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A Note of Caution on the Relation between Money Growth and Inflation

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A Note of Caution on the Relation between Money Growth and Inflation*

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ABSTRACT: We assess the bivariate relation between money growth and inflation in the euro area and the United States using hybrid time-varying parameter Bayesian VAR models. Model selection based on marginal likelihoods suggests that the relation is statistically unstable across time in both regions. The effect of money growth on inflation weakened notably after the 1980s before strengthening after 2020. There is evidence that this time variation is related to the pace of price changes, as we find that the maximum impact of money growth on inflation is increasing in the trend level of inflation. These results caution against asserting a simple, time-invariant relationship when modeling the joint dynamics of monetary aggregates and consumer prices.

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1. Introduction

Money has typically played a minor role in the literature on monetary policy the last thirty years.[1] However, the recent surge in inflation – preceded by non-standard monetary policy measures which have increased the size of central banks' balance sheets and money supply – has revived the debate regarding the role of money growth for inflation.[2] For example, Borio *et al*. (2023a) argue that under some conditions forecasters of inflation could have done better by taking the information contained in the bivariate relation between the two variables into account.

From a forecasting perspective, a key issue is whether the relation between money growth and inflation is stable over time. The empirical literature is ambiguous, with a number of papers suggesting a significant, albeit weakening relationship over time; see, for example, De Grauwe and Polan (2005), Berger and Österholm (2011a; 2011b), Sargent and Surico (2011), Dreger and Wolters (2014) and Gertler and Hofmann (2018).[3] To inform this discussion, we apply the hybrid time-varying parameter bivariate Bayesian VAR framework of Chan and Eisenstat (2018) to data from the euro area and the United States to assess if the relation between money growth and inflation is stable or time varying.

2. Data and model

Our analysis employs data on CPI inflation and M3 growth in the euro area and the United States; see Figures 1 and 2. CPI inflation is given as $\pi_t = 100(P_t/P_{t-4} - 1)$, where P_t is the consumer price index at time *t*; money growth is given as $\mu_t = 100(M_t/M_{t-4} - 1)$, where M_t is M3 at time *t*. The euro area data range from 1971Q1 to 2022Q4 and the US data from 1961Q1 to 2022Q4.[4]

Defining the vector of dependent variables as $\boldsymbol{y}_t = (\pi_t \quad \mu_t)'$, we employ the framework of Chan and Eisenstat (2018) to estimate Bayesian VAR (BVAR) models with stochastic volatility and potentially time-varying parameters. The framework allows us to assess if there is time variation in none, one, or both equations of the model.[5]

The model in its general form is:

$$\boldsymbol{B}_{0t}\boldsymbol{y}_t = \boldsymbol{\delta}_t + \boldsymbol{B}_{1t}\boldsymbol{y}_{t-1} + \cdots + \boldsymbol{B}_{pt}\boldsymbol{y}_{t-p} + \boldsymbol{\varepsilon}_t \quad (1)$$

where $\boldsymbol{B}_{0t}$ is a 2x2 lower triangular matrix with ones on the diagonal, $\boldsymbol{\delta}_t$ is a 2x1 vector of intercepts and $\boldsymbol{B}_{1t}, \ldots, \boldsymbol{B}_{pt}$ are 2x2 matrices with the parameters describing model dynamics. The disturbances $\boldsymbol{\varepsilon}_t$ are assumed

[1] For example, the New-Keynesian models dominating both the academic literature and many central banks' toolboxes, have generally paid little attention to money, focusing instead on the interest rate channel of monetary policy. Among the major central banks, only the ECB maintains a "two-pillar strategy" explicitly featuring monetary analysis (ECB (2003, 2021)).

[2] See, for example, Issing (2021), Papadia and Camaduro (2021), Congdon (2022), King (2022), Ambler and Kronick (2023), and Hall *et al.* (2023).

[3] An early study providing evidence of time variation in the relation between money and a number of macroeconomic variables is Friedman and Kuttner (1992).

[4] The euro area data – where CPI inflation is given by HICP inflation – combine the Euro Area Business Cycle Network's Area Wide Model data and Eurostat data for the 19 members as of 2022. The US data were sourced from the FRED database of the Federal Reserve Bank of Saint Louis.

[5] For empirical analyses employing the framework to Okun's law and the Phillips curve, see Karlsson and Österholm (2020, 2023).

to be orthogonal, normally distributed, and subject to stochastic volatility – that is, $\varepsilon_{i,t} \sim N(0, \boldsymbol{\Sigma}_t)$ where $\boldsymbol{\Sigma}_t = diag\left(exp(h_{\pi t}), exp(h_{\mu t})\right)$; the log volatilities are assumed to evolve as random walks:

$$\boldsymbol{h}_t = \boldsymbol{h}_{t-1} + \boldsymbol{\zeta}_t \quad (2)$$

where $\boldsymbol{\zeta}_t \sim N(\boldsymbol{0}, \boldsymbol{\Sigma}_{\boldsymbol{h}})$. Finally, the free parameters of $\boldsymbol{\delta}_t$ and $\boldsymbol{B}_{it}$ are gathered in the parameter vector $\boldsymbol{\theta}_t$, which follows a random walk as well:

