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Andersson, Fredrik N G

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LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00

Long Run Inflation Indicators
– Why the ECB got it Right

Fredrik NG Andersson*
Department of Economics, Lund University

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Abstract

This paper studies the issue of whether money contains useful information about future inflation in a panel of nine developed countries. A low frequency estimate of excess money growth is compared to an estimate of the inflation trend following the discussion in Woodford (2007). The empirical analysis shows that money contains more information about future CPI-inflation than an estimate of the inflation trend, and that the output gap has some influence over the medium run movements of inflation, but the effect varies over time. The result is the same for small countries as it is for large countries. Money thus contains information about future headline inflation that the inflation trend does not.

JEL Classification: E31, E32, E41, C19
Keywords: Inflation, Money, Inflation Indicators, wavelet analysis

1. Introduction

As monetary policy is implemented over the medium to long term, monetary policy decisions are based on indicators of future headline inflation (CPI-inflation). This paper applies a bandspectrum regression to study the inflation process from a short, medium, and long run perspective (following King and Watson 1996 and Estrella Mishkin 1997). The empirical analysis is applied to data from nine countries, Australia, Canada, Denmark, the Eurozone, New Zeeland, Norway, Sweden, the United Kingdom and the United States for the period

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* Corresponding Author: Department of Economics, Lund University, Box 7082, 220 07 Lund, Sweden
Email: ngf.andersson@nek.lu.se
Telephone: +46 (0)46 222 4290

1971Q2 to 2003Q1, and shows that money and inflation are correlated in the long run, and that this relationship is table over time. Furthermore, there is approximately a two year lag between increases in the money supply and inflation, which implies that money growth contains useful long run information about future headline inflation.

Bernanke and Woodford (1997) showed that the public's inflation expectations cannot be used as a long run inflation indicator in a successful inflation targeting environment. If the central bank fulfils its inflation target for a certain period of time, there is no incentive for the public to gather the necessary information to develop their own inflation forecasts. Instead, they come to rely on the central bank's inflation target as their forecast. Bernanke and Woodford suggest using a structural model and gathering information from many sources to forecast future inflation.

During periods of stability, it is possible to study the risks for inflation by using variables such as interest rates, the output gap etc, as suggested by Bernanke and Woodford (1997), Woodford (2007), Rudebush and Svensson (2002) and Svensson (2003), however, during periods of regime shifts such as those brought about by institutional or policy changes, key relationships in the economy are likely to change (see Lucas 1976). For example, most macroeconomic models include the natural rate of interest (see for example Wicksell 1898 and Woodford 2003), which Wicksell (1898) argued was likely to change over time. Laubach and Williams (2003) find, in an empirical analysis of the United States that the natural interest rate has changed at least four times during the last 40 years, and a similar result is found for the Eurozone by Curesma *et. al.* (2005), and Mésonnier and Renne (2007). If these changes are not recognized, which is likely to be the case initially, monetary policy can cause great disturbances in the economy (for further discussion see for example Friedman 1968, Orphanides and Williams 2002 and Issing 2005).

Friedman (1963) argues that "inflation is always and everywhere a monetary phenomenon". This statement can be interpreted in two different ways; one possible interpretation is that inflation is caused by an increase in the money stock, another possible interpretation is that an increase in the price level (for some reason) leads to an increase in the demand for money, and that these changes occur simultaneously. According to both interpretations, the price level cannot increase permanently without an increase in the money stock. Money growth and inflation are thus correlated, but money is not necessarily an exogenous variable (Svensson 2007).

Nelson (2003) views money growth as an estimate of demand in the economy; which can be related to Wicksell's (1898) discussion on the natural rate of interest. When the market rate of interest is below the natural rate of interest, demand for money (or credit) increases and vice versa, which implies that money is an indicator of demand in the economy, which in turn causes inflation. In this sense, money could be interpreted as a proxy for the difference between the market rate of interest and the natural rate of interest, and since the natural rate of interest is not directly observable, money may be quite informative.

The European Central Bank (ECB) decomposes its monetary policy strategy into two pillars; analysis of the real economy and monetary analysis (ECB 2004). ECB (2003) interprets the first pillar as short to medium run threats to price stability while the second pillar is an analysis of the long run. Issing (2003) argues for the same interpretation of the monetary strategy as the ECB, and calls the second pillar the "ultimate monetary determinants of inflation". Issing moreover argues that there is no easy way to combine the first and the second pillars into a uniform economic model, and the separation of the economy into time horizons (and the monetary policy strategy into pillars) is motivated by this difficulty. Gerlach (2003) therefore calls the ECB's monetary policy strategy the two pillar Phillips curve, where the first pillar is represented by the output gap in the Phillips curve, and the second pillar represents the long run inflation trend.

ECB's argument that money is a long run inflation indicator is supported empirically by, for example, Estrella and Mishkin (1997), Gerlach (2003), Assenmascher-Wesche and Gerlach (2006 a, b, c) and Neuman and Greiber (2004), who study the inflation process for individual countries (United States, Eurozone and Switzerland) using spectral methods[1]. They find that there is a long run relationship between money and inflation, but no short run relationship for the Eurozone and Switzerland. Estrella and Mishkin (1997) also find support of a long run relationship between money and inflation for the United States, but the support is weaker than the results found for the other countries. The lack of a short run relationship can be explained by money being used not just as a medium of exchange, but also for what Friedman (1970) calls speculative money. Temporary fluctuations in money demand are thus not necessarily associated with movements in the real economy.

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[1] Other studies which do not use spectral methods include; Hallman *et.al.* (1991) who studies money and inflation using the P*-model on data from the United States, Gerlach and Svensson (2003) who use the same model on data from the Eurozone, De Gauwe and Polan (2001) who studies the relationship between money and inflation in a panel of countries, and King (2002) who studies the correlation between money and inflation over different horizons. They all find that there is a long run correlation between money and inflation, but De Gauwe and Polan only find a stable relationship for high inflation countries.

