years before an inflationary burst and calculate the h-step-ahead probabilities, $\xi_{t+h|t}$, on the basis of the "modified" money indicator. The outcome of this exercise is displayed in Figure (5). A couple of remarks are worth highlighting. First of all, observing monetary developments does (slightly) improve the signal of entering a high inflation regime. In particular, the signal delivered by the model incorporating actual money data does anticipate the burst of the inflationary episodes as the h-step-ahead probabilities of entering the high inflation regime generated using actual money series start to increase before the inflationary episodes, rather than in proximity of it, as is the case when the money indicator is kept constant. Moreover, despite the rather diversified inflation experiences featured by the analysed countries, the inclusion of the monetary indicator seems to influence the signal of inflationary risk mainly in the first part of the sample, i.e. the 70s and the early 80s, in periods featuring exceptionally high rates of inflation. From the 90s on, money fails to display any leading indicator property: its inclusion in the information set does not help to detect increasing risk of inflationary pressure in a more timely fashion. This evidence is particularly striking for the 2007-2009 inflationary episode and more so in the case of the Euro area.[6]

[6] As alternative excercise to tackle the same issue we compared the h-step-ahead probabilities obtained from the baseline BVAR specification with those produced using a univariate AR for inflation. The results are available upon request and are in line with those of the counterfactual analysis. In particular, we see that including the monetary indicator in the information set, i.e. estimating a VAR instead of an AR would to some extent provide additional insight about the timing and the persistence of the inflationary risk. On the other hand, the predictive content of

At this point of the analysis, it might be worth reminding that the results we present here are the outcome of a rather simplified baseline specification of a reduced form model, which is hardly the most suitable one to analyse more complex inflation dynamics, such as those featured in the last part of our estimation sample. In other words, the current model specification might be failing to detect the information content of money in times where price developments are likely to be the product of several shocks of diverse nature. To conclude, our results are to be considered as preliminary and call for further analysis but they also document the presence of a monetary signal and hence constitute encouraging ground to pursue further model extensions. In particular, we are currently working on a new MS BVAR specification, in which we allow a set of observable variables, such as a monetary indicator[7], to explicitly enter the state transition mechanism. In other words, the transition probabilities will no longer be fixed but time-varying and parameterized according to a (probit) function.

6 Conclusion

In this paper we developed a simple single-country bivariate MS VAR model for inflation and money growth with fiexd transition probabilities. We applied the model to data from the US, the US, the euro area and Japan, using quarterly data from the early 1960s to 2012. We estimated its parameters using Bayesian techniques. The results obtained support the view that money growth contains relevant information for future inflation dynamics. In particular, the estimation results clearly identify different inflation regimes for the four analyzed countries, validating the suitability of a MS framework and in turn providing sound evidence regarding the presence of nonlinearities in the money growth-inflation relationship. In other words, in this bivariate model, money growth plays a determinant role in the allocation of regimes A number of robustness checks, including the estimation of alternative specifications, confirm this general conclusion.

As far as the assessment of the predictive content of the monetary indicator for future inflation goes, descriptive evidence based on simple correlation analysis highlighted a positive relationship between the probability of accelerating inflation and (lagged) money growth, with the Euro area displaying the highest correlation coefficient. In order to explore the time-dimension of the predictive content of the monetary indicator from a forecast-oriented perspective, we run a counterfactual exercise. We concluded that observing monetary developments does (slightly) improve the signal of entering a high inflation regime but the influence of money on such signal seems to be relevant mainly in the first part of the estimation sample, i.e. the 70s and the early 80s, i.e. in periods featuring exceptionally high rates of inflation. From the 90s on, money fails to display any leading indicator

money growth seems to vanish after the early 90s.

[7]Additional meaningful variable are a global liquidity indicator (D'Agostino and Surico (2007), T-bill rates rather than long-term government bond yields, as suggested in Teles and Uhlig (2010), or a portfolio-shift-adjusted monetary indicator (Hoffman (2008)).

property.

To sum up, our evidence confirms that the relationship between money and inflation appears to be relatively weak during periods featuring low and stable inflation. It is also worth noticing that our current conclusions are based on a rather simple baseline specification of the model and hence are to be considered as preliminary. At the same time, we consider them encouraging enough to justify the pursue of model extensions which might allow to reach more clear cut and thorough conclusions. In particular, on our current research agenda there is a panel extension featuring time-varying transition probabilities modeled as function of a set of monetary indicators.