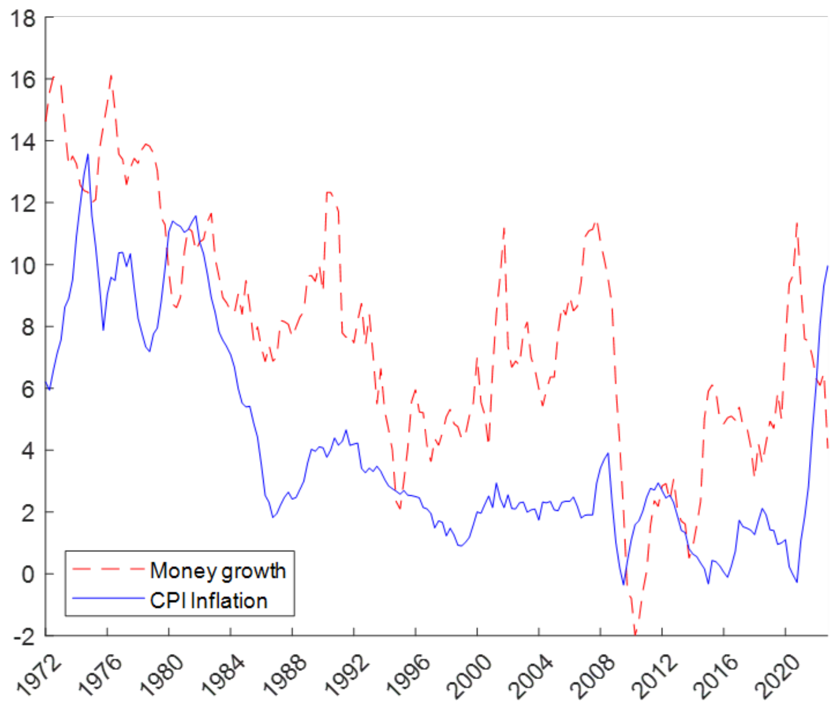
$$\boldsymbol{\theta}_t = \boldsymbol{\theta}_{t-1} + \boldsymbol{\eta}_t \quad (3)$$

where $\boldsymbol{\eta}_t \sim N(\boldsymbol{0}, \boldsymbol{\Sigma}_{\boldsymbol{\theta}})$. The vector $\boldsymbol{\theta}_t$ can be split into two – one that contains the parameters for the equation for inflation ($\boldsymbol{\theta}_{1,t}$) and one for the equation for money growth ($\boldsymbol{\theta}_{2,t}$). When the model is estimated with constant parameters, $\boldsymbol{\Sigma}_{\boldsymbol{\theta}}$ is set to zero.

The bivariate system estimated allows four different combinations of time variation: *i)* both equations have constant parameters (no time variation in $\boldsymbol{\theta}_{1,t}$ and $\boldsymbol{\theta}_{2,t}$), *ii)* time variation in the parameters of the equation for inflation ($\boldsymbol{\theta}_{1,t}$) but not for money growth ($\boldsymbol{\theta}_{2,t}$), *iii)* time variation in the parameters of the equation for the money growth ($\boldsymbol{\theta}_{2,t}$) but not for inflation ($\boldsymbol{\theta}_{1,t}$) and *iv)* time-varying parameters in both equations (time variation in both $\boldsymbol{\theta}_{1,t}$ and $\boldsymbol{\theta}_{2,t}$).

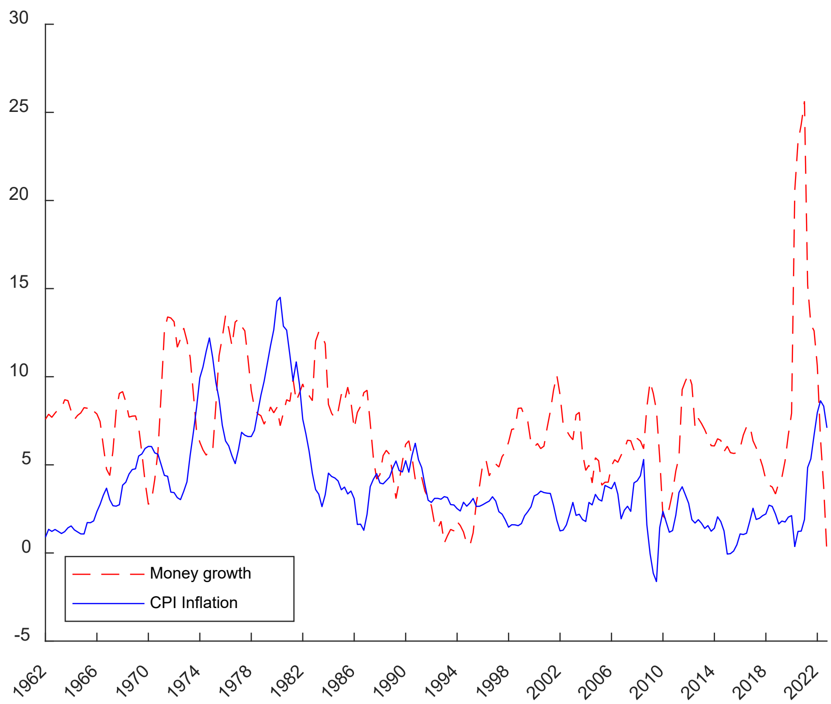
When estimating the models, we set lag length equal to $p = 4$. Concerning priors, we use an uninformative normal prior on the initial states of the regression parameters, $\boldsymbol{\theta}_{1,0}$ and $\boldsymbol{\theta}_{2,0}$, $N(0,5\boldsymbol{I})$ and a normal prior, $h_{i,0} \sim N(\gamma_i, 0.25)$, for the initial log volatilities, where γ_i is set to match the prior mean of $exp(h_{i,0})$ with the residual variance of a constant parameter univariate AR(4) model. The diagonal elements of $\boldsymbol{\Sigma}_{\boldsymbol{\theta}}$ have inverse Gamma, $iG(5,0.08)$, priors for constants and $iG(5,0.0004)$ for other parameters. Finally, the diagonal elements of $\boldsymbol{\Sigma}_{\boldsymbol{h}}$ have $iG(5,0.4)$ priors.

