Institut für Makroökonomie
und Konjunkturforschung
Macroeconomic Policy Institute

Working Paper

6/2009

Low-frequency determinants of inflation in the euro area

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August 2009

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Low-frequency determinants of inflation in the euro area*

by Sven Schreiber†

this version: August 2009

Abstract

We use frequency-wise Granger-causality tests and error-correction models to investigate the driving forces behind longer-run inflation developments in the euro area. Employing an eclectic approach we consider various relevant theories. With a general-to-specific testing strategy we distill the unemployment rate and long-term interest rates as causal for low-frequency variations of inflation. Money growth is found to be causal for inflation only if other variables are omitted, which we therefore interpret as a spurious result.

Keywords: money growth, Granger causality, quantity theory

JEL: E31, E40

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*This paper has benefitted from comments by Dieter Nautz, Jörg Breitung, Till van Treeck, and by seminar participants at Goethe University. Nonetheless errors are mine.

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1 Introduction

Understanding the causes behind inflation movements at low frequencies is important for all types of economic agents, where low-frequency developments may be thought of as the slower but long-lasting, longer-run changes of a variable. For monetary policy it is important to predict the long-run inflation developments in order to assess inflationary pressures and to be able to adjust its policy stance accordingly. But private agents of course also undertake long-term financial planning and must therefore forecast the more persistent movements of inflation.

A popular view of the forces behind inflation movements is based on the traditional quantity theory of money. According to that view, inflation is predominantly a monetary phenomenon, and therefore movements of money growth are supposed to cause inflation changes. But already a casual look at the data of many (developed) countries often suggests that money growth and inflation can be quite disconnected at least in the short term, see figure 1 for the euro-area data. By now this empirical assessment seems to have emerged as a consensus and is also reflected in the practice of modern macroeconomics to build models without monetary aggregates.

As a consequence of this state of affairs, many central banks have abandoned looking closely at the developments of monetary aggregates. However, other economists such as the intellectual founders of the European Central Bank (ECB) had saved the monetary view by inventing the "two-pillar" approach which reserves a whole pillar and thus a "prominent role for money" (ECB, 2004) for the longer run, but which acknowledges that other forces than money growth cause inflation in the short to medium term. Empirical two-pillar Phillips-curve equations adopt this view by adding money growth to reduced-form models of inflation (Gerlach, 2004; ECB, 2004; Beck and Wieland, 2007).

Additionally, in a series of papers (Assenmacher-Wesche and Gerlach, 2007, 2008a,b)

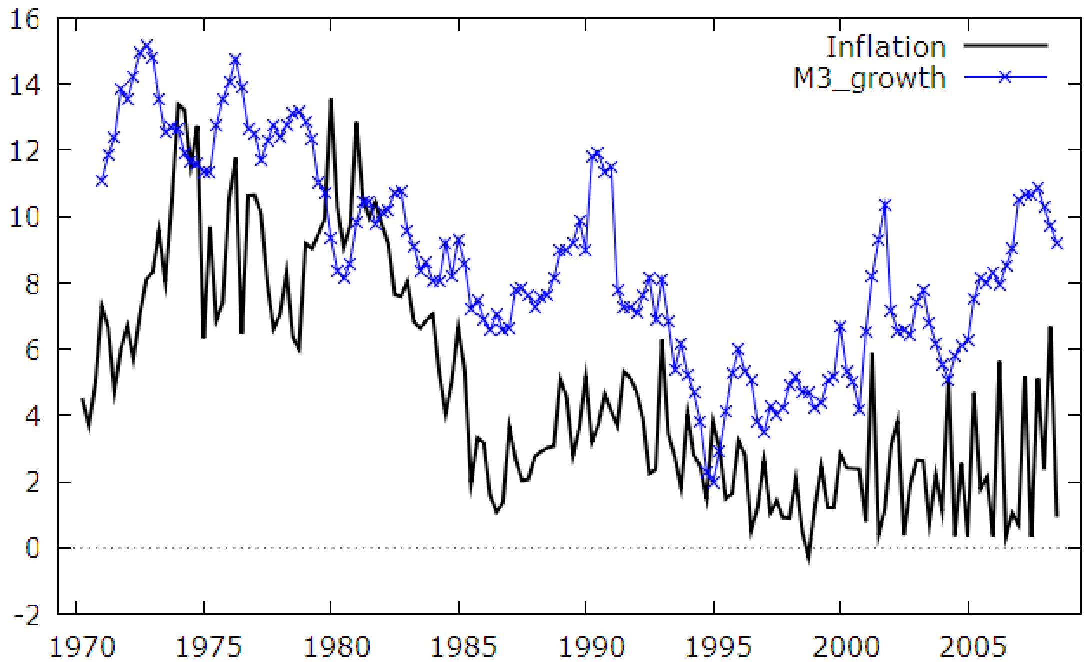

Figure 1: Money growth and inflation (CPI-based) in the euro area

AW&G have recently argued that the longer-run causal impact of money growth on inflation can be empirically established if appropriate econometric techniques are used. These results attribute to money growth a low-frequency role in the inflation process and therefore directly support the approach of the ECB.

In this paper we use a broader theoretical foundation for the low-frequency determinants of inflation, including the quantity theory of money but considering also other possible influences coming from goods, labor, and financial markets. Mirroring the approach of considering more than one theory, our empirical strategy is to perform a general-to-specific search routine where empirically non-causal variables are successively excluded from the analysis. This procedure automatically checks whether money is an important causal variable for inflation or other variables. At each step of this search routine we employ similar econometric methods as AW&G, especially low-frequency causality tests in a system conditional on other persistent variables. After having distilled the relevant causal variables, we also estimate vector (system) error-correction models to quantify the long-run relations.

