DISCUSSION PAPER SERIES

No. 5868

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INTERNATIONAL MACROECONOMICS

Centre for Economic Policy Research

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Available online at: **www.cepr.org/pubs/dps/DP5868.asp**

ISSN 0265-8003

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Discussion Paper No. 5868
October 2006

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CEPR Discussion Paper No. 5868

October 2006

ABSTRACT

Money at Low Frequencies*

Many central banks have abandoned monetary targeting because the link between money growth and inflation seemed to disappear in the 1980s. Using spectral regression techniques, we show that for the euro area, Japan, the UK and the US there is a unit relationship between money growth and inflation at low frequencies when the impact of interest rate changes on money demand is accounted for. We estimate Phillips-curve equations in which the low-frequency information from money growth is combined with high-frequency information from the output gap to explain movements in inflation.

JEL Classification: C22 and E3
Keywords: frequency domain, Phillips curve, quantity theory and spectral regression

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* This paper was prepared for the invited session on "Money in Monetary Policy" at the EEA 2006 Annual Congress, Vienna, August 24 – 28, 2006. We are grateful to Jörg Breitung for providing us with the program for the frequency-wise causality test and to Günter Beck, Martin Brown, Petra Gerlach-Kristen, Matthias Lutz, Volker Wieland and Pinar Yesin for comments. The views expressed are solely our own and are not necessarily shared by the SNB or the BIS.

Submitted 05 September 2006

1. Introduction

Reflecting the practice of gearing monetary policy directly to the ultimate goal of price stability, central banks in industrialised economies have abandoned monetary targeting. Despite this, most continue to attach some weight, large or small, to the information contained in monetary aggregates in assessing the economic conditions and in setting interest rates. This raises the issue of how central banks can combine monetary data with measures of the cyclical state of the economy and cost-push shocks in analysing and forecasting inflation.

In considering this question, it should be recalled that the quantity theory implies that a change in the growth rate of money leads to an equally large change in the rate of inflation. However, since the transmission mechanism from changes in money to prices entails long and variable lags, this effect is only apparent after the effects of other shocks have disappeared. Much of the empirical literature testing for the presence of a proportional relationship between money growth and inflation has therefore focused on either filtered data (e.g. Lucas 1980, Fitzgerald 1999) or on long samples (e.g., Haug and Dewald 2004, Benati 2005), and typically finds such a link. In short samples, by contrast, the presence of such a link is often rejected, except, of course, in periods of hyperinflation (De Grauwe and Polan 2005).

The fact that money growth and inflation are closely tied only in the long run or, more technically, at low frequencies suggests that other factors determine inflation in the short run or at higher frequencies.[1] Assenmacher-Wesche and Gerlach (2006a,b) hypothesise that money growth plays a causal role for inflation at low frequencies and the output gap a causal role for inflation at higher frequencies. They argue this is a natural way to formalise the ECB's (and the SNB's) view that inflation is determined by money growth in the long run and use spectral regressions and tests for causality across frequency bands to demonstrate that it is compatible with euro-area and Swiss data. Furthermore, Assenmacher-Wesche and Gerlach (2006c) show that import price shocks, which capture the influence of exchange rate changes and oil price shocks, explain a large part of movements in euro area inflation at even higher frequencies.

In this paper we explore whether the determinants of inflation vary across frequency bands also in Japan, the UK and the US. These are all large economies in which the central banks

[1] The European Central Bank (ECB) and the Swiss National Bank (SNB), both of which continue to attach considerable weight to inflation in setting interest rates, appear to hold this view. See ECB (2003) and Jordan, Peytrignet and Rich (2001).

appear to attach little, if any, weight to monetary aggregates in setting interest rates, presumably because money growth is not seen as containing information useful for forecasting inflation. For comparison purposes we present results also for the euro area.