A Data appendix

All empirical models are estimated using yearly growth rates computed as logarithmic fourth-differences of the original quarterly series in levels, i.e. the consumer price index (CPI) and a nominal indicator of money supply. For each of the four considered countries, we employed the broad monetary aggregate used by the respective central banks, that is M2 for the US, M4 for the UK, M3 for the euro area, and M2 for Japan. All the datasets span from 1950Q1 to 2012Q3, with the exception of Japan, whose sample starts in 1957Q1.

A.1 US

The source of the data is the Federal Reserve Economic Data provided by the Federal Reserve Bank of St. Louis. Quarterly data on the monetary aggregate (M2) are available since 1959Q4; therefore we used yearly data on M2 from Mitchell and Ame (1998), subject to quarterly BFL interpolation.

A.2 UK

From 1957Q1 to 2012Q3 the source of the data is the IMF International Financial Statistics. Earlier data for the CPI index and the monetary aggregate (M4) are available only on a yearly basis and come from Global Data Finder and from Mitchell and Eur (1998), rispectively. The BFL interpolation procedure was employed to obtain quarterly series.

A.3 Euro area

From 1992Q1 to 2012Q3 we employed official euro area data from the ECB website. For the 1950Q1 to 1991Q4 period we used German data. In particular, the Bundesbank real time data base was the source for data spanning from 1962Q1 to 1998Q4 while earlier (yearly) data were obtained from Buba 1988 and interpolated using the BFL interpolation procedure to obtain quarterly data.

A.4 Japan

The sources for the CPI index and for the money supply (M2) series, both starting in 1957Q1, are the Japanese Statistics Bureau and the Bank of Japan, respectively.

References

Amisano, A., and G. Fagan (2013): "Money growth and inflation: A regime switching approach", *Journal of International Money and Fianance*, 33, 118-145.

Amisano, A., and R. Giacomini (2007): "Comparing density forecasts via weighted likelihood ratio tests ", *Journal of Business and Economic Statistics*, 25(2), 177-190.

Berger, H., and P. Österholm (2008a): "Does money growth granger-cause inflation in the euro area? Evidence from out-of-sample forecasts using Bayesian VARs", *IMF Working Papers*, no. 08-53.

Berger, H., and P. Österholm (2008b): "Does money matter for US inflation? Evidence from Bayesian VARs", *IMF Working Papers*, no. 08-76.

D´Agostino, A., and P. Surico (2009): "Does Global Liquidity Help to Forecast U.S. Inflation?", *Journal of Money, Credit and Banking*, 41(2-3), 479-489, 03.

D´Agostino, A., and P. Surico (2012): "A Century of Inflation Forecasts", *The Review of Economics and Statistics*, 94(4), 1097-1106.

De Santis, R. (2012): "Quantity theory is alive: the role of international portfolio shifts", *ECB Working Paper Series No. 1435.*

Beyer, A., Doornik, J.A. and D.F. Hendry (2000): "Reconstructing Aggregate Euro-zone Data", *Journal of Common Market Studies*, 38(4), 613 - 624.

Bruggemann, R., M. Marcellino and M. Polan (2008): "Forecasting Euro Area Variables with German Pre-EMU Data", *Journal of Forecasting*, 27, 465-481.

Bundesbank (1988): *40 Jahre Deutsche Mark: Monetare Statistiken, 1948-1987.*

ECB (2004): *The Monetary Policy of the ECB*, European Central Bank.

Geweke, J., and G. Amisano (2011): "Hierarchical Markov Normal Mixture Models with Applications to Financial Asset Returns", *Journal of Applied Econometrics*, 26, 1-29.

Hofmann, B. (2008): "Do Monetary Indicators Lead Euro Area Inflation?", *ECB Working Paper Series No. 867.*

Kaufmann, S., and P. Kugler (2008): “Does Money Matter For Inflation In The Euro Area?”, *Contemporary Economic Policy*, Western Economic Association International, 26(4), 590-606.