Based on the richer information set in our analysis we arrive at conclusions that are different from AW&G's. Money growth turns out as non-causal, while unemployment and long-term interest rates drive the low-frequency movements of inflation. (However, note that since inflation in turn is non-causal for variables such as unemployment, our results do not support the interpretation that higher inflation can actively "buy" lower unemployment.) Since we can replicate (qualitatively) AW&G's results in a bivariate dataset with money growth and inflation only, it appears that their findings suffer from an omitted-variable bias.[1]

In the following section 2 we discuss the underlying theories. Then in section 3 we briefly introduce the frequency-domain causality measures and tests, and we report the empirical details of the search routine and its results. After that we present the error-correction model estimates in section 4. Both sections 3 and 4 contain separate subsections dealing with the respective bivariate analyses that replicate AW&G's results. Finally, section 5 concludes.

2 Economic theory

In this section we consider several theories that are potentially relevant for low-frequency movements of inflation. All relationships are presented in a bare-bones form suppressing constants, error terms and richer dynamics. The empirical methods in this paper account for that.

We start with the quantity theory of money in log-differenced form as in AW&G, where inflation π is related to money growth Δm, real output growth Δy, and changes of velocity Δv:

$$\pi = \Delta m - \Delta y + \Delta v \tag{1}$$

Of course equation (1) as such is an identity, not a theoretical hypothesis. Apart from

[1] See Lütkepohl (1982) for the theory of omitting variables in Granger-causality tests.

possible additional assumptions about the properties of velocity such as relative stability or whether it is related to interest rate changes as in AW&G, the key theoretical issue is precisely given by the hypothesis that money growth tends to determine inflation and not vice versa.

Next, it is natural to consider the New Keynesian Phillips curve (NKPC, see e.g. Galí and Gertler, 1999) as a modern theory of inflation, where inflation is driven by discounted expected marginal costs, with λ and β as parameters:

$$\pi_t = \lambda \sum_{k=0}^{\infty} \beta^k \mathsf{E}_\mathsf{t}(\text{marg. costs}_{t+k}) \tag{2}$$

The standard approach is to use (log) real unit labor costs $ulc - p$ (essentially the labor share) as a proxy for unobservable marginal costs. However, it should be noted that the theory is originally formulated for business-cycle frequencies and may fail at lower frequencies. Also, since it is *expected* future marginal costs that drive current inflation, if the theory is correct then the predictive Granger causality should run the other way around, from realized inflation to realized marginal costs.

Wage-curve models yield additional insights about which factors may affect inflation (see e.g. Blanchard and Katz, 1997, 1999). From the point of view of wage setters, expected real hourly wage growth can be written as $\Delta w_t - \pi_t^e$ (where Δw is hourly nominal wage growth and π^e is expected inflation) and depends on lagged real unit labor costs, unemployment[2] u_t, and the growth of real labor productivity per labor input (hours) Δq:

$$\Delta w_t - \pi_t^e = -(1-\alpha)(ulc-p)_{t-1} - \beta_u u_t + (1-\alpha)\Delta q_t, \qquad \alpha \in [0;1], \beta_u > 0,$$

which can be extended with more complicated dynamics. Using the identities $\Delta ulc_t = \Delta w_t - \Delta q_t$ and $\Delta q_t = \Delta y_t - \Delta h_t$, where h is total labor inputs (log hours), we can rearrange the

[2]More generally it is the overall labor market tightness which matters. The unemployment rate serves as a reasonable proxy here.

equation as follows:

$$-\pi_t^e = -\Delta ulc_t - (1-\alpha)(ulc-p)_{t-1} - \beta_u u_t - \alpha\Delta y_t + \alpha\Delta h_t \tag{3}$$

Another theoretical relationship to justify the inclusion of the growth rate of (nominal) unit labor costs is given by a simple differenced mark-up pricing rule:

$$\pi = \Delta ulc^{(e)}, \tag{4}$$

where we write "(e)" to denote that it may be either realized or expected developments of unit labor costs which determine inflation, depending on the timing of information flows. Again, if the true relationship is expectational, $\pi = \Delta ulc^e$, then the empirical Granger causation would actually run from inflation to unit labor costs. Indeed this appears to be the general empirical finding at least for US data and without differentiating between frequency bands (Mehra, 1991; Strauss and Wohar, 2004). Note that a 1:1 relation between π and Δulc in the long-run will hold in all standard models (see e.g. Sbordone, 2002).

Finally we consider the Fisher relation, where the long-term (nominal) interest rate r consists of an equilibrium real rate (proxied by a constant natural rate of interest which again is suppressed here) and fluctuations determined by inflation expectations:

$$r = \pi^e \tag{5}$$

Long-term interest rates r thus should be predictive for realized inflation.

Altogether, the set of variables that are included in the analysis is given by:[3]

$$\pi, \Delta m, \Delta ulc, ulc - p, u, r, \Delta y$$

3 Frequency-domain analysis[4]

For long-term interest rates we use 10-year government bond yields, for money we use the M3 aggregate, and inflation is CPI-based. The data are taken from the ECB's area-wide model (AWM) dataset which is extended using available equivalent data from the OECD and the IMF (IFS), such that the available sample is 1971-2008 with roughly 150 quarterly observations. It should be noted that the sample is dominated by the synthetic AWM data referring to the period prior to the actual formation of the euro area. While the aggregation to a virtual euro area before 1999 may of course be problematic, there is no obvious way around this issue; furthermore that dataset is widely used in policy analysis. Figures 1 through 4 plot all included variables.