Woodford (2007) criticizes the two pillars Phillips curve as being inconsistent with economic theory. Money demand and prices are influenced by the same variables and therefore indirectly related, but all the information that can be found in the monetary aggregates is just a proxy for other variables. The second pillar is thus unnecessary because the first pillar contains all the relevant variables that can cause inflation. Woodford also claims that an estimate of the inflation trend is more informative about future headline inflation than long run money growth.

In this paper we study the question of whether money contains useful information about future headline inflation or if Woodford (2007) is correct, and an estimate of the inflation trend is more informative. The study is carried out in two steps. First, a bandspectrum regression (see Engle 1974) is carried out to study the inflation process from a time horizon perspective. Second, a correlation study between present long run money growth and future headline inflation is conducted, and compared to the correlations obtained where money is replaced by an estimate of the inflation trend. Unlike Gerlach (2003), Assenmacher-Wesche and Gerlach (2006a, b, c) and Neuman and Greiber (2004), the bandspectrum regression is applied to panel data model with nine developed countries that are pooled together. In a small sample of 20-30 years of data there are only 4-5 long run observations available per individual[2], but by pooling countries we can increase the number of long run observations, and obtain better parameter estimates. The countries included in this study are Australia, Canada, Denmark, the Eurozone, New Zeeland, Norway, Sweden, the United Kingdom and the United States covering the period 1971Q2 to 2003Q1.

Another feature of this paper is that we use a discrete wavelet transform and not the orthonormal discrete Fourier transform which is commonly used in bandspectrum regressions. It has been suggested that the variability in some macroeconomic variables has declined over the last few years (see Blanchard and Simon 2001 and Bernanke 2004), which implies that the features of the time series' spectrum may have changed. It is therefore desirable to combine time and frequency resolution in the transform, since the transform may otherwise misrepresent the time series in the frequency domain. There are many different methods for doing this; one of which is the discrete wavelet transform (DWT) that directly combines both time and frequency resolution.

The result of our analysis shows that there is a one-to-one long-run relationship between money and inflation in all countries, and that this is stable over time. In the medium run

[2] The long run is defined as developments once the business cycle has been accounted for.

(fluctuations with a periodicity of 2-4 years) the link between money and inflation is weaker, and the output gap also has some influence on the inflation process. The influence of the output gap is not stable over time or countries, however. In total three different estimates of the output gap are considered; a Hodrick Prescott cycle, a gap estimated as the difference between observed logged real GDP and a linear trend, and an unemployment gap, but only the Hodrick Prescott cycle seems to have any statistically significant effect. In the short run (1 quarter to 2 years), none of the variables have any significant effect on inflation.

A correlation study is also carried out to analyze whether money contains more information about future headline inflation than an inflation trend. Two different estimates of the inflation trend are used; a Hodrick Prescott trend, and the trend from a DWT of headline inflation. The results show that money contains more information about future headline inflation, starting with a horizon of two years, than either of the two inflation trend estimates do. Money is thus a relevant variable for the central banker to monitor. In other words, the ECB was right to include monetary analysis in its monetary policy strategy.

2. Empirical Analysis

2.1 The Two Pillar Phillips Curve

The ECB's monetary policy strategy rests on two pillars - real economic analysis and monetary analysis. According to ECB (2003), these two pillars may be interpreted as representing different time horizons; the first pillar represents the short- to the medium-term and the second pillar the long-term. Gerlach (2003, 2004), Assenmacher-Wesche and Gerlach (2006 a, b) call the monetary policy strategy the two pillars Phillips curve. Headline inflation, π_t, can accordingly be decomposed into a short-run component, π_t^{SR}, and a long-run component, π_t^{LR}

$$\pi_t = \pi_t^{SR} + \pi_t^{LR}, \qquad (1)$$

$$\pi_t^{SR} = \beta_g g_{t-1} + \gamma_t, \qquad (2)$$

$$\pi_t^{LR} = \alpha_\mu \mu_t^{LR} - \alpha_y y_t^{LR} + \alpha_v v_t^{LR}, \qquad (3)$$

where g_{t-1} is the output gap that is lagged one period[3] and γ_t captures short run cost shocks, such as an oil price shock or a change in the exchange rate (Gerlach 2004). μ_t^{LR} is long run

[3] We lag the output gap one period following Assenmacher-Wesche and Gerlach (2006c).

money growth y_t^{LR} is long run GDP growth (trend growth) and v_t^{LR} captures long run changes in velocity[4] . Related to the ECB's policy strategy, the first pillar is represented by equation (2) and the second pillar by equation (3).

Engle (1974) proposed a bandspectrum regression to estimate models where different variables affect the dependent variable at different horizons as in (1). The bandspectrum regression is estimated in the frequency domain instead of in the time domain, since it is easier to identify the various horizons in the frequency domain than in the time domain. For example, the low frequency component represents the long run and the high frequencies represent the short run.

In this paper the bandspectrum regression is estimated in a panel data model where nine countries have been pooled together; Australia, Canada, Denmark, the Eurozone, New Zealand, Norway, Sweden, the United Kingdom and the United States. Previous studies of individual countries have shown that money growth has no effect on inflation during the first five to eight years. If cycles with a periodicity up to eight years are removed there are only four or five long run observations remaining in a sample of approximately 30 years of observations. By pooling countries the number of long run observations is increased, which improves the efficiency of the parameter estimates.[5]

Another feature of this study is that we use a discrete wavelet transform instead of the Fourier transform. It is common to use the orthonormal Fourier transforms (ODFT) in bandspectrum regressions, but any orthonormal transform with frequency resolution can be applied. This paper uses a discrete wavelet transform (DWT), because it combines both time and frequency resolutions. When the ODFT transforms the time series to the frequency domain, it loses all time resolution and the ODFT therefore cannot distinguish between recurring cycles and non-recurring events such as an outlier or a structural break. If the time series contain non-recurring events the ODFT will probably misrepresent the data in the frequency domain, but this misrepresentation may be avoided if the DWT is used instead.