Kim, C.-J., and C. R. Nelson (1999): *State-space Models with Regime Switching: Classical and Gibbs-Sampling Approaches with Applications.* MIT Press: Cambridge MA.

Lenza, M. (2006): : “Does money help to forecast inflation in the euro area?”„ *mimeo*, European Central Bank.

Lucas, R. (1980): “Two Illustrations of the Quantity Theory of Money”, *American Economic Review*, 70(5), 1005–1014.

Mitchell, B.R. (1998a): *International historical statistics, Europe, 1750-1993*, Basingstoke: McMillan.

Mitchell, B.R. (1998b): *International historical statistics, the Americas, 1750-1993*, London: McMillan.

OECD (2007): *Economic Survey of the Euro Area 2007: The Role of Monetary Aggregates in Monetary Policy*, Paris: OECD.

Stock , J., and M. W. Watson (2006): “Why Has U.S. Inflation Become Harder to Forecast?”, *NBER Working Paper* no. 12324.

Teles , P., and H. Uhlig (2010): “Is quantity theory still alive?”, *NBER Working Paper* no. 16393.

Reichlin, L., and M. Lenza (2007): “On short term and long-term causality of money to inflation: understanding the problem and clarifying some conceptual issues”, *mimeo.*

Sargent, T. J., and P. Surico (2011): “Two Illustration of the Quantity theory of Money: Breakdowns and Revivals”, *American Economic Review* 101(1), 109-28.

Stavrev, E., and H. Berger (2012): “The information content of money in forecasting euro area inflation”, *Applied Economics*, 44:31, 4055-4072.

Table 1: Posterior simulation, US

	mean	volatility	ergodic prob		transition prob matrix		
					regime 1	regime 2	regime 3
regime 1	2.4	0.14	0.36	regime 1	0.81	0.11	0.08
regime 2	4.1	0.31	0.38	regime 2	0.12	0.73	0.14
regime 3	5.8	1.15	0.26	regime 3	0.11	0.18	0.71

Unconditional (state-specific) mean and volatility within each of the regimes identified by the 3-state Markov switching model. These values would be the mean and variance of the inflation process in the case the system remained indefinitely in each of the states.

Table 2: Posterior simulation, UK

	mean	volatility	ergodic prob		transition prob matrix		
					regime 1	regime 2	regime 3
regime 1	3.6	0.34	0.55	regime 1	0.87	0.05	0.09
regime 2	4.4	0.74	0.14	regime 2	0.18	0.62	0.20
regime 3	9.6	2.59	0.31	regime 3	0.15	0.08	0.77

Unconditional (state-specific) mean and volatility within each of the regimes identified by the 3-state Markov switching model. These values would be the mean and variance of the inflation process in the case the system remained indefinitely in each of the states.

Table 3: Posterior simulation, JP

	mean	volatility	ergodic prob		transition prob matrix		
					regime 1	regime 2	regime 3
regime 1	1.7	0.36	0.75	regime 1	0.95	0.03	0.021
regime 2	4.5	0.99	0.13	regime 2	0.15	0.69	0.16
regime 3	15.7	4.87	0.12	regime 3	0.16	0.16	0.68