3.1 Spectra

Before we apply the frequency-wise causality tests we turn to the fundamental properties of the variables in the frequency domain, i.e. we look at their spectra. The spectrum can be interpreted as measuring the contributions of different cycle components (at different frequencies) for the total variation of the process x_t. The typical spectral shape for many macroeconomic processes is that low frequencies (long-run variations) dominate the spectrum. In figure 5

[3] Since the quantity theory (1) is an identity, we do not need to consider velocity changes once the other three variables are accounted for. Information about the growth rate of total hours Δh is not available for our sample of the euro area.

[4] All empirical results were produced with gretl, see Cottrell and Lucchetti (2009). The B&C tests used Breitung's Gauss code that was ported to the gretl scripting language by the authors and is now available under the general public license (GPL), with permission from Jörg Breitung. Soon the code should be downloadable as a gretl function package from the official gretl package server.

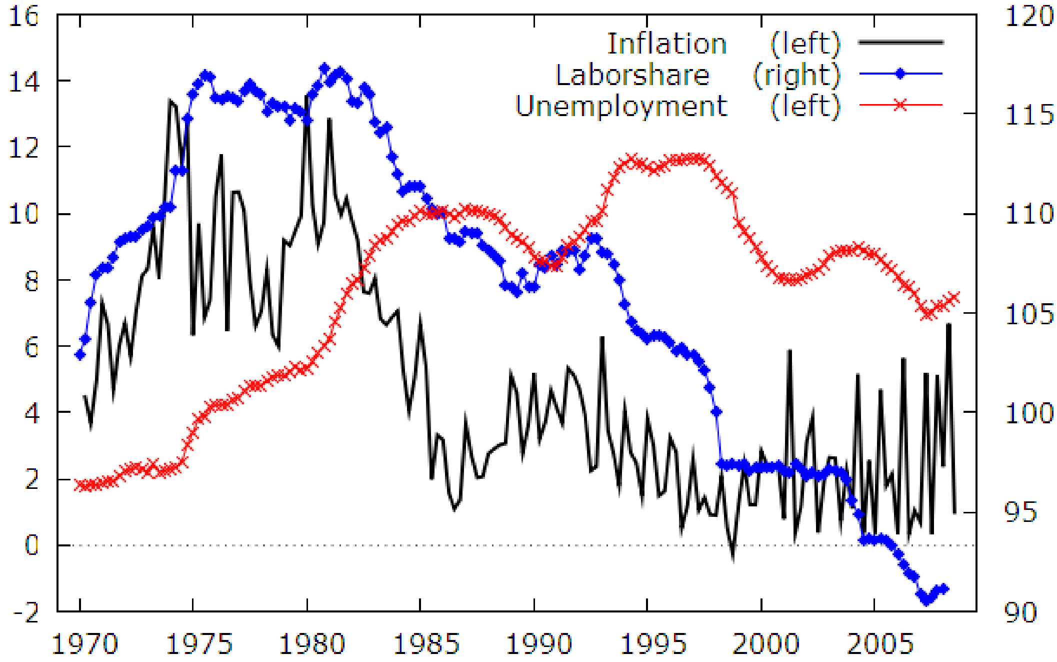

Figure 2: Inflation with labor share and unemployment

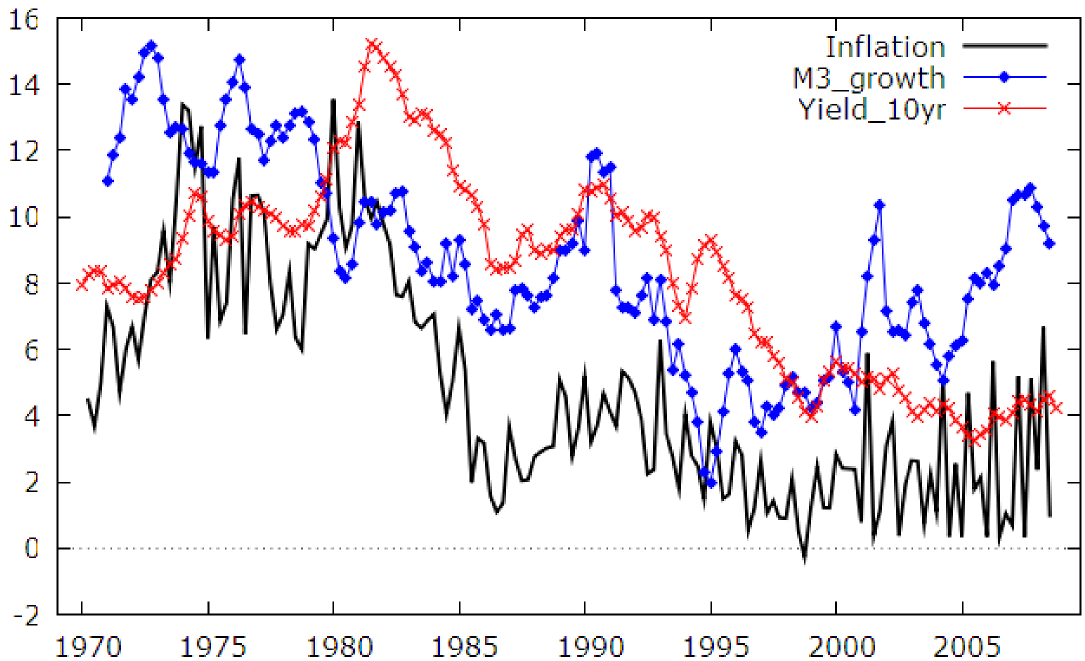

Figure 3: Inflation with money growth and long-term interest rates

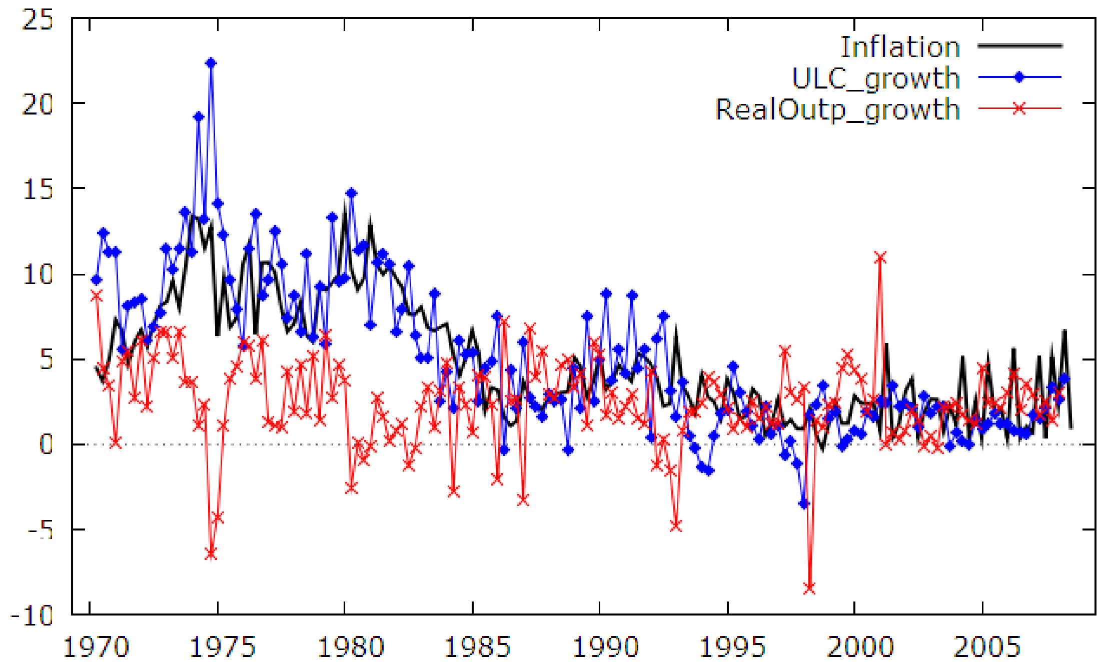

Figure 4: Inflation with unit labor cost growth, and real output growth