Before proceeding we highlight that we do not discuss whether our results are compatible with the New Keynesian Phillips Curve (NKPC), which has become the predominant model of inflation and which asserts that inflation depends on expected future inflation and real marginal cost. Empirical applications use GMM to model expected inflation and unit labour cost as a proxy for real marginal cost.[2] In our setup, low frequency money growth is implicitly viewed as capturing expected inflation and the output gap as capturing the cyclical changes in marginal cost. A more thorough investigation of this interpretation, however, is left for future research.

To preview the main results, we confirm that low-frequency money growth is useful for predicting inflation also in Japan, the UK and the US in the long run.[3] It is sometimes asserted that, even if this were true, it would be sufficient for central banks to rely on the variables that impact on inflation in the short run in setting interest rates since “the long run consists of a number of short runs.” While seemingly persuasive, once one thinks of the long run as a statement regarding the determination of inflation at low frequencies it is clear that this argument is incorrect. Thus, the determinants of inflation, irrespectively of what frequency bands they are relevant for, act on inflation at all points in time. Disregarding the low frequency determinants therefore renders the link between the high frequency determinants and inflation unstable. Of course, since the low frequency components evolve slowly over time, this instability may be difficult to detect but it nevertheless remains present.

The paper is organised as follows: Section 2 reviews the data, Section 3 discusses the results and Section 4 concludes.

2. Data

The data start in 1970Q1 and end in 2005Q4. Since the ECB attaches particular weight to M3, we use this definition of money for the euro area. For the other countries we also use a broad monetary aggregate, in particular M2 plus Certificates of Deposit (CD) for Japan, M4 for the

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2 Galí, Gertler and López-Salido (2005) discuss issues related to the estimation of NKPCs.

3 These economies have historically experienced little inflation (in “zones 2 and 3” in the terminology of Bordo and Filardo (2007). Thus, our results suggest that money growth may be useful as an indicator even at low rates of inflation.

UK and M2 for the US. We use the three-month interest rate to capture the opportunity cost of holding money, but recognise that since broad monetary aggregates bear interest, the choice of the opportunity cost variable is contentious. Inflation is measured by the quarterly change in the consumer price index and the output gap is calculated as the logarithmic difference between real gross domestic product and a trend, which is defined to contain only fluctuations with a periodicity of more than 48 quarters (see Assenmacher-Wesche and Gerlach 2006a).

Figure 1 plots the low-frequency part of quarterly inflation and money growth. We define low (high) frequency as cycles with a periodicity of more (less) than 5.6 years since Assenmacher-Wesche and Gerlach (2006a) found that this distinction seems to fit the euro area data best.[4] While Figure 1 shows little relation between money growth and inflation in the UK and the US, in Japan and the euro area money growth and inflation share the same trend. Moreover, money growth seems to lead inflation.

Discrepancies between money growth and inflation must be due to either changes in the growth rate of output or changes in velocity. Figure 2 shows that at low frequencies changes in velocity and interest rates are closely related in all countries. This suggests that the link between money growth and inflation would be clearer if we controlled for the effect of interest rate changes on velocity.

There are two sources of shifts in velocity. First, shifts can be due to portfolio reallocations induced by changes in interest rates. Reynard (2006) argues that the fall in the steady-state level of inflation in the US from the late 1970s to the early 1980s led to a substantial increase in the demand for money and in the level of money holdings, which masked the relationship between money growth and inflation. Second, shifts in velocity can occur because of financial innovation. Of course, shifts in velocity for either of these two reasons will affect the quantity of money but not inflation.

To control for shifts in velocity due to changes in interest rates, we first estimate the long-run interest elasticity of money demand, α_r, by regressing real money, $m–p$, on real output, y, and the three-month interest rate, r:[5]

(1) $$m_t - p_t = \alpha_c + \alpha_y y_t + \alpha_r r_t + \varepsilon_t^m .$$

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[4] While this distinction is arbitrary, Assenmacher-Wesche and Gerlach (2006a,c) find that the results for the euro area and for Switzerland are robust to variations in the cut-off point between two and eight years. The estimates below are also robust to variations in the definition of the low and high-frequency bands.

[5] We use DOLS (Stock and Watson 1993) to estimate the coefficients and the standard errors.