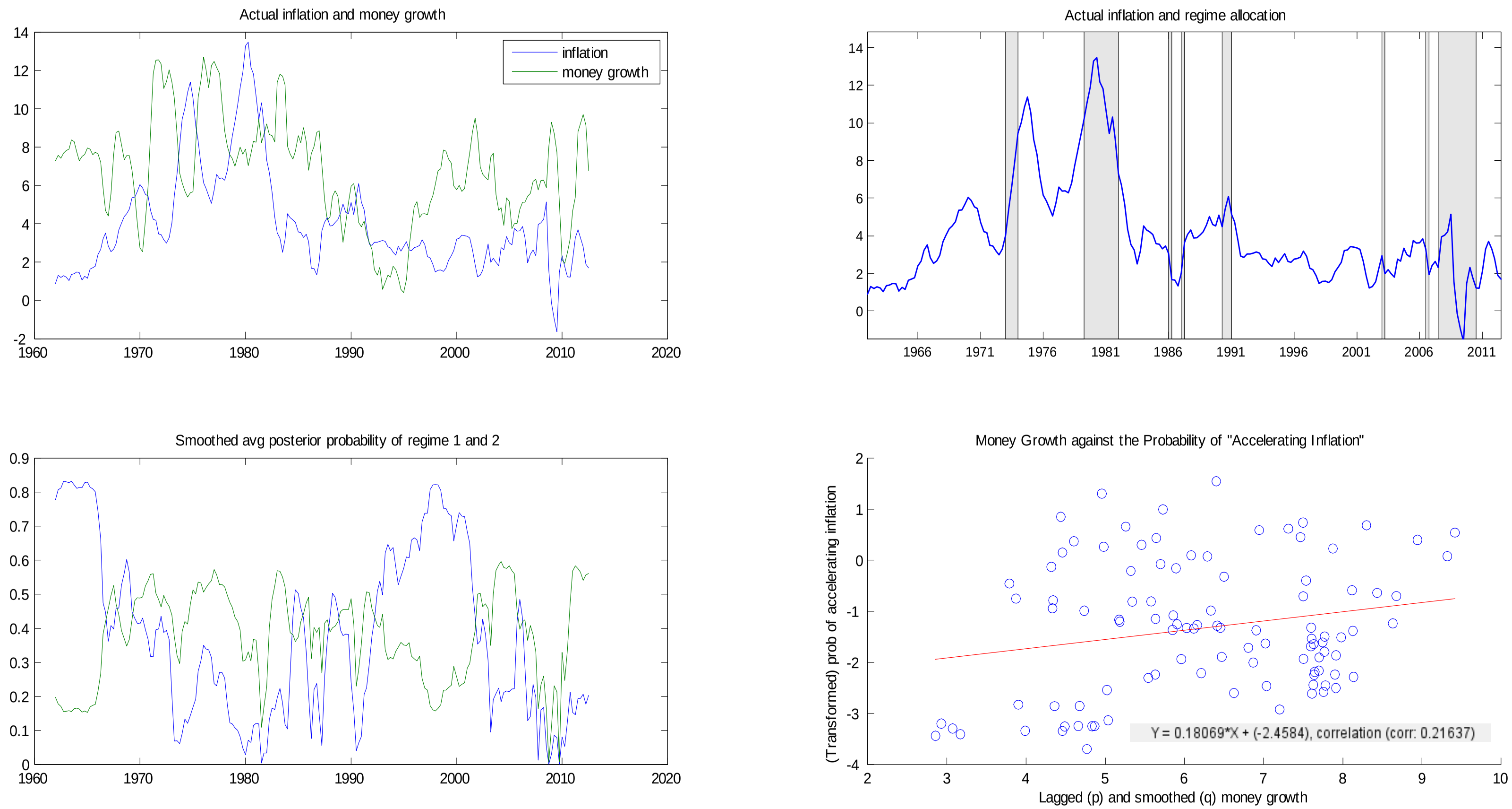
Unconditional (state-specific) mean and volatility within each of the regimes identified by the 3-state Markov switching model. These values would be the mean and variance of the inflation process in the case the system remained indefinitely in each of the states.

Table 4: Posterior simulation, euro area

	mean	volatility	ergodic prob		transition prob matrix		
					regime 1	regime 2	regime 3
regime 1	2.5	0.09	0.75	regime 1	0.94	0.06	-
regime 2	5.1	0.79	0.25	regime 2	0.18	0.82	-
regime 3	-	-	-	regime 3	-	-	-