Figure 1. Euro area inflation and money growth
(In percent)



Source: Euro Area Business Cycle Network, Eurostat and authors' calculations.

Figure 2. United States inflation and money growth
(In percent)



Source: Federal Reserve Bank of Saint Louis and authors' calculations.

3. Results

Table 1 indicates that the model with time-varying parameters in both equations is preferred in both the euro area and the United States, while the constant-parameter model is ranked last. To compare the strength of the evidence, we use the commonly applied scale of two times the difference in log marginal likelihood and compare the model with time-varying parameters in both equations to that with constant parameters in both equations. Using the terminology of Kass and Raftery (1995, p. 777), the evidence in favor of the model with time-varying parameters in both equations is "*very strong.*" The evidence in favor of the model with time-varying parameters in both equations compared to the models with only one time-varying equation is "*positive*" or "*very strong*".

Table 1. Log marginal likelihoods

	Euro area	United States
Both equations are constant	-458.2	-622.2
Time variation in equation for π_t	-455.7	-616.4
Time variation in equation for μ_t	-452.5	-620.6
Both equations are time varying	**-449.9**	**-614.6**

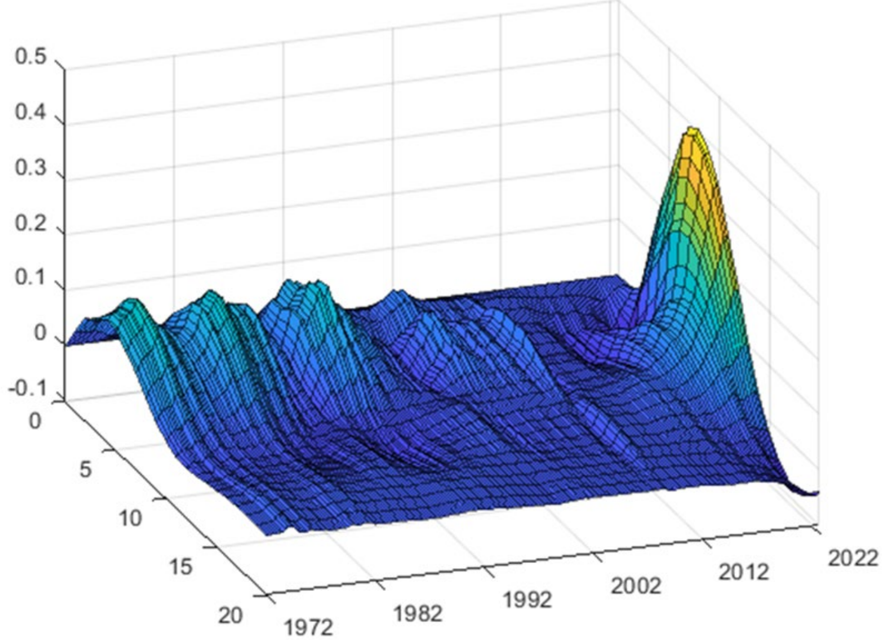
Note: Highest marginal likelihood given in **bold**.

Figures 3 and 4 show the impact that a one-standard-deviation shock to money growth has on inflation in the preferred model with time-varying parameters.[6] The dynamics of the model have changed notably across the sample period in both the euro area and the Unites States. In both regions, money growth shocks had a clear positive impact on inflation in the 1980s; in the euro area, we find this also in the 1970s. However, the relationship between the two variables became very weak or non-existent starting in the 1990s before making a sudden dramatic comeback in the early 2020s.