We then adjust the low-frequency money growth rate, μ^{LF}, for changes in low-frequency interest rates, ρ^{LF},

(2) $$\tilde{\mu}_t^{LF} = \mu_t^{LF} - \hat{\alpha}_r \rho_t^{LF},$$

and use $\tilde{\mu}^{LF}$ as a regressor in the inflation equations we estimate below.[6] Of course, this procedure does not control for changes in velocity arising from financial innovation, so that the issue whether money growth is informative for inflation remains.

3. Results

Table 1 shows the results from a band spectrum regression of the low frequency part of inflation on low-frequency adjusted money growth and low-frequency output growth.[7] We note that the hypothesis that money growth impacts with a unit coefficient on inflation is marginally rejected only for the US, suggesting that financial innovation has had a large impact on velocity in this economy. By contrast, the coefficient on output growth is insignificantly different from minus unity in all countries, though standard errors are large. Unreported F-tests strongly reject the hypothesis that coefficients are identical for the low and the high-frequency bands.[8]

The last row of Table 1 shows the point estimates for the interest elasticity of money demand which we use to calculate the adjusted money growth rates. It is negative for all countries, but is significant only in the cases of the euro area and the US.

Next we estimate reduced-form “two-pillar Phillips curve” models (Gerlach 2004) in which we regress headline inflation, π, on the low-frequency component of adjusted money growth, $\tilde{\mu}^{LF}$, low-frequency output growth, γ^{LF}, and the high-frequency part of the output gap, g^{HF}.

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[6] Another strategy would be to include an interest rate in the inflation equation but the resulting endogeneity of interest rates (which can arise because inflation impacts on long interest rates or because short-term rates are set in response to inflation) would complicate estimation. Our approach only requires us to assume, as is common in the large literature on estimating money demand, that interest rates are predetermined relative to the real money stock. It does however introduce generated regressors bias (see Pagan 1984).

[7] Engle (1974) demonstrated that a regression model in the time domain can be transferred into the frequency domain by taking Fourier transforms of the data and estimating it on the transformed variables. If all frequencies are included, the results are identical to those obtained if the model is estimated in the time domain. If some frequencies are excluded, one can test whether the model varies across frequencies. Heuristically, one can think of Engle's method as filtering the data and regressing the components corresponding to certain frequencies on each other. Since filtering involves a loss in degrees of freedom, we adjust the standard errors accordingly.

[8] The finding that money growth and inflation are closely tied at low frequencies is compatible with the model of “cross-checking” proposed by Beck and Wieland (2007).

Table 2 shows the results. In contrast to the regression in Table 1 the dependent variable in this case is not filtered. To account for the dynamics, we include four lags of the inflation rate:

(3) $$\pi_t = \beta_\mu \tilde{\mu}_t^{LF} + \beta_\gamma \gamma_t^{LF} + \beta_g g_{t-1}^{HF} + \sum_{i=1}^{4} \beta_i \pi_{t-i} + \varepsilon_t$$

Note first that except for the UK low-frequency output growth all variables enter with significant coefficients. Since the quantity theory suggests that the long run coefficient of money should be unity, we expect that the sum of the parameter on $\tilde{\mu}^{LF}$ and the lagged inflation terms to be unity. Perhaps surprisingly, this restriction is not rejected in any country. Furthermore, the point estimates of the long-run impact of γ^{LF} are close to -1, that is, that the long-run income elasticity of money demand is unity.[9] The bottom panel of Table 2 gives the p-values for F-tests of various hypotheses. The first row shows that the joint hypothesis that the long-run coefficients on money growth and output growth are unity and minus unity respectively is not rejected. In the second row the hypothesis that the high-frequency part of money growth and output growth and the low-frequency part of the output gap help explain inflation is tested and rejected, except for the UK. A closer inspection of the regression results indicates that the current value of high-frequency output growth contains information that is not included in the lagged output gap, perhaps because of the difference in timing. In the last row we therefore test whether the high-frequency money growth and the low-frequency output gap are jointly significant and do not reject this hypothesis.