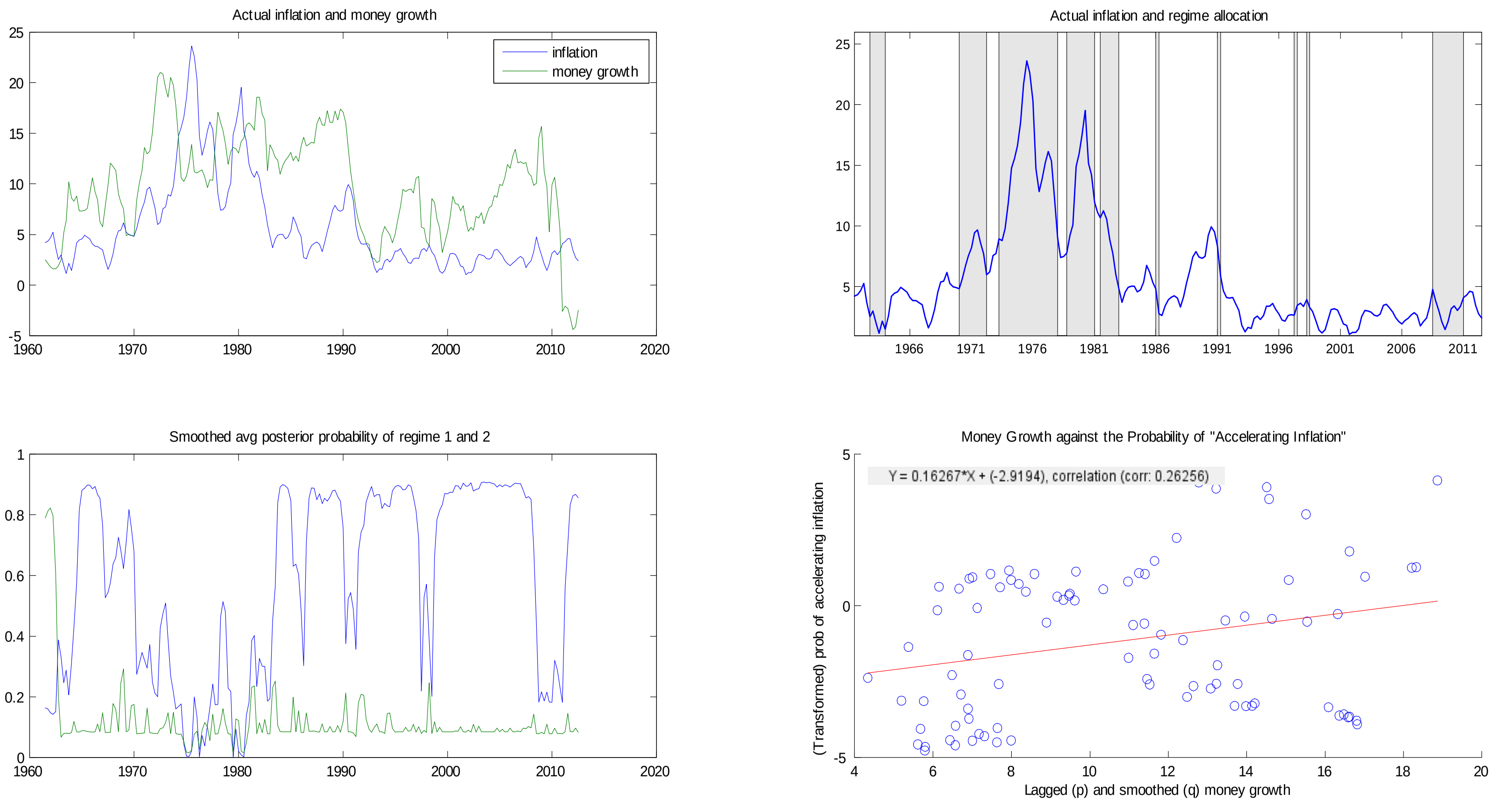
Unconditional (state-specific) mean and volatility within each of the regimes identified by the 2-state Markov switching model. These values would be the mean and variance of the inflation process in the case the system remained indefinitely in each of the states.