It has been suggested in the macroeconomic literature that the variability in many macroeconomic variables has decreased since the mid-eighties (see Sock and Watson 2002 and Cogley and Sargent 2005). This implies that features of the spectrum may have hanged

[4] More specifically we have $\mu_t = \log(money_t) - \log(money_{t-1})$, $y_t = \log(\text{realGDP}_t) - \log(\text{realGDP}_{t-1})$, and $v_t = \log(\text{velocity}_t) - \log(\text{velocity}_{t-1})$.

[5] Each individual time series is transformed to the frequency domain individually, and they are only pooled when the bandspectrum regression is being used.

over time. Due to its combination of time and frequency resolution, the DWT can decompose the data to the frequency domain despite these changes. To be able to apply the ODFT, however, the exact point of these changes would have to be identified before the transformation. Each sub-sample, one representing the time series before and one after the decline in variability, would then be decomposed individually. Such an approach would be sensitive to the choice of break point in the data, and we therefore only use the DWT in this study. For more information about this method see for example Ramsey (2002), Percival and Walden (2006) and Crowley (2007).

The estimated inflation model is a fixed effects panel data model

$$\pi_{if} = \beta_{1f}\mu_{if} - \beta_{2f}y_{if} + \beta_{3f}g_{if} + \beta_{4f}\Delta oil_{if} + \varepsilon_{if}\ , \quad (4)$$

where *i* denotes the country, *t* is time and *f* is frequency, and where

$$\varepsilon_{it} = \lambda_i + \upsilon_{it}\ . \quad (5)$$

μ_{if} is quarterly changes in logged money growth, y_{if} is quarterly change in logged real GDP, Δoil_{if} is the quarterly change in logged real oil prices, and g_{if} is the output gap. υ_{it} is iid $(0, \sigma^2_{\upsilon i})$, and ε_{it} is iid $(\lambda_i, \sigma^2_{\upsilon i})$[6]. Changes in real logged oil prices, Δoil, was added to (4) as a proxy for cost shocks (γ_t in equation (2)) following Neumann and Greiber (2004). According to the theoretical model, (1)-(3), different variables affect inflation at different frequencies. Even if we expected variables such as the output gap to have no long run effect on inflation, all variables were included at all frequencies. By including all variables at all frequencies no restriction on the time horizons in the model were imposed before estimation.

Data for all countries was collected from Thomson's Financial Datastream on a quarterly basis for the period 1971Q2 to 2003Q1[7,8]. Money was defined as currency in circulation

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[6] The quantity equation is an identity and the residuals at the frequencies where money is a significant variable in the inflation model therefore captures, among other things, changes in velocity. Velocity can be a function of different variables, for example, interest rates or financial development (see Bordo and Jonung 1987). Assenmacher-Wesche and Gerlach (2006c) include interest rates in their model to model changes in velocity, but Neuman and Greiber (2004) do not. Since we cannot obtain interest data for all countries for the period 1971Q2-2003Q1, we follow Neuman and Greiber exclude it from the model.

[7] The DWT requires 2^J, where *J* is an integer, number of observations. This is caused by the introduction of time resolution in the transform. Since quarterly growth rates are applied, the first observation is 1971Q2. More observations could be added through data padding, however, it would not yield any more long run observations, and the analysis therefore ends in 2003Q1. For more information about the DWT.

[8] The data covers exactly the same period of time as in Gerlach (2004)

(M0), following the advice in Friedman and Schwarz (1970). The broader monetary aggregates are defined differently in different countries, which could affect our regression results, but by using M0 we avoid any such problems. M0 data is, however, unavailable for the Eurozone and M3 was therefore used instead since it is the ECB's preferred monetary aggregate (see ECB 2004)[9].

Three estimates of the output gap were considered; the cyclical component from a Hodrick Prescott filter, a gap estimated as the difference between observed logged real GDP and a linear trend, and an unemployment gap. The unemployment gap was defined as the high frequency component of the observed unemployment rate. Inflation was calculated as the quarterly change in the consumer price index (CPI), except for the United Kingdom (where the Retail Price Index was used) and for the Eurozone (where OECD's Main Economic Indicators' CPI index was used) since no official CPI exists until the late 1990s for either country. GDP growth was calculated as the quarterly change in logged real GDP, and changes in real logged oil prices were measured in the national currency.

Tables 1 and 2 show the fractional integration order for all time series, as estimated using the maximum likelihood estimator presented in Percival and Walden (2006). As can be seen in these tables, all time series are stationary, which implies that Engle's bandspectrum regression estimator can be used, without the risk of spurious results.

In total, the regressions were based on 128 quarterly observations, and the DWT[10,] decomposed the time series into six frequency bands reflecting fluctuations with a periodicity of respectively 2, 4, 8, 16, and 32 quarters and fluctuations with a periodicity of more than 32 quarters.

The lack of long run observations for each country means that we could not test the null hypothesis of poolability against the alternative that each country is different. However, it is possible to test against the alternative that groups of countries are different. We therefore estimated the inflation model for both the full panel, and for two sub-panels; large countries (Eurozone, the United Kingdom and the United States), and small countries (Australia, Canada, Denmark, New Zealand, Norway and Sweden). The sample was also split into two

[9] Using M3 for the Eurozone does not change our overall results. There are no statistically differences between the results when we include the Eurozone compared to the results we obtain when we exclude the Eurozone. We therefore present the results where the Eurozone is included.