The snapshots in Figure 5 further illustrate these changing dynamics. Shocks to money growth had an inverted u-shape effect on inflation in 1982Q4, while in 2015Q4 – at a time when inflationary pressure was low and both the ECB and the Federal Reserve were struggling to increase inflation – the response was indistinguishable from zero. In 2022Q4, we see that inflation increases again with a shock to money growth, albeit with more of a delay. The quantitatively larger effect in the United States in the third period is related to the larger underlying shock (see Figure A2 in the Appendix).

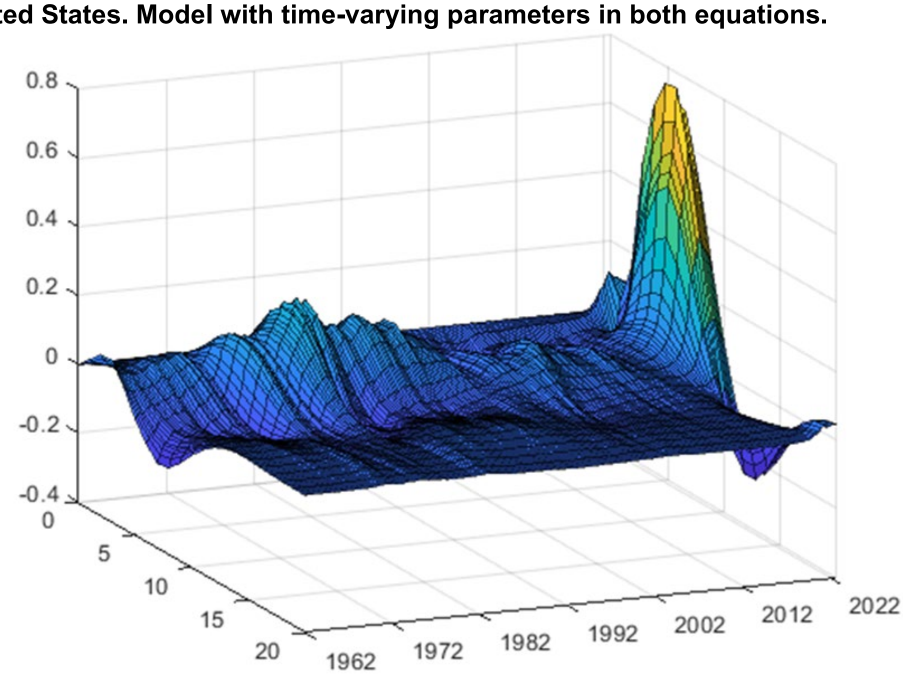
[6] Since the model has stochastic volatility, the size of the impulse is time varying; see Figures A1 and A2 in the Appendix.

Figure 3. Impulse-response function: Effect of shocks to money growth on inflation in the euro area. Model with time-varying parameters in both equations.



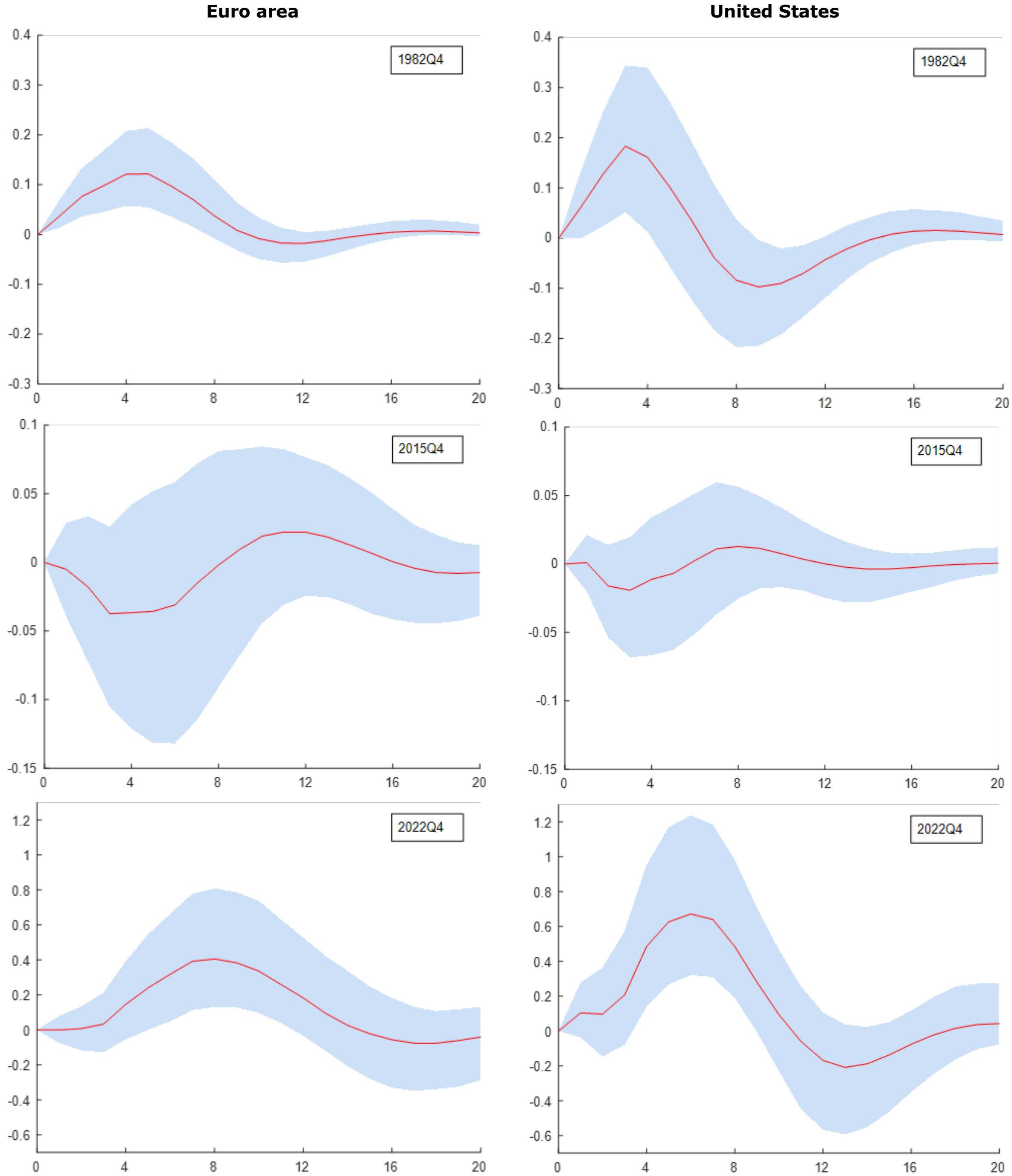
Note: Size of impulse is one standard deviation. Effect in percentage points on vertical axis. Horizon in quarters and dates on horizontal axes.
Source: Authors' calculations.