we can confirm this phenomenon for six of the seven considered variables. Only real output growth has an almost flat spectrum, and so it is clearly stationary. But this means that there cannot be any longer-run connection of real output growth with persistent variables like inflation or money growth.

3.2 Granger causality in the frequency domain – the framework

The well-known notion of causality proposed by Granger (1969) rests on predictive power. If (and only if) the variable x_{cause} is Granger-causal (G-causal) for the variable x_{target}, then adding x_{cause} to the available information set gives better predictions of x_{target}. A generalization of this concept was introduced by Geweke (1982), who noted that causal effects can be different at different cycle frequencies. Using the vector moving average (VMA) representation $z_t = \Psi(L)\eta_t$ for $z_t = (x_{target,t}, x_{cause,t})'$ (with L as the lag operator, and η_t is a white noise

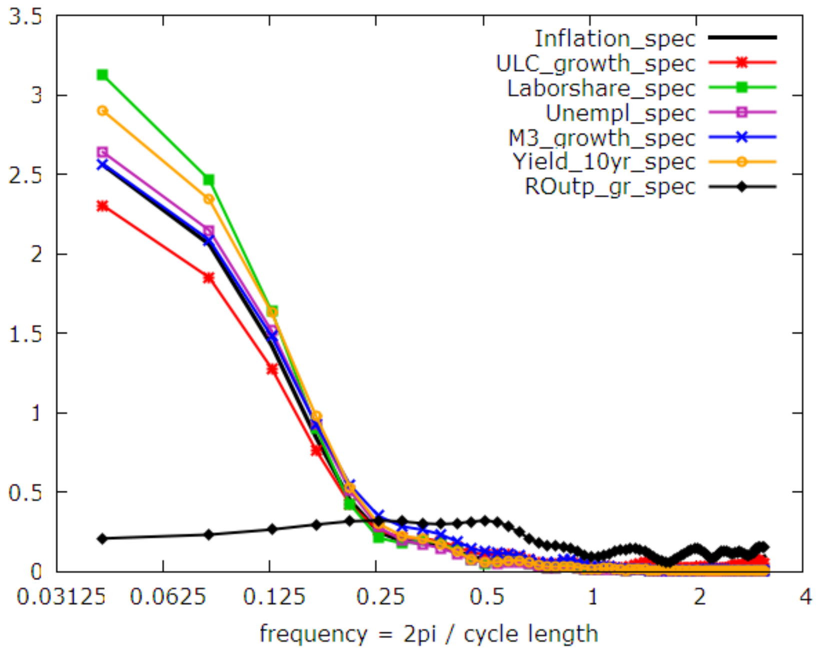

Figure 5: Spectra of the variables. The frequency axis is given in logarithmic scale to emphasize the low-frequency portion. Variables were normalized to have unit variance.

innovation process) it is useful to partition the lag polynomial $\Psi(L)$ as:

$$\Psi(L) = \begin{pmatrix} \Psi_{11}(L) & \Psi_{12}(L) \\ \Psi_{21}(L) & \Psi_{22}(L) \end{pmatrix} \tag{6}$$

Geweke's causality measure for the frequency $\omega \in (0;\pi)$ is given by:

$$M(x_{cause} \rightarrow x_{target};\omega) = \log\left(1 + \frac{|\Psi_{12}(\exp(-i\omega))|^2}{|\Psi_{11}(\exp(-i\omega))|^2}\right), \tag{7}$$