Figure 1: Inflation regime allocation, US



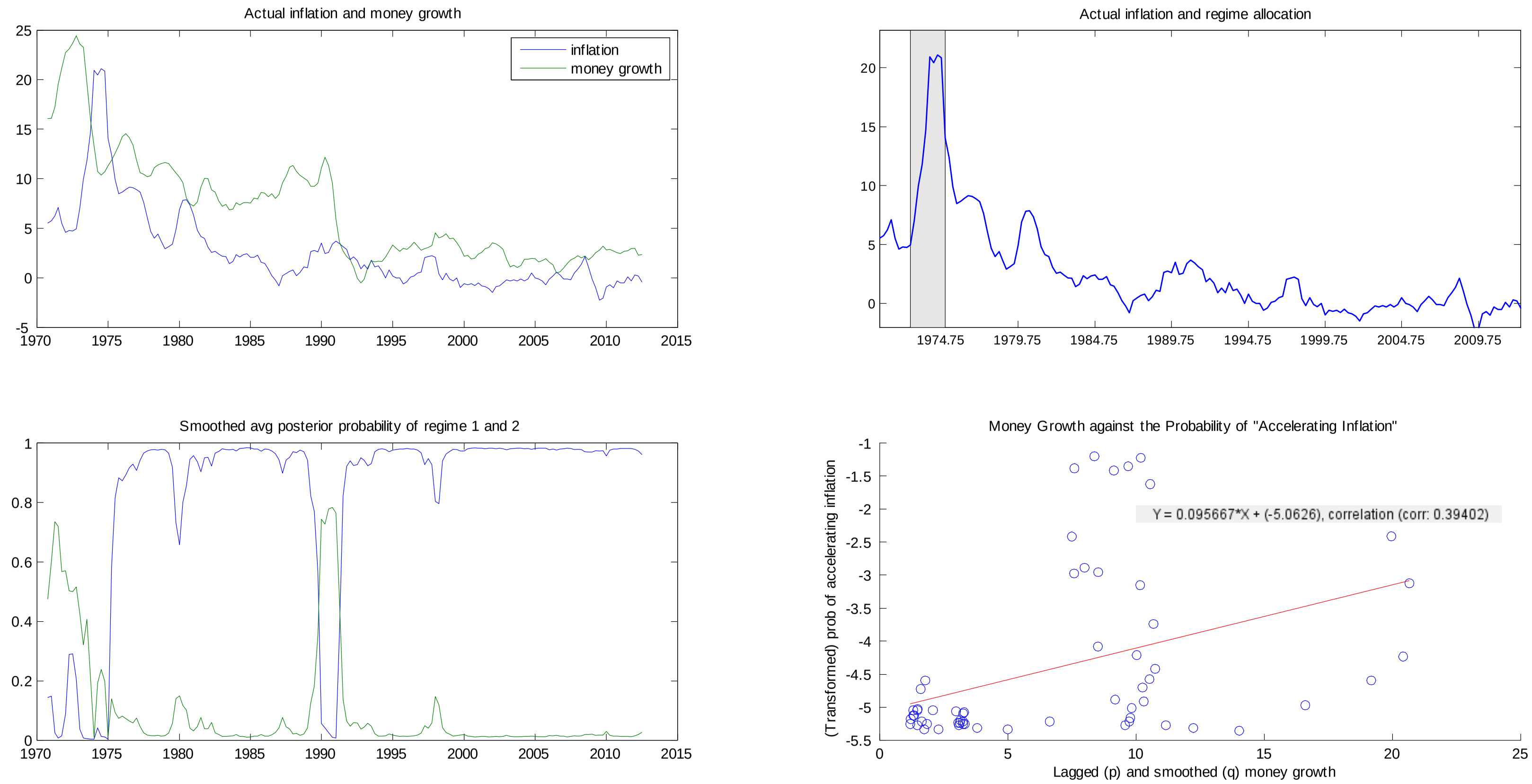
Top left panel: Money growth and inflation data. Top righ panel: inflation series (shaded areas correspond to periods in which the model assigns high probability to being in regime 3, featuring high inflation levels and sustained volatility). Bottom righ panel: p is the lag order of the indicator variable and q is the MA order of its transformation in the correlation analysis; here: p=9 and q=5.