Of course, the unit long-run relationship could merely reflect a money demand relationship. To better understand whether money growth (Granger) causes, or is caused by, inflation, Figure 3 shows the test statistics for a frequency-wise measure of causality (see Granger and Lin 1995, Breitung and Candelon 2006), along with the 5% critical value. The horizontal axis measures the frequencies as fractions of π.[10] The causality tests are conducted in a VAR comprising adjusted money growth, inflation and the output gap. With the exception of the UK, the graphs show that at low frequencies causality runs unidirectionally from money growth to inflation, and that there is little evidence of causality from inflation to money growth.

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9 In contrast to the studies for the euro area, which typically find an income elasticity greater than unity, our inflation equation implicitly allows for a trend in levels by including a constant.

10 In interpreting the figure recall that the frequency π corresponds to the smallest cycle distinguishable with quarterly data, that is, 2 quarters. The frequency of 0.10π corresponds to $2/0.10 = 20$ quarters. Similarly, $0.25\pi = 8$ quarters and $0.50\pi = 4$ quarters.

4. Conclusion

The results discussed above demonstrate that low frequency money growth plays a more important role than perhaps commonly understood in the inflation process in all four economies studied. They also suggest that it may be useful to augment standard reduced-form Phillips curve models of inflation with low-frequency measures of money and output growth. Finally, they show how the information in monetary variables can be combined with that of other variables when analysing inflation. We highlight that since the different frequency bands are orthogonal by construction, the information in low frequency variables adds to that in higher frequency variables.

As noted in the introduction, it is an important objective for future research to establish how these results can be interpreted in light of the literature on NKPCs. Conversely, it is desirable to see how NKPCs can account for relationships across frequency bands between money, output and inflation established here.

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Tables and Figures

Table 1. Band spectrum regression

The dependent variable is the low frequency component of inflation.

	Euro area	*Japan*	*UK*	*US*
LF adjusted money growth	0.79**	0.97**	0.61**	0.64**
	(0.13)	(0.20)	(0.20)	(0.16)
LF output growth	-1.10**	-1.79**	-1.67**	-1.12**
	(0.43)	(0.68)	(0.69)	(0.36)
$\bar{R}^2$	0.75	0.62	0.54	0.64
Interest rate elasticity of money demand	-2.02**	-0.84	-0.28	-5.24**
	(0.40)	(1.36)	(3.04)	(0.99)

Note: The sample period is 1970Q2 to 2005Q4. Newey-West robust standard errors with 4 lags are reported in parenthesis. The constant is not shown. ** denotes significance at the 1% level. The last row gives the coefficient α_r in equation (1) from a separate regression estimated by DOLS (Stock and Watson 1993) with two leads and lags of the regressors and an AR(2) correction for the error process. This value is used to calculate the adjusted money growth rate in equation (2).