An obviously interesting hypothesis to test is that of non-causality at a given frequency ω_0, i.e. that $M(x_{cause} \rightarrow x_{target};\omega_0) = 0$. Using the fact that $M = 0 \Leftrightarrow |\Psi_{12}(e^{-i\omega})| = 0$, Breitung and Candelon (2006, B&C) recently showed that this hypothesis is equivalent to two special but linear restrictions in the underlying VAR, and the test of non-causality therefore has standard asymptotics. It also allows to account for further conditioning variables which

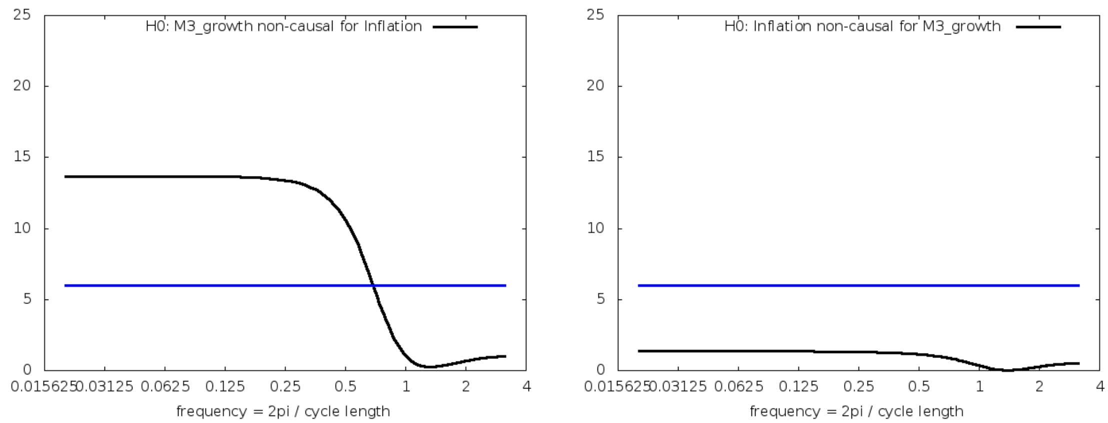

Figure 6: B&C test results, bivariate system. Left panel: target variable is the inflation rate. Right panel: target variable is money growth. The critical value is represented by the horizontal line.

is desirable given the potential omitted-variable problems mentioned before. And finally, the B&C test is also applicable to cointegrated systems without having to impose the cointegration restrictions.

3.3 Replicating the Assenmacher-Wesche & Gerlach results

When we analyze only a bivariate dataset comprising inflation and money growth we can replicate the findings by AW&G quite closely. Figure 6 shows that money growth seems G-causal for inflation at low frequencies (left panel) and no G-causality in the other direction. Therefore our different findings are due to the broader information set that we use, not to technical differences or to implementation details.

3.4 Test results and directed graphs

We will use the B&C test as a tool to clarify the possibly complex G-causal relationships between the variables in our dataset. Our empirical strategy is as follows:

1. start with all potentially G-causal variables

2. determine significant low-frequency G-causality relations (and their directions) with the B&C test

3. drop variables which are non-causal (at low frequencies) and repeat the procedure from the second step until no further non-causal variables remain

With respect to the first step we exclude real output growth given that it does not have significant spectral mass at low frequencies.[5] The starting information set therefore comprises six variables. In the second step, the potential G-causal effects of each variable on all other variables are assessed conditional on the respective remaining variables to avoid finding spurious causality. While this procedure involves a large number of individual tests, it does not imply an excessive computational burden since the tests themselves are based only on linear restrictions. "Non-causal" variables are those which do not G-cause any other variable in a frequency band ranging from zero to roughly 0.25 (where the cycle periodicity is roughly 25 quarters, or about six years).

For all underlying VAR systems a uniform lag length of three was chosen, which in most cases was the recommendation by standard information criteria.

In figures 7 and 8 we report the detailed test results for all frequencies with inflation and money growth as target variables, respectively. It already appears here that inflation is G-caused at low frequencies only by the unemployment rate and borderline significantly by long-term interest rates. Money growth in turn is G-caused also by unemployment and the yield, and in addition by unit labor cost growth.

To assess whether a variable is non-causal we also have to look at the remaining possible plots with all other variables as targets. In order to summarize the information contained in all those plots we employ a straightforward suggestion by Eichler (2007) and represent the G-causal relations as a "directed graph". Such a graph consists of nodes and connecting lines or "edges", which can have arrowheads at either end (including none or both). The nodes

[5]Including real output growth does not change the results significantly but clutters the graphs.

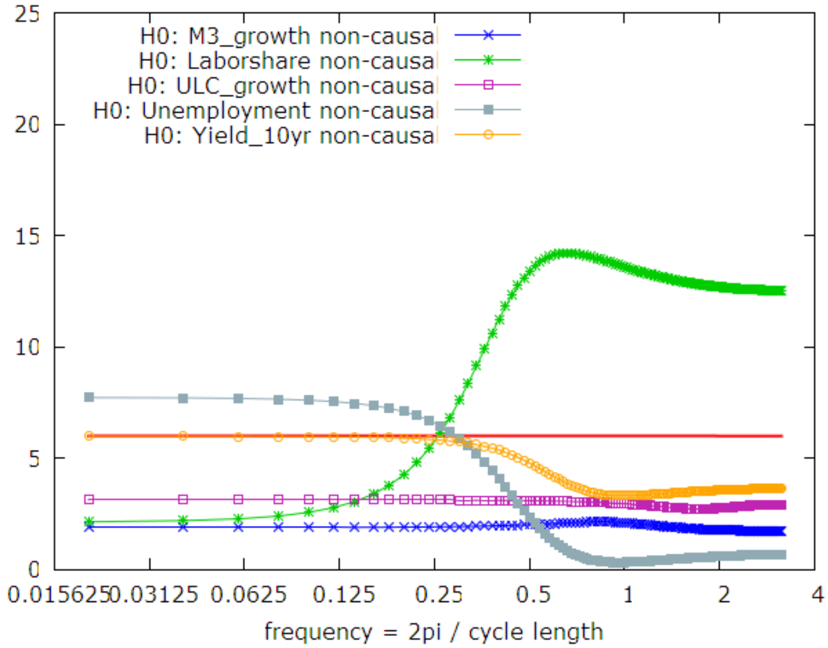

Figure 7: Detailed B&C test results, full variable set, target variable is the inflation rate. The critical value is represented by the horizontal line.