Figure 4. Impulse-response function: Effect of shocks to money growth on inflation in the United States. Model with time-varying parameters in both equations.



Note: Size of impulse is one standard deviation. Effect in percentage points on vertical axis. Horizon in quarters and dates on horizontal axes.
Source: Authors' calculations.

Figure 5. Impulse-response functions: Effect of shocks to money growth on inflation at different timepoints. Model with time-varying parameters in both equations.



Note: Size of impulse is one standard deviation. Effect in percentage points on vertical axis. Horizon in quarters on horizontal axis. Shaded band is 68 percent credible interval.

Source: Authors' calculations.

These results suggest that ignoring the lack of stability in the response of inflation to an unexpected increase in money growth and assuming instead a model with constant parameters over time (see Figures A3 and A4 in the Appendix) would provide a misleading description of economic circumstances for policymakers.

As a final exercise, we relate the effect that money growth has on inflation to the level of trend inflation.[7] Among others, Borio *et al*. (2023a) suggest that the impact of money growth on inflation could be stronger at higher levels of inflation. To see whether this hypothesis holds within our empirical framework, we calculate a time-varying measure of trend inflation and relate it to the time-varying impact of money growth on inflation.

To compute trend inflation, we rewrite the VAR in equation (1) in its reduced form:

$$\boldsymbol{y}_t = \boldsymbol{\alpha}_t + \boldsymbol{A}_{1t}\boldsymbol{y}_{t-1} + \cdots + \boldsymbol{A}_{pt}\boldsymbol{y}_{t-p} + \boldsymbol{e}_t \quad (4)$$

where $\boldsymbol{\alpha}_t = \boldsymbol{B}_{0t}^{-1}\boldsymbol{\delta}_t$, $\boldsymbol{A}_{it} = \boldsymbol{B}_{0t}^{-1}\boldsymbol{B}_{it}$ and $\boldsymbol{e}_t = \boldsymbol{B}_{0t}^{-1}\boldsymbol{\varepsilon}_t$. The model is then expressed in its companion form as:

$$\tilde{\boldsymbol{y}}_t = \tilde{\boldsymbol{\alpha}}_t + \boldsymbol{A}_t\tilde{\boldsymbol{y}}_{t-1} + \tilde{\boldsymbol{e}}_t \quad (5)$$