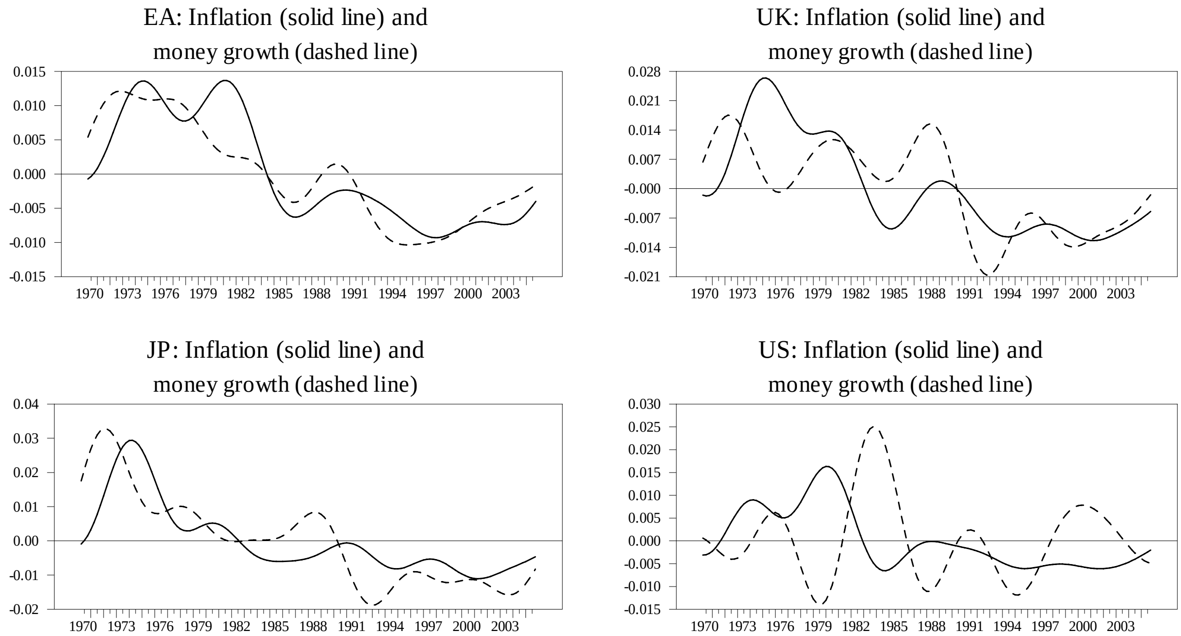
Table 2. Two-pillar Phillips curve

The dependent variable is headline inflation.

	Euro area	*Japan*	*UK*	*US*
LF adjusted money growth	0.30**	0.39**	0.19*	0.24**
	(0.06)	(0.11)	(0.08)	(0.06)
LF output growth	-0.29*	-0.63*	-0.26	-0.29*
	(0.14)	(0.21)	(0.29)	(0.14)
HF output gap (*t*-1)	0.12**	0.35**	0.29**	0.08**
	(0.04)	(0.06)	(0.07)	(0.03)
Sum of AR coefficients, $\Sigma\beta_i$	0.69**	0.67**	0.80**	0.71**
	(0.06)	(0.08)	(0.09)	(0.07)
$\bar{R}^2$	0.84	0.67	0.61	0.76
Unit coeff. on money and income growth	0.96	0.54	0.97	0.64
Significance of orthogonal variables	0.05	0.00	0.34	0.01
Significance of HF money growth and LF output gap	0.36	0.16	0.24	0.31

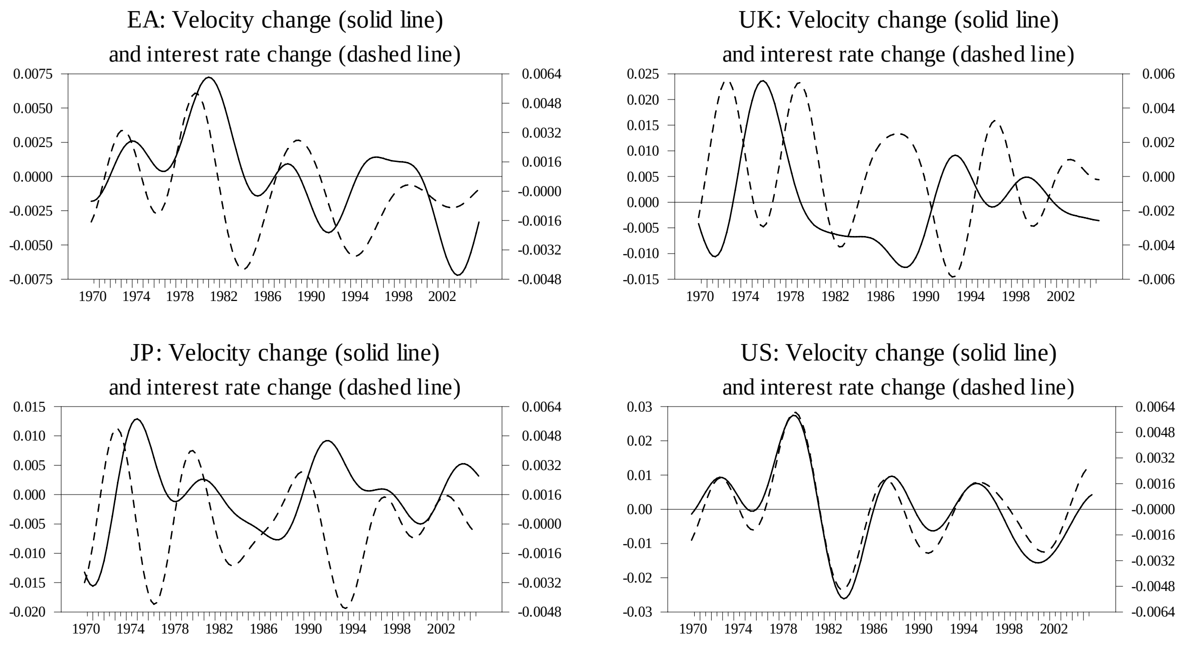
Note: The sample period is 1971Q1 to 2005Q4. Four lags of the dependent variable are included. The constant is not shown. * denotes significance at the 5% level, ** significance at the 1% level. The last rows show the p-values for the F tests of the hypotheses shown in the first column.