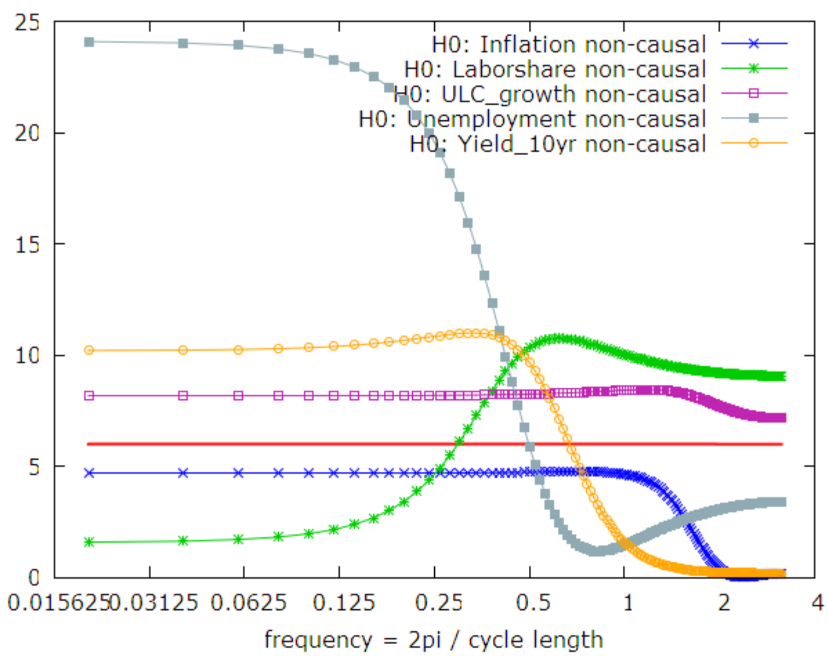

Figure 8: Detailed B&C test results, full variable set, target variable is money growth. The critical value is represented by the horizontal line.

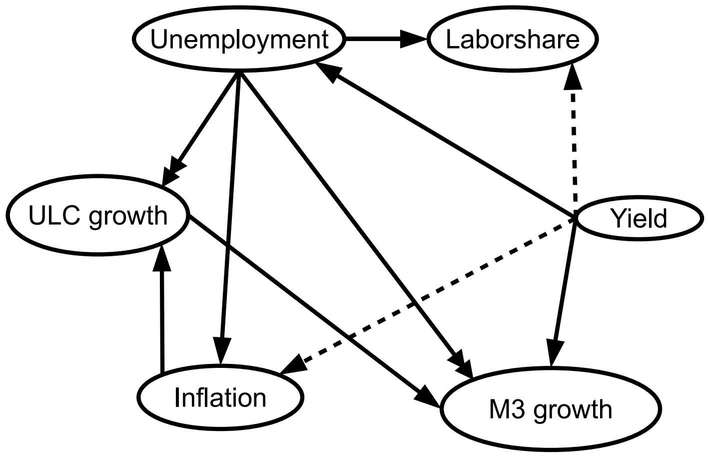

Figure 9: G-causality graph, full variable set. Drawn arrows indicate significant low-frequency Granger causality (G-causality). Double arrowheads indicate extremely significant test results, dashed lines denote borderline significant results.

are formed by the variables, and the edges indicate the G-causality direction conditional on the entire information set. Such a graph may contain some direct feedback G-causality or indirect circular G-causality paths.

In figure 9 we depict the implied G-causality graph with the full variable set, including but of course not limited to those results we already reported in figures 7 and 8. It is interesting that inflation G-causes labor cost growth and not vice versa, so the euro-area data confirm the usual results for US data mentioned in the introduction. Thus the close co-movement of unit labor cost growth and inflation cannot be empirically exploited to learn about longer-run inflation movements. Another interesting finding is that inflation does not directly nor indirectly G-cause unemployment, so we do not find a long-run Phillips-curve tradeoff in the sense that inflation would drive unemployment developments. The non-causal variables are obviously the labor share and money growth. We decided to retain the central variable money growth as long as possible and thus removed the labor share from the dataset first.

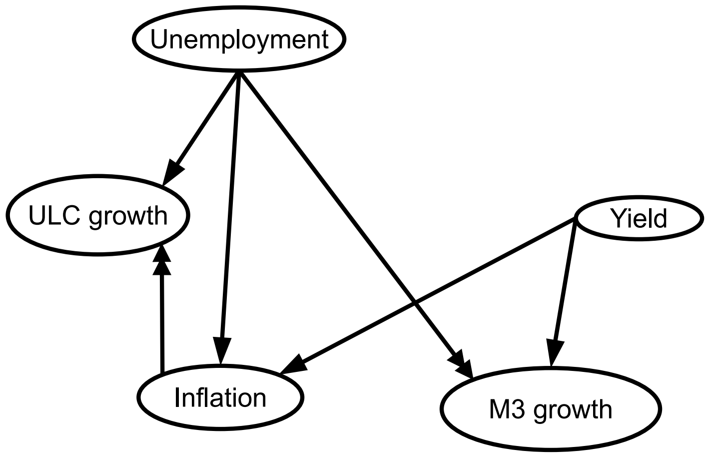

Figure 10: G-causality graph, 2nd iteration

The resulting second iteration of the G-causality graph (see figure 10) changes in so far as the yield (long-term interest rates) does not appear as G-causal for unemployment anymore, and unit labor cost growth does not G-cause money growth significantly anymore. Thus ULC growth becomes non-causal, and we remove it in order to retain once more the money growth variable in our information set.