[10] There are many different wavelet functions which the wavelet transform can be based on. We use the Daubechie (4) wavelet in this paper, but we also tested the Haar wavelet. There were however, only minor differences in the result compared to the Daubechie (4) wavelet.

time sub-samples to test whether there have been any changes in the inflation process over time. The first sub-sample represented the period (1971Q2 to 1987Q1), and the second sub-sample the period (1987Q2 to 2003Q1) [11].

2.2 Empirical Results

The regression results can be found in Tables 3-11. The results for the full panel are shown in Tables 3-5, Tables 6-8 contain the results for the large countries, and Tables 9-11 contain the results for the small countries. These results indicate that the inflation process may be divided into three horizons – the short run, the medium run and the long run. The short run is defined as the horizon where no variable has any significant effect on inflation, the medium run is defined as fluctuations caused by the business cycle (output gap), and the long run are frequencies lower than the business cycle frequencies. We find that the short run lasts between one quarter and two years, the medium run between two to four years, and the long run begins after four years. This result is in line with the results found in Gerlach (2003) and Assenmacher-Wesche and Gerlach (2006 c), who define the long run as starting after 5.6 years, and in Englund *et. al* (1992) where the business cycle lasts between three and eight years.

The short-run results run should be interpreted with care, however, for although some parameter estimates are statistically different form zero at the 5%-level, the explanatory power of the inflation models is small and often close to zero (between 0.2% and 17.8%). These short run regression results may be affected by outliers or seasonal effects, and are therefore not commented on further.

The explanatory power of the inflation model is modest in the medium run, between 31.4% and 45.0%. For the long run it is substantially higher, and the R^2 value increases to between 75.1% and 89.6%. As expected, neither the output gap or oil prices have any significant effect on inflation in the long run model. The output gap is by definition zero in the long run, and if changes in real oil prices are interpreted as a proxy for supply shocks, they also should have no long run effect on inflation. The only significant variables in the long run model are money growth and real GDP growth.

It is not possible to reject the hypothesis that money elasticity with respect to income is equal to one, this restriction is therefore imposed on the model and the parameter estimates

[11] It is possible to identify the first and the second half of the sample because the DWT coefficients have both a time and a frequency interpretation. The entire time series is thus transformed and the coefficients representing the first and the second half are then identified.

presented here can be interpreted as excess money growth (EMG)[12]. The estimated long run parameter value for EMG varies between 0.915 and 1.195 depending on panel and time period. We cannot reject the hypothesis that the true parameter value for EMG is equal to one for any of the panels, which means that the results imply that there is a stable long run one-to-one relationship between EMG and headline inflation for all countries.

In all panels, the medium run parameter estimate for EMG is smaller than the long run parameter estimate. The medium run parameter estimate is between 0.265 and 0.523; it is in general larger for the 1971Q2-1987Q1 period than for the latter 1987Q2-2003Q1 period. The parameter estimate for the output gap, measured with a Hodrick Prescott cycle, is significant in some but not all panels; it is not significant for the panel representing all countries 1971Q2-1987Q1 or for small countries 1971Q2-1987Q1 for example. The other two estimates of the output gap, the linear trend and the unemployment gap, have no statistically significant effect in any of the regressions, and are therefore excluded from further consideration.

Oil price is also a significant medium run variable, but only for the first half of the sample. This result is not surprising since the first half includes the 1973 and 1979 oil price shocks. The parameter estimates for oil price in the first sub-sample lie between 0.037 for small countries and 0.065 for large countries. These estimates are small compared to those for excess money growth and the output gap, but the amplitude of the medium run oil price cycles are on the other hand substantially higher than the amplitude for the medium run EMG cycles and medium run output gap cycles. The medium run amplitude of logged real oil prices varies between 4.2% and 11.5% compared to 0.8% and 2.0% for the output gap and 1.4% and 5.5% for EMG[13]. Of the three variables in the medium run inflation model, EMG is the most important if both the amplitude of the cycles and the parameter estimates are taken into account.

These inconclusive medium run results[14] for real oil price and the output gap may be interpreted as implying that the structure of the economy has changed since 1971, and that one model therefore cannot be used to represent the entire sample. It is also evident that these kinds of variables cannot be relied upon as inflation indicators when the structure of the economy is changing (see Lucas 1976), and that other variables must also be considered.

[12] Excess money growth (EMG) is defined as money growth minus GDP growth.

[13] These figures are for the first sub sample only.

[14] We test the hypothesis of poolability against the alternative that each group of countries is different using a Chow test (see Baltagi 2005). For the long run model, we cannot reject the null hypothesis that all countries can be pooled. For the medium run results we reject it at the 10% level but not at the 5% level.

Woodford (2007) argues that a long run relationship between excess money growth and inflation does not imply that money causes inflation. He claims that other variables affect both of them, and that the relationship is therefore caused by an indirect link. An estimate of the inflation trend would therefore contain more information about the future direction of headline inflation than an estimate of EMG.

Even if EMG is just an estimate of the inflation trend, it can still contain useful information about headline inflation. Monetary policy operates with a lag, which implies that an estimate of EMG may indicate in which direction the inflation trend is moving. EMG may therefore contain more information about future headline inflation than an estimate of the present inflation trend. We test whether EMG is an informative long run inflation indicator or if Woodford is right in his claims about the inflation trend, by performing a correlation study. We estimate the correlations between lagged EMG and headline inflation, where EMG is lagged between one up to 60 quarters (15 year), and compare these correlations to those obtained when we replace EMG with an estimate of the inflation trend. Two estimates of the inflation trend are used; a DWT trend estimate at the same frequency as EMG, and a Hodrick Prescott (HP) trend obtained by using the default settings in EViews 5.1 (λ=100).