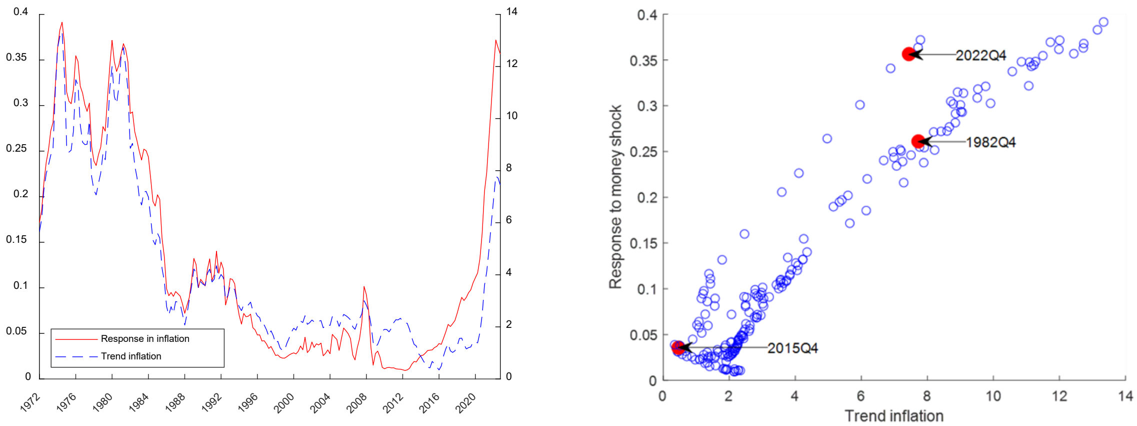
where $\tilde{\boldsymbol{y}}_t = \left(\boldsymbol{y}_t', \boldsymbol{y}_{t-1}', \dots, \boldsymbol{y}_{t-p+1}'\right)'$, $\tilde{\boldsymbol{\alpha}}_t = (\boldsymbol{\alpha}_t', \boldsymbol{0}', \dots, \boldsymbol{0}')'$, $\boldsymbol{A}_t = \begin{pmatrix} \boldsymbol{A}_{1t} & \boldsymbol{A}_{2t} & \cdots & \boldsymbol{A}_{p-1,t} & \boldsymbol{A}_{pt} \\ \boldsymbol{I} & \boldsymbol{0} & \cdots & & \boldsymbol{0} \\ \boldsymbol{0} & \ddots & & & \\ \vdots & & \ddots & & \vdots \\ \boldsymbol{0} & \cdots & \boldsymbol{0} & \boldsymbol{I} & \boldsymbol{0} \end{pmatrix}$ and $\tilde{\boldsymbol{e}}_t = (\boldsymbol{e}_t', \boldsymbol{0}', \dots, \boldsymbol{0}')'$, where trend inflation is given by the first element of $\boldsymbol{\phi}_t = (\boldsymbol{I} - \boldsymbol{A}_t)^{-1}\tilde{\boldsymbol{\alpha}}_t$.

Next, we relate the maximum effect on inflation of a unit shock to money growth to trend inflation.[8] Figures 6 and 7 show that the maximum effect of money growth indeed tends to be higher at higher levels of trend inflation. The co-movement appears to be stronger for the euro area (correlation 0.95) than the United States (correlation 0.64) but is clearly present in both currency areas.

[7] Trend inflation is the "local mean" and represents the value to which the inflation forecasts from the model would converge. This terminology has been used by, for example, Faust and Wright (2013) and Clark and Doh (2014). Cogley and Sargent (2005) denoted this *core inflation*.

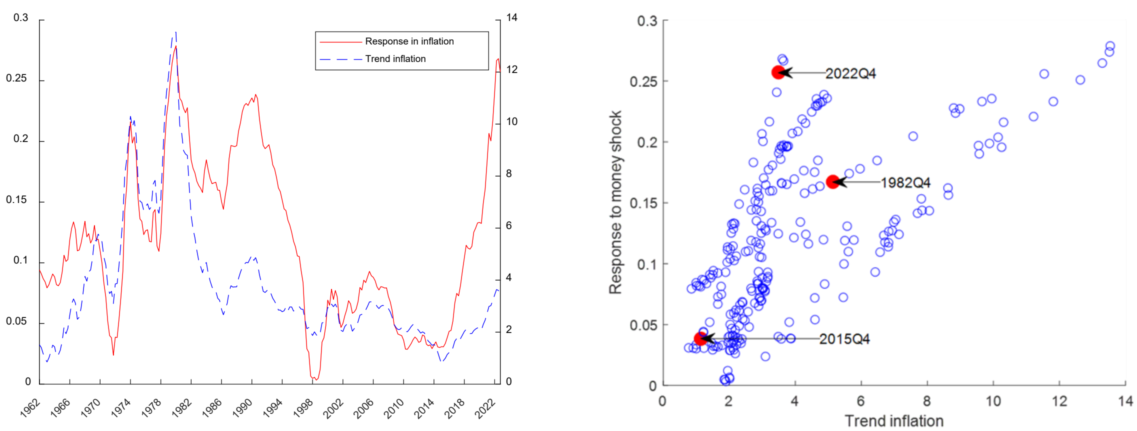
[8] Note that we here use a shock size of unity rather than one standard deviation (which was employed in Figures 3 and 4) in order to make the effects comparable over time. It should also be noted that for different points in time, the maximum effect can appear at different horizons.

Figure 6. Trend inflation and maximum inflation response of shock to money growth in the euro area. Model with time-varying parameters in both equations.



Note: Size of impulse is unity. Left panel: Maximum effect on inflation in percentage points on left vertical axis. Trend inflation in percent on right vertical axis. Right panel: Maximum effect on inflation in percentage points on vertical axis. Trend inflation in percent on horizontal axis.
Source: Authors' calculations.

Figure 7. Trend inflation and maximum inflation response of shock to money growth in the United States. Model with time-varying parameters in both equations.