Figure 2: Inflation regime allocation, UK



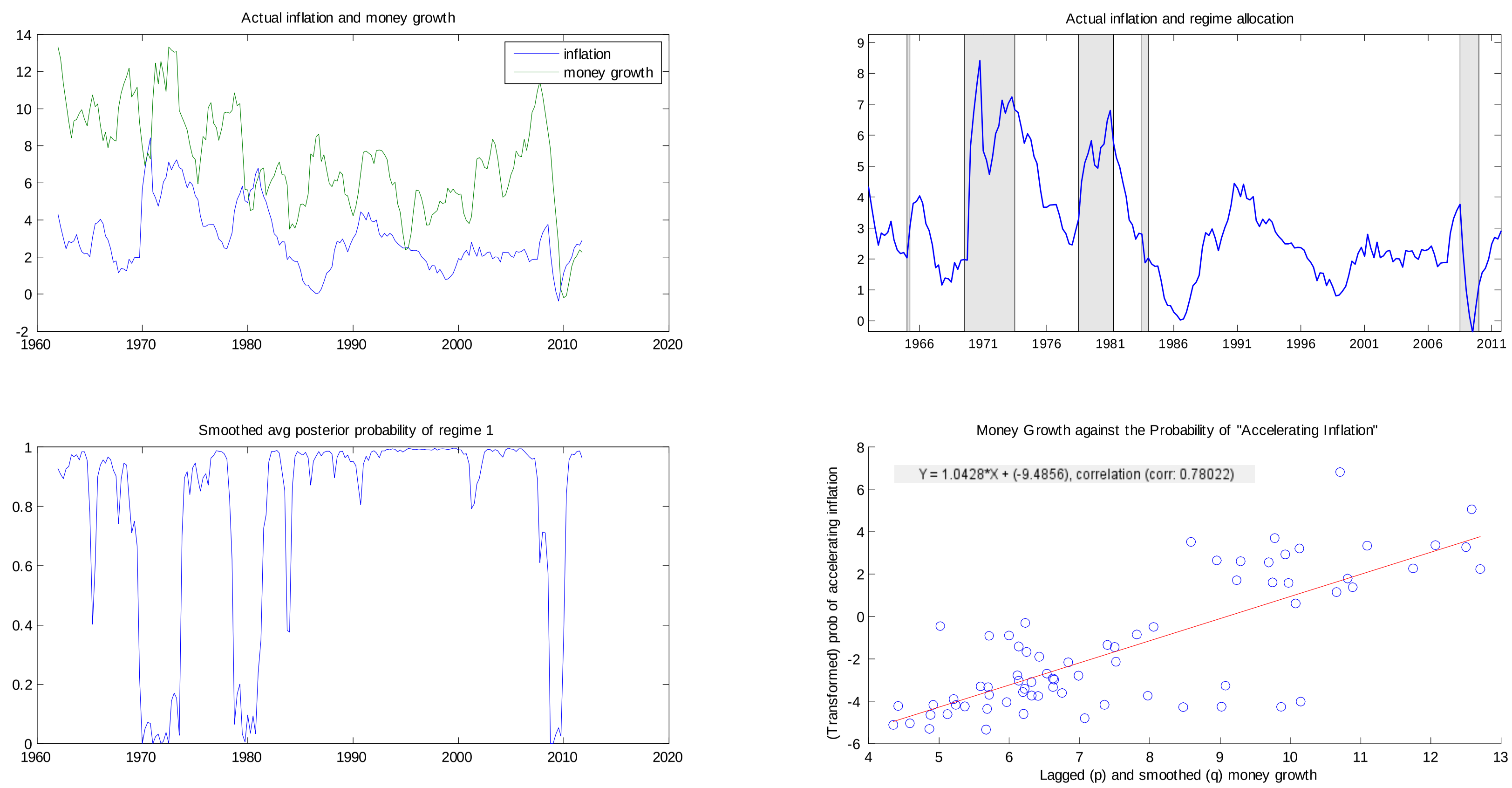
Top left panel: Money growth and inflation data. Top righ panel: inflation series (shaded areas correspond to periods in which the model assigns high probability to being in regime 3, featuring high inflation levels and sustained volatility). Bottom righ panel: p is the lag order of the indicator variable and q is the MA order of its transformation in the correlation analysis; here: p=9 and q=5.