Results of the correlation study are available in Figures 1 (all countries) 2 (large countries) and 3 (small countries). Table 12 presents the correlations for five selected horizons; 4, 8, 16, 32 and 40 quarters for the individual countries and for the full panel. Correlations were also estimated for each time sub-sample, but as these results were based on just one long run observation per country, and the results were inconclusive and are not presented in the paper.

For the full sample the correlation between long run excess money growth and headline inflation increases during the first eight quarters before it begins to decline. For both inflation trends the correlations are highest for the first quarter and then decline more rapidly than long run EMG. After ten to fifteen quarters the correlations for the two inflation trend estimates are both less strong than the correlation for excess money growth. The correlations from the HP-trend decline the quickest and have a cyclical pattern, which indicates that the HP-trend also contains a business cycle component. The correlations for a lag length of four years are 0.610 for long run excess money growth, 0.589 for the DWT trend and 0.526 for the HP-trend for the full sample. For a lag length of ten years the corresponding correlations are 0.507, 0.335 and 0.281.

The results for the sub-panels, large and small countries, follow the same general pattern as for the full panel, see Figures 2 and 3. The DWT trend has the highest correlation with future headline inflation for the first four to eight quarters before excess money growth becomes more highly correlated with headline inflation than the inflation trend estimates. EMG is especially informative compared to the inflation trend for small countries. The results for the group of large countries are to a great extent affected by the results for the United Kingdom, where the Hodrick Prescott inflation trend has the highest correlation with headline inflation for horizons exceeding four quarters, see Table 12. EMG, on the other hand, is a better predictor of future inflation for the United States and, in particular, the Eurozone. The correlation coefficient between headline inflation and EMG (with money lagged eight years) is 0.771 in the Eurozone, compared to 0.500 and 0.484 for the correlations between headline inflation and the wavelet inflation trend and the Hodrick Prescott inflation trend respectively.

The implication of the correlation study is that the monetary transmission process lasts approximately two to three years, and that money contains information about future headline inflation that estimates of the present inflation trend do not. EMG is therefore one important inflation indicator that should be monitored.

3. Conclusions

Excess money growth and inflation have a one-to-one long run relationship that is stable both across countries and over time. Moreover, there is a roughly two year lag between excess money growth and headline inflation. Woodford (2007) argues that an estimate of the inflation trend contains more information about future inflation than EMG. The correlation study performed in this paper shows that this is not the case. Future headline inflation is more correlated with present excess money growth than with present inflation trends for horizons exceeding ten quarters.

Medium run movements in the inflation rate can be explained by excess money growth, the output gap and oil prices, but of these variables only EMG has a stable effect over time and countries. The output gap has become more significant at the end of the sample, while oil prices had a greater effect at the beginning of the sample. These results may be interpreted as evidence of the Lucas (1976) critique.

Monetary policy decisions are based on many different indicators. The strong long run correlation between money and inflation shows that money is certainly one important variable that should be monitored. This is especially true during volatile times when the structure of the economy is changing, and when variables such as the output gap and interests rates are therefore no longer reliable inflation indicators. ECB’s monetary policy strategy of combining monetary analysis and real economic analysis therefore makes sense.

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Table 1: Fractional Integration Order and Confidence Intervals [1, 2]

Country	Inflation			Money Growth			GDP Growth		
	d_{low}	d	d_{high}	d_{low}	d	d_{high}	d_{low}	d	d_{high}
Australia	0.10	0.31	0.51	0.14	0.38	0.60	-0.01	0.18	0.35
Canada	0.04	0.23	0.41	0.23	0.45	0.66	0.02	0.20	0.37
Denmark	-0.07	0.11	0.27	-0.51	-0.36	-0.23	-0.03	0.16	0.33
Eurozone	0.10	0.31	0.50	0.06	0.25	0.43	0.09	0.29	0.47
Norway	0.01	0.19	0.36	0.09	0.29	0.48	-0.12	0.07	0.23
New Zealand	0.15	0.36	0.55	-0.06	0.13	0.30	-0.46	-0.27	-0.11
Sweden	0.04	0.23	0.41	-0.09	0.08	0.24	-0.18	-0.02	0.13
United Kingdom	0.08	0.28	0.46	-0.01	0.18	0.43	-0.12	0.06	0.23
United States	0.07	0.26	0.44	0.25	0.45	0.63	0.06	0.25	0.43

Note

1. Percival and Walden (2006) maximum likelihood estimator is used to estimate the fractional integration order.

2. d is the integration order, d_{lower} and d_{upper} denote the lower and upper boundaries for a 95% confidence interval.

Table 2: Integration Order and Confidence Intervals Continued[1, 2]

Country	Unemployment			Δ Logged Oil Prices		
	d_{lower}	d	d_{upper}	d_{lower}	d	d_{upper}
Australia	-0.35	-0.17	-0.01	-0.31	-0.09	0.11
Canada	-0.13	0.09	0.29	-0.26	-0.04	0.18
Denmark	-0.01	0.18	0.36	-0.13	0.07	0.27
Eurozone	0.06	0.25	0.42	0.20	0.38	0.55
Norway	-0.33	-0.16	0.05	-0.15	0.06	0.25
New Zealand	-0.10	0.09	0.25	-0.18	0.04	0.24
Sweden	-0.04	0.13	0.28	-0.18	0.03	0.22
United Kingdom	0.02	0.21	0.39	-0.25	-0.04	0.16
United States	-0.17	0.03	0.21	-0.23	-0.02	0.19

Note

1. Percival and Walden's (2006) maximum likelihood estimator is used to estimate the fractional integration order.

2**.** d is the integration order, d_{lower} and d_{upper} denote the lower and upper boundaries for a 95% confidence interval.