Next, the third iteration in figure 11 does not present any surprises, the only change being that inflation now appears as borderline G-causal for money growth (at low frequencies, as always throughout this paper). This means that now money growth is the only remaining non-causal variable in this four-variable information set and we are forced to remove it according to our strategy.

Finally we are left with the three variables inflation, unemployment, and long-term interest rates, and the resulting directed graph displayed in figure 12 is very simple. Both unemployment and long-term interest rates determine inflation at low frequencies in the sense of being G-causal. Other G-causality connections between these variables do not exist.

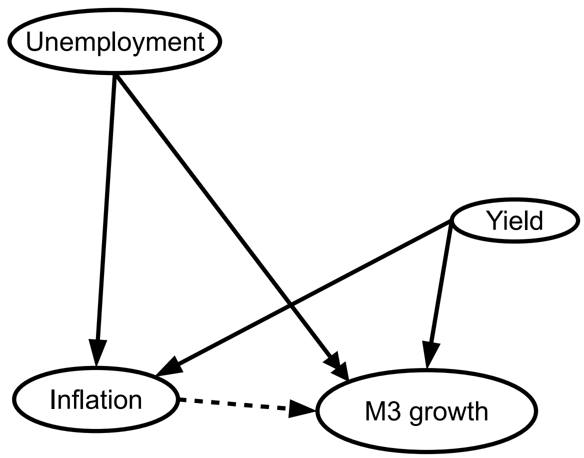

Figure 11: G-causality graph, 3rd iteration

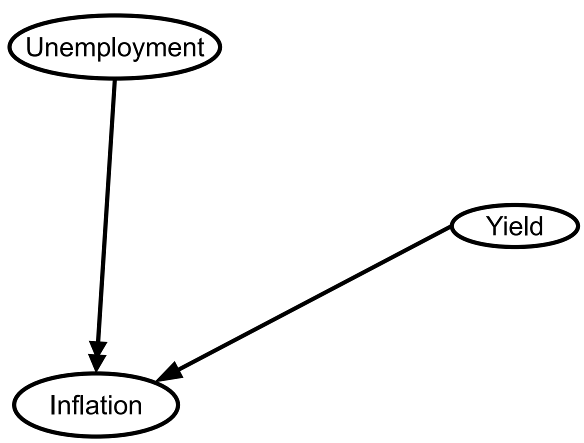

Figure 12: G-causality graph, final

4 Error-correction model estimates

The previous section presented test results concerning the existence of low-frequency G-causality relationships, but remained silent on the quantitative dimension. In this section we provide a quantitative model of the long-run determinants of inflation. We employ the standard tool of an vector error-correction model (VECM, i.e. a suitable representation of a cointegrated VAR). Strictly speaking this choice means that we are not analyzing the frequency band from 0 to 0.25 anymore but that we are concentrating on the zero frequency itself. So far we merely assumed that the variables were "persistent" in the relatively vague sense that a large fraction of the spectral mass was concentrated at lower frequencies. Now, when we model a cointegrated system, we are indeed assuming that the included variables are I(1), i.e. have a spectral peak (singularity) at the zero frequency. While these assumptions are theoretically very different, in empirical practice the distinction between I(1) proper and "only" persistent is usually blurred. We argue that euro area inflation and the other included variables are close enough to being I(1) to warrant the application of the VECM model framework,[6] and especially that this approach yields a useful practical model.

4.1 The bivariate system of money growth and inflation

In section 3.3 we showed that in a bivariate setup the results of AW&G appear, namely that money growth seems to be long-run G-causal for inflation. Now we investigate the characteristics of the corresponding bivariate VECM.

Not surprisingly, the Johansen cointegration test indeed finds cointegration between inflation and money growth, see the upper panel of table 1. Furthermore, the lower panel reports that it is statistically acceptable to restrict the corresponding cointegration vector to a 1:1 re-

[6]We can back up this claim by formal unit root tests, but reporting the results yields almost no value added over what is known in the literature, namely that results are often borderline when applied to inflation series of many (advanced) countries.

Table 1: Bivariate cointegration analysis

rank	eigenvalue	trace stat.	l-max stat.
0	0.114	20.165 [0.050]	17.69 [0.023]
1	0.0168	2.475 [0.686]	2.475 [0.685]

Notes: Johansen cointegration rank test; p-values in brackets; lag order = 5; sample 1972:2 - 2008:3 (T=146), restricted constant

	Inflation	M3 growth	constant
ECT	1	-1	3.893 (0.463)
loadings	-0.274 (0.066)	0	-

Notes: VECM estimates; standard errors in parentheses; test of the two restrictions Chi2(2) = 0.203 (p = 0.903)

lationship. The super-consistent coefficients of this irreducible cointegration vector enjoy the property that they are asymptotically invariant to extensions of the information set.

Mirroring the results of the bivariate B&C tests in section 3.3, the adjustment coefficients (loadings) also appear to support the hypothesis that inflation adjusts to long-run deviations while money growth is not caused by it. But note that the loading coefficients may be misleading if the system is misspecified, because they are attached to stationary terms and thus the standard omitted-variables bias applies.

4.2 Preferred estimates

Applying the Johansen cointegration test to the three-variable system distilled in section 3.4 (inflation, unemployment, long-term interest rates) also indicates one cointegration relation at the 5% and 1% significance levels, see the upper panel of table 2.