Note: Size of impulse is unity. Left panel: Maximum effect on inflation in percentage points on left vertical axis. Trend inflation in percent on right vertical axis. Right panel: Maximum effect on inflation in percentage points on vertical axis. Trend inflation in percent on horizontal axis.
Source: Authors' calculations.

4. Conclusions

We provide evidence that the bivariate relation between money growth and inflation in the euro area and the United States has changed over time. Model selection based on marginal likelihoods confirms that the relation is statistically unstable across time in both regions. Results from models with time-varying parameters illustrate that the dynamic relation between money growth and inflation weakened notably after the 1980s before making a comeback after 2020. There is evidence that this time variation might be related to the pace of inflation, as the maximum impact of money growth on inflation is increasing in the trend level of inflation. These findings caution against asserting a simple, time-invariant relationship between the dynamics of monetary aggregates and consumer prices both for forecasting and policy-making purposes.

Our results add to the long-standing but recently rejuvenated discussion around the role of money for inflation. Among others, Berger and Österholm (2011a, 2011b) and Gertler and Hofmann (2018) documented the weakening relationship between money growth and inflation over time. Noting the co-movement of money growth and inflation in many countries since 2020, Borio *et al* (2023a) suggested that the way to reconcile these stylized facts might be that money can help forecasting inflation conditional on the presence of a high-inflation regime.[9] The argument mirrors previous findings by de Grauwe and Polan (2005) and Gertler and Hofmann (2018), who reported the money-growth and inflation nexus to be stronger among high-inflation countries. Our results generalize the results as they do not depend on the necessarily arbitrary definition of what constitutes a "high" inflation regime or country.

[9] See also Borio *et al.* (2023b).

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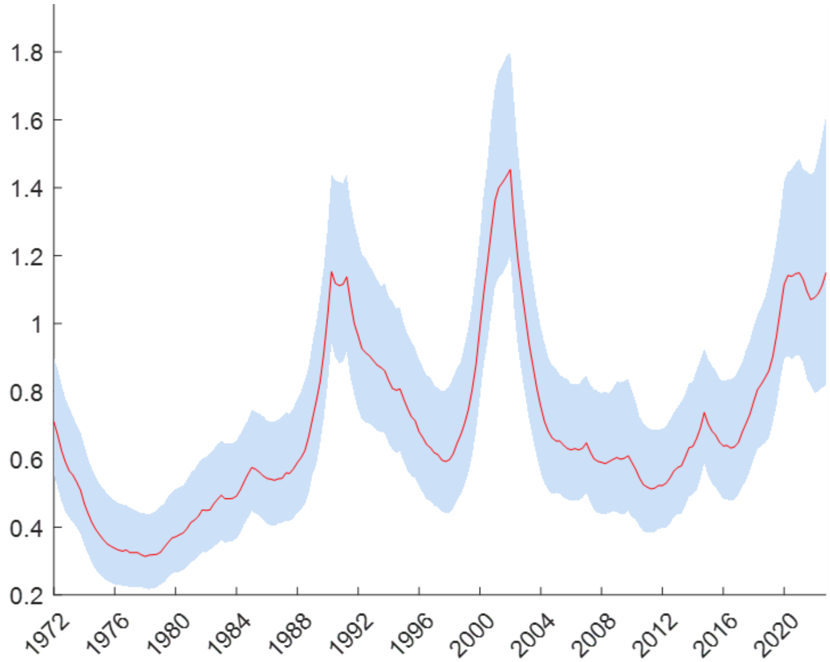
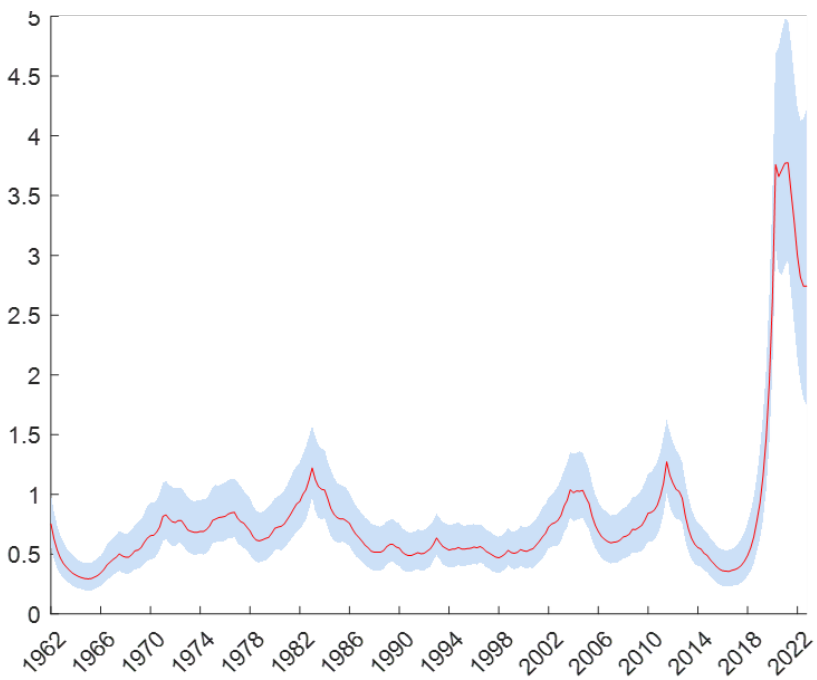
Appendix

Figure A1. Standard deviation of shocks to money growth in the euro area.