Table 3: Bandspectrum Regression – All Countries 1971Q2 – 2003Q1

Periodicity (years)	Excess Money Growth	Δ Logged Oil Prices	Output gap	R^2 (%)
4-	1.001***	0.017	0.240	78.9
	(0.048)	(0.268)	(0.457)	
2-4	0.314***	0.022***	0.135*	35.4
	(0.066)	(0.009)	(0.087)	
1-2	0.070**	0.004	0.088**	4.6
	(0.020)	(0.007)	(0.041)	
1/2 -1	0.017***	0.011***	0.082***	7.9
	(0.007)	(0.002)	(0.012)	
1/4-1/2	0.024***	0.006***	0.055***	2.3
	(0.005)	(0.002)	(0.011)	

Table 4: Bandspectrum Regression – All Countries 1971Q2 – 1987Q1

Periodicity (years)	Excess Money Growth	Δ Logged Oil Prices	Output gap	R^2 (%)
4-	1.047***	0.011	0.437	83.0
	(0.060)	(0.036)	(0.487)	
2-4	0.384***	0.042***	0.063	45.0
	(0.104)	(0.014)	(0.116)	
1-2	0.157***	0.015	0.061	10.0
	(0.064)	(0.015)	(0.056)	
1/2 -1	-0.022	0.014***	0.055	6.3
	(0.015)	(0.006)	(0.034)	
1/4-1/2	0.020***	0.007***	0.036**	2.4
	(0.007)	(0.003)	(0.017)	

Table 5: Bandspectrum Regression – All Countries 1987Q2 – 2003Q1

Periodicity (years)	Excess Money Growth	Δ Logged Oil Prices	Output gap	R^2 (%)
4-	1.028***	-0.001	0.463	75.1
	(0.064)	(0.032)	(0.524)	
2-4	0.282***	-0.007	0.213**	31.4
	(0.068)	(0.010)	(0.097)	
1-2	-0.004	-0.005	0.080*	0.2
	(0.031)	(0.006)	(0.058)	
1/2 -1	0.030***	0.024***	0.075**	13.7
	(0.011)	(0.004)	(0.035)	
1/4-1/2	0.029***	0.005**	0.077***	1.8
	(0.007)	(0.003)	(0.014)	

Table 6: Bandspectrum Regression – Large Countries[1] 1971Q2 – 2003Q1

Periodicity (years)	Excess Money Growth	Δ Logged Oil Prices	Output gap	R^2 (%)
4-	0.915***	0.049	0.120	75.8
	(0.095)	(0.045)	(0.721)	
2-4	0.523**	0.028	-0.020	39.5
	(0.229)	(0.024)	(0.165)	
1-2	0.217**	0.000	0.211**	5.9
	(0.105)	(0.012)	(0.093)	
1/2 -1	0.160***	0.024***	0.390***	1.7
	(0.048)	(0.007)	(0.106)	
1/4-1/2	0.023	-0.377***	0.407***	0.6
	(0.023)	(0.109)	(0.162)	

Note

1. Eurozone, United Kingdom and the United States

Table 7: Bandspectrum Regression – Large Countries[1] 1971Q2 – 1987Q1

Periodicity (years)	Excess Money Growth	Δ Logged Oil Prices	Output gap	R^2 *(%)*
4-	1.195***	0.086**	0.198	89.6
	(0.083)	(0.040)	(0.54)	
2-4	0.397*	0.065*	-0.080	35.4
	(0.265)	(0.045)	(0.221)	
1-2	0.413**	-0.006	0.241**	2.3
	(0.197)	(0.027)	(0.139)	
1/2 -1	0.183***	0.023**	0.387***	3.5
	(0.074)	(0.011)	(0.141)	
1/4-1/2	-0.019	-0.403***	0.444**	0.6
	(0.040)	(0.141)	(0.205)	

Note

1. Eurozone, United Kingdom and the United States

Table 8: Bandspectrum Regression – Large Countries[1] 1987Q2 – 2003Q1

Periodicity (years)	Excess Money Growth	Δ Logged Oil Prices	Output gap	R^2 (%)
4-	1.086***	0.018	0.518	79.7
	(0.102)	(0.050)	(0.693)	
2-4	0.444**	0.017	0.007	35.3
	(0.193)	(0.014)	(0.171)	
1-2	0.042	0.002	0.295***	20.2
	(0.078)	(0.008)	(0.097)	
1/2 -1	0.130**	0.030***	0.592***	3.3
	(0.056)	(0.007)	(0.203)	
1/4-1/2	0.053**	-0.115	0.062	0.2
	(0.024)	(0.210)	(0.336)	

Note

1. Eurozone, United Kingdom and the United States

Table 9: Bandspectrum Regression – Small Countries[1] 1971Q2 – 2003Q1

Periodicity (years)	Excess Money Growth	Δ Logged Oil Prices	Output gap	R^2 (%)
4-	0.972***	-0.013	0.452	79.3
	(0.057)	(0.035)	(0.610)	
2-4	0.265***	0.018**	0.200**	33.2
	(0.069)	(0.010)	(0.103)	
1-2	0.059*	0.006	0.069*	4.2
	(0.036)	(0.008)	(0.047)	
1/2 -1	0.003	0.018***	0.046**	8.5
	(0.010)	(0.004)	(0.025)	
1/4-1/2	0.023***	0.005**	0.055***	5.4
	(0.005)	(0.002)	(0.011)	

Note

1. Australia, Canada, Denmark, Norway, New Zealand and Sweden

Table 10: Bandspectrum Regression – Small Countries[1] 1971Q2 – 1987Q1

Periodicity (years)	Excess Money Growth	Δ Logged Oil Prices	Output gap	R^2 (%)
4-	0.939***	0.132	1.472*	78.7
	(0.114)	(0.120)	1.001	
2-4	0.341***	0.037***	0.142	43.6
	(0.109)	(0.007)	(0.136)	
1-2	0.134**	0.022*	0.035	13.2
	(0.070)	(0.017)	(0.063)	
1/2 -1	-0.037***	0.009*	0.025	14.7
	(0.014)	(0.006)	(0.032)	
1/4-1/2	0.021***	0.007**	0.037**	4.8
	(0.007)	(0.003)	(0.014)	