The estimate of that equilibrium long-run relation is shown in the lower panel of table 2. The point estimates ($\pi = 6.1 - 0.7\,urate + 0.5\,yield$) imply that unemployment is negatively related to inflation such that for example high unemployment would tend to dampen inflation

Table 2: Cointegration analysis and VECM estimation results

rank	eigenvalue	trace stat.	l-max stat.
0	0.21470	55.697 [0.0001]	36.496 [0.0001]
1	0.088179	19.201 [0.0684]	13.939 [0.0996]
2	0.034245	5.2616 [0.2653]	5.2616 [0.2648]

Notes: Johansen cointegration rank test; p-values in brackets, restricted constant, lag order = 3, sample: 1971:1 - 2008:3 (T = 151),

	Inflation	Unempl.	Yield_10yr	cnst
ECT	1	0.70 (0.07)	-0.51 (0.08)	-6.06 (0.86)
loadings	-0.65 (0.11)	0	0	-

Notes: VECM estimates; standard errors in parentheses; restriction test: Chi2(2) = 2.74 (p = 0.255); VECM contains restricted constant, levels lag order 3, sample: 1971:1 - 2008:3 (T = 151).

in the long run, which is a plausible result. For long-term interest rates we find a positive coefficient, in line with the Fisher effect motivation. However, the strict Fisher interpretation fails, as the coefficient is significantly different from unity.

The equilibrium deviations (error correction term, see also figure 13) enter in the inflation equation, which confirms that we indeed are explaining the long-run developments of inflation. In contrast, the error-correction terms do not enter the unemployment and interest-rate equations significantly; the corresponding exclusion restrictions can be tested with a standard χ^2 test and are not rejected (p=0.255). This means that unemployment and long-term interest rates are “weakly exogenous” and thus not caused by other variables in the long run (at the zero frequency), which completely confirms the low-frequency G-causality (B&C) test results.[7]

[7] Furthermore it turns out that long-term interest rates are actually strongly exogenous in this three-variable system, meaning that in addition to the long-run exogeneity the short-run dynamics are not affected either, neither by inflation nor by unemployment. (The F-test for these joint restrictions produces: F[4, 145] = 1.14, p-value = 0.339.)

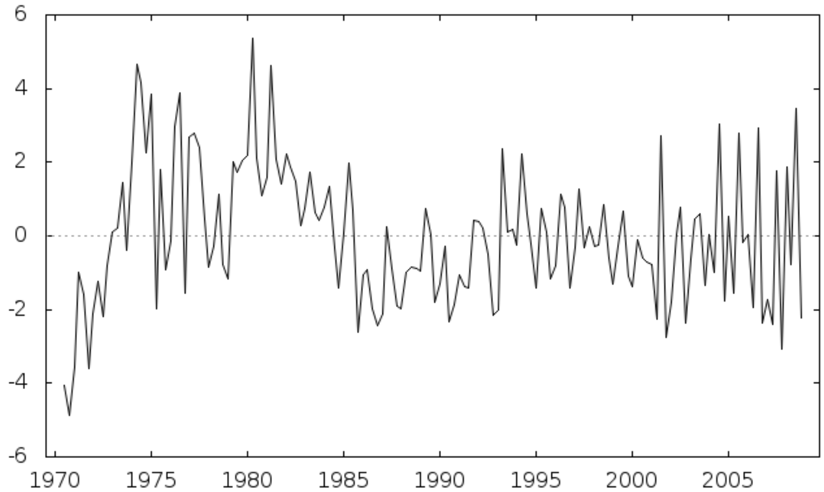

Figure 13: Plot of the error-correction term $ect_t = inflation_t + 0.701\, unemployment_t - 0.511\, yield_t$

5 Conclusions

The main result of this paper is that we find clearcut evidence for unemployment and long-term interest rates as predictors of low-frequency movements of inflation in the euro area. It is intuitively plausible that unemployment as the main indicator of labor market tightness affects inflation (for example, rising unemployment tends to dampen inflation in the long run).[8] Equally plausible is the positive long-run effect of long-term interest rates on inflation, because they signal movements of long-run inflation expectations which later materialize in observed inflation rates.

We can confirm that there is a bivariate equi-proportional (1:1) long-run relation between money (M3) growth and inflation in the euro area. In a reduced bivariate dataset we could also replicate the result by Assenmacher-Wesche and Gerlach (2007, 2008a) that the Granger causality at low frequencies appears to run from money to inflation. However, our results show that this apparent causality vanishes after accounting for the mentioned relevant vari-

[8] Schreiber and Wolters (2007) found a similar relationship between unemployment and inflation in German data.

ables. The findings of this paper therefore do not support a prominent role for money even in the longer run, contrary to what is often claimed by the ECB. According to our results, for longer-term inflation assessments the ECB as well as the general public should instead focus on the unemployment rate and long-term interest rates.

With respect to interest rates one might argue that they are themselves being determined by the central bank, so they could carry no additional information for monetary policy makers and just reflect their own policy reaction to their own inflation forecast. And indeed, if the central bank's long-term inflation forecast is not completely off track, such a reaction-function mechanism would produce predictive Granger causality from interest rates to realized inflation at low frequencies. Nevertheless, the central bank only controls the short-term policy rates and the link from short-term to long-term rates (i.e., the yield curve) is not constant. Therefore long-term rates may well contain additional information. In any case, only the policy makers themselves know for sure to what extent changes in their policy rate are reactions to changed long-run inflation expectations. They are free to discard the information contained in long-term rates. But for private agents the signals emitted by movements of long-term interest rates are clearly valuable to assess the long-run inflation outlook.

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Publisher: Hans-Böckler-Stiftung, Hans-Böckler-Str. 39, 40476 Düsseldorf, Germany
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ISSN: 1861-2199

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