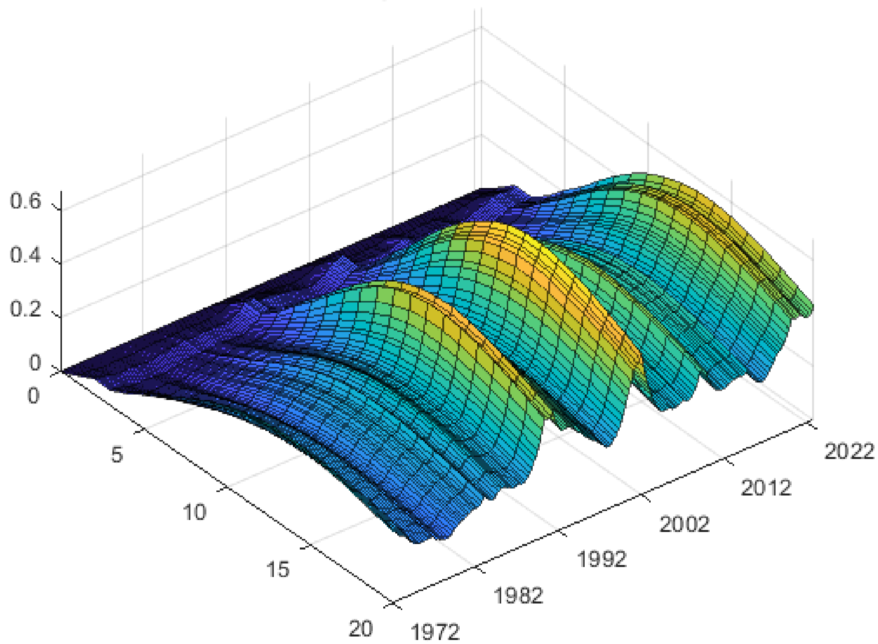
Note: Estimated standard deviation of structural shock. Shaded band is 68 percent credible interval.
Source: Authors' calculations.

Figure A2. Standard deviation of shocks to money growth in the United States.



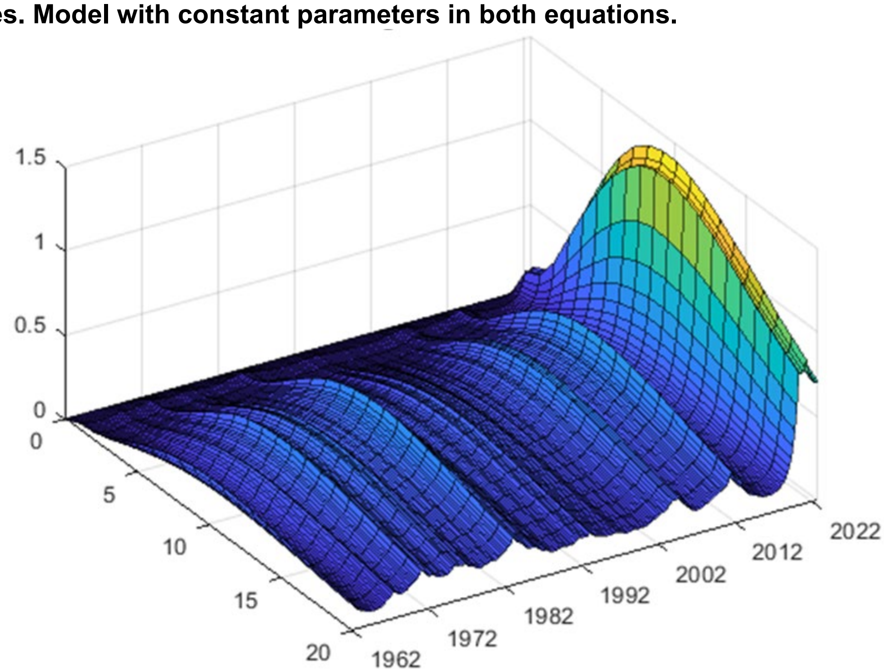
Note: Estimated standard deviation of structural shock. Shaded band is 68 percent credible interval.
Source: Authors' calculations.

Figure A3. Impulse-response function: Effect of shocks to money growth on inflation in the euro area. Model with constant parameters in both equations.



Note: Size of impulse is one standard deviation. Effect in percentage points on vertical axis. Horizon in quarters and dates on horizontal axes.
Source: Authors' calculations.

Figure A4. Impulse-response function: Effect of shocks to money growth on inflation in the United States. Model with constant parameters in both equations.



Note: Size of impulse is one standard deviation. Effect in percentage points on vertical axis. Horizon in quarters and dates on horizontal axes.
Source: Authors' calculations.

PUBLICATIONS

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