Figure 3: Inflation regime allocation, Japan



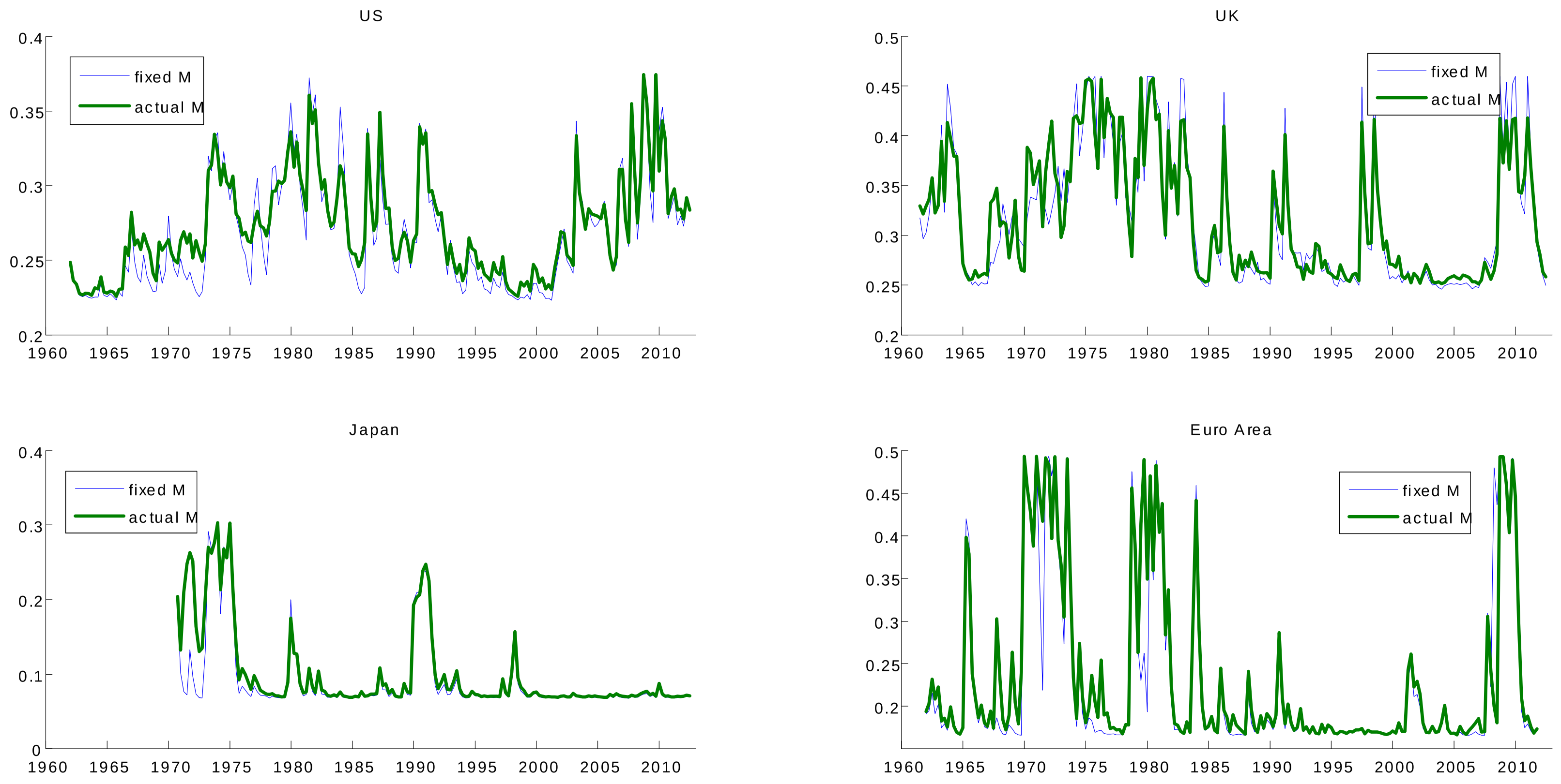
Top left panel: Money growth and inflation data. Top righ panel: inflation series (shaded areas correspond to periods in which the model assigns high probability to being in regime 3, featuring high inflation levels and sustained volatility). Bottom righ panel: p is the lag order of the indicator variable and q is the MA order of its transformation in the correlation analysis; here: p=9 and q=5.

Figure 4: Inflation regime allocation, Euro Area



Top left panel: Money growth and inflation data. Top righ panel: inflation series (shaded areas correspond to periods in which the model assigns high probability to being in regime 3, featuring high inflation levels and sustained volatility). Bottom righ panel: p is the lag order of the indicator variable and q is the MA order of its transformation in the correlation analysis; here: p=9 and q=5.

Figure 5: Counterfactual analysis: h-step ahead probabilities of "high inflation" regime, h=4



h-step-ahead probabilities obtained with an information set including the actual (observed) money growth series (bold line) and the "modified" one. "High inflation" regime features high level and sustained volatility.