Note

1. Australia, Canada, Denmark, Norway, New Zealand and Sweden

Table 11: Bandspectrum Regression – Small Countries[1] 1987Q2 – 2003Q1

Periodicity (years)	Excess Money Growth	Δ Logged Oil Prices	Output gap	R^2 *(%)*
4-	1.002***	-0.010	0.416	72.2
	(0.080)	(0.041)	(0.732)	
2-4	0.275***	-0.016	0.226**	30.5
	(0.076)	(0.012)	(0.121)	
1-2	-0.006	-0.006	0.037	2.6
	(0.036)	(0.008)	(0.071)	
1/2 -1	0.026**	0.025***	0.062**	17.8
	(0.012)	(0.005)	(0.037)	
1/4-1/2	0.026***	0.003	0.075***	6.0
	(0.008)	(0.003)	(0.015)	

Note

1. Australia, Canada, Denmark, Norway, New Zealand and Sweden

Table 12: Correlations with Headline Inflation

Country	h^1=4			h=8			h=16			h=32			h=40		
	EMG[2]	WT[3]	HPT[4]	EMG	WT	HPT	EMG	WT	HPT	EMG	WT	HPT	EMG	WT	HPT
Australia	0.681	0.680	**0.731**	**0.704**	0.698	0.575	0.599	**0.614**	0.483	**0.577**	0.564	0.422	**0.531**	0.478	0.206
Canada	0.619	0.749	**0.803**	0.683	**0.709**	0.661	**0.676**	0.575	0.526	**0.676**	0.395	0.409	**0.565**	0.295	0.217
Denmark	0.694	0.721	**0.739**	**0.700**	0.693	0.666	**0.634**	0.594	0.613	**0.617**	0.441	0.436	**0.515**	0.310	0.246
Eurozone	0.843	0.844	**0.887**	**0.858**	0.799	0.784	**0.818**	0.692	0.662	**0.771**	0.500	0.484	**0.746**	0.506	0.404
New Zeeland	0.572	0.738	**0.783**	0.674	**0.710**	0.664	**0.758**	0.591	0.565	**0.745**	0.349	0.309	**0.677**	0.130	0.239
Norway	0.217	0.699	**0.716**	0.395	**0.675**	0.588	0.541	**0.582**	0.503	**0.646**	0.412	0.336	**0.692**	0.254	0.131
Sweden	0.638	0.657	**0.695**	**0.655**	0.614	0.593	**0.671**	0.527	0.448	**0.649**	0.336	0.265	**0.627**	0.356	0.355
United Kingdom	0.521	0.624	**0.707**	0.517	**0.618**	0.544	0.494	**0.565**	0.430	0.462	**0.491**	0.211	0.408	**0.424**	0.290
United States	0.737	0.606	**0.758**	**0.665**	0.495	0.492	**0.514**	0.343	0.341	**0.330**	0.217	0.080	**0.407**	0.320	0.270
All (Panel)	0.609	0.707	**0.758**	0.642	**0.681**	0.629	**0.610**	0.589	0.526	**0.550**	0.426	0.339	**0.507**	0.335	0.281

Notes:

1. The number of time observations that excess money growth or the inflation trend are lagged compared to headline inflation