Figure 1. Inflation and money growth



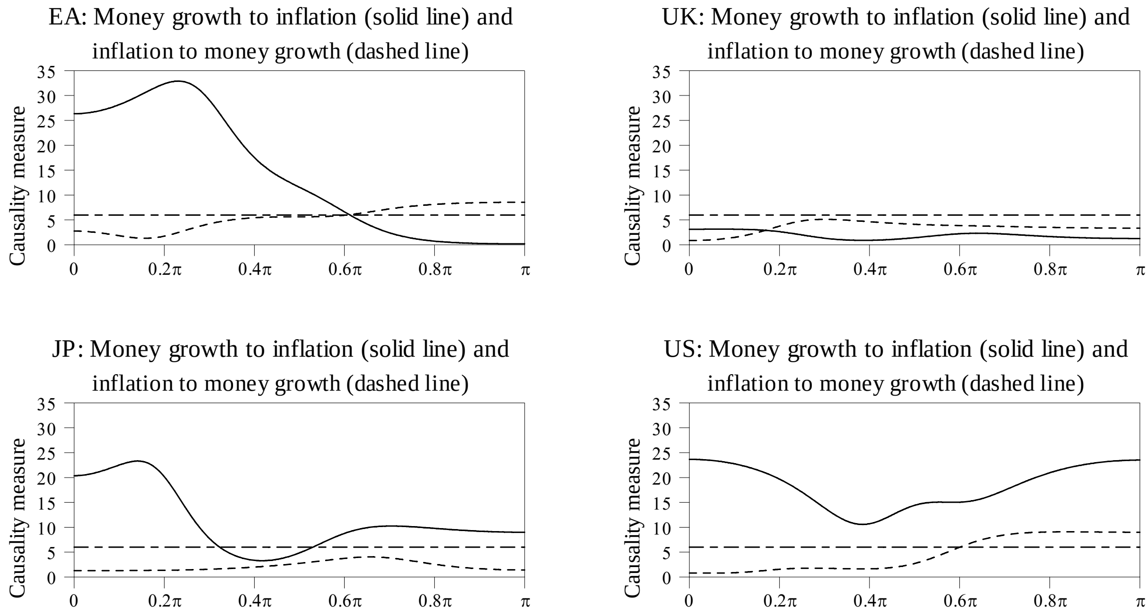
Note: The figure shows the low frequency components of inflation and money growth, which are defined as cycles with a periodicity with less than 5.6 years.

Figure 2. Changes in interest rates and velocity



Note: The figure shows the low frequency components of the change in the interest rate and the change in velocity, defined as cycles with a periodicity with less than 5.6 years.

Figure 3. Frequency-wise measure of causality



Note: The causality measure is derived from a three-variable VAR with four lags including money growth, inflation and the output gap. The horizontal line is the 5% critical value.