2. EMG = Excess Money Growth

WT = Wavelet Trend

4. WT = Hodrick Prescott Trend

Figure 1: Correlations with Headline Inflation – All Countries

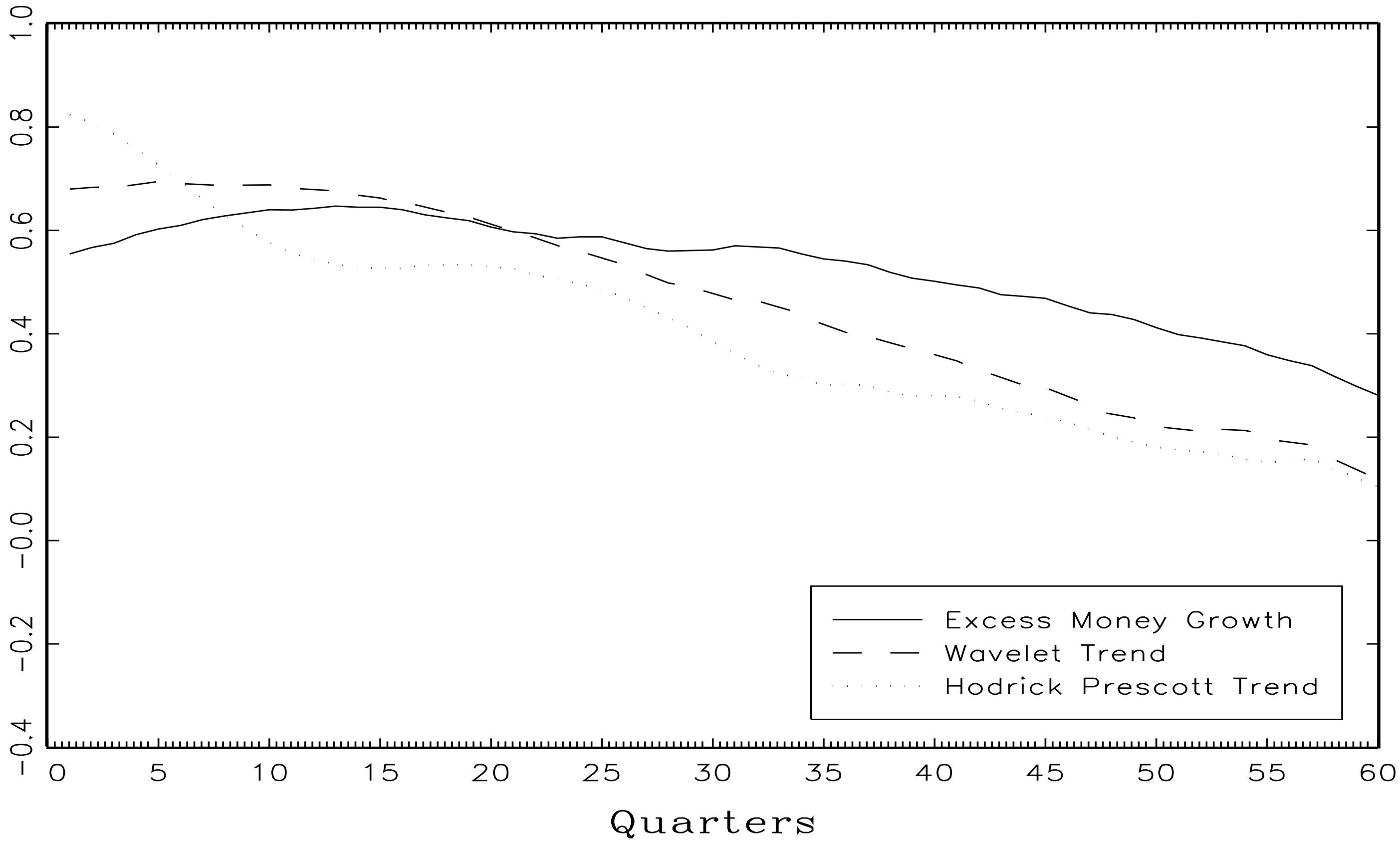

Figure 2: Correlations with Headline Inflation - Large Countries

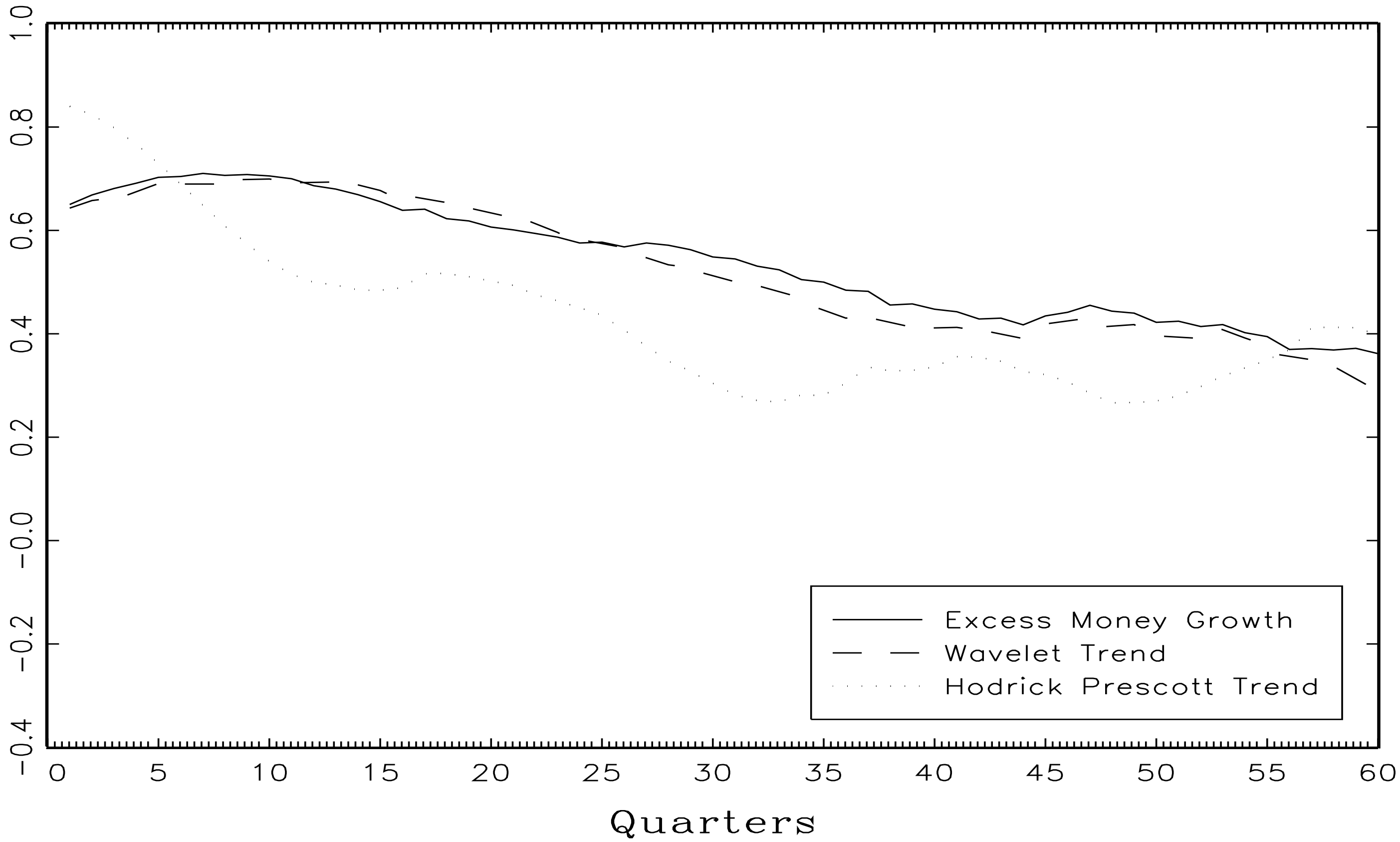

Figure 3: Correlations with Headline Inflation – Small Countries