Monetary Policy and Inflation
– A wavelet analysis of money growth and the purchasing power of money

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Abstract
This paper investigates the relationship between monetary policy and inflation using
a two pillar Phillips curve. We measure inflation using five different price indices,
consumer prices, GDP deflator, consumer food prices, house prices and share prices.
We find that money causes consumer price inflation in the long run, but not in the
short to medium term. However, there is a direct medium run relationship between
money and deflator inflation, food price inflation, house price inflation and share
price inflation. There is, furthermore, a direct one-to-one relationship between
money and share price inflation in the short run. Money growth thus causes inflation
at all horizons.

Key Words: Inflation, Money, Purchasing Power of Money, Wavelets

JEL Codes: E31, E32, E41, C19

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Introduction

Gerlach (2004), Neuman and Greiber (2004) and Assenmacher-Wesche and Gerlach (2008a, b), among others, study the relationship between consumer price inflation and money growth at different time horizons in Switzerland and the Euro Area. They find a stable long run relationship between consumer price inflation and money growth, but no or only a weak relationship in the short- to medium run. However, consumer price are not the only prices in the economy that are affected by the central bank’s monetary policy. In this paper we therefore consider a similar two pillar Phillips curve as in these papers, with alternative measures of inflation, i.e. GDP deflator inflation, consumer food price inflation, house price inflation and share price inflation.

Most central banks use a consumer price index as their main price index. In the long run, it is reasonable to assume that any broad price index, such as a consumer price index, accurately captures the true rate of monetary policy induced inflation (monetary inflation). However, a price index that does not include all prices in the economy is not necessary an accurate measure in the short to medium term. Monetary policy implemented over the medium term based on only a sub set of prices may thus increase the volatility in sectors of the economy that are not captured by the chosen price index.

A monetary policy shock generates a transmission process that is completed once all prices have with an equally large increase or decrease to the shock (Keynes, 1930). Some prices, however, are sticky and respond slowly to the shock while others are more flexible and are quick to respond. The speed transmission process is thus not uniform for all prices. Consumer prices are in fact considered to be among the stickiest (see e.g. Woodford, 2003). The true effect of a monetary policy decision is thus not experienced for many years, and a central bank that aims at fulfilling a consumer price target before the transmission process has been completed may exaggerate its policy decisions and create unnecessary volatility in the
economy. It thus important to understand how different price indices respond to monetary policy shocks.

Fischer (1911), Lindahl (1929), Alchian and Klein, (1973) takes the argument one step further, they argue that since monetary policy affects the purchasing power of money the central bank should measure the purchasing power of money and not the cost of living (consumer prices). These arguments are based on the reasoning that present welfare depends on future and present utility. Since the consumer price index only measures the cost of present flows of consumption it does not capture the true cost of maintaining a certain welfare level. A central bank that ignores prices of future flows of consumption (asset prices) is thus not neutral in its monetary policy between those who wish to consume today and those who wish to consume in the future. Favouring present consumption may in the end affect people’s willingness to save and have real effects on the economy.

A price index that includes asset prices is difficult to construct. Vickers (1999), Woodford (2003) and ECB (2003a) argue against adding asset prices to the price index because it is difficult to assign weights to the different items of such an index. Furthermore, asset prices have a low signal to noise ration, which implies that these prices contain very little information about monetary inflation (see e.g. Bryan et. al (2002).

Arguments for using a consumer price index as the central banks main price series are many. First, they cover a large and important sector of the economy. Second, it is a relatively broad price index with prices of many different goods and services and is thus likely to capture the overall true rate of monetary inflation, at least in the long run. Third, these prices are relatively easy to observe and it is also easy to assign weights to each price in the overall price index.

The results in Gerlach (2004), Neuman and Greiber (2004) and Assenmacher-Wesche and Gerlach (2008a, b) indicate that the transmission process lasts between four to eight years for
consumer prices, yet most central banks aim at implementing their consumer price inflation targets over a shorter horizon (see e.g. Issing 2003b; ECB 2003b). Such a short target for consumer price inflation may cause unnecessary volatility.

The issues we study in this paper, is how quickly different price indices respond to monetary policy shocks, and how long it takes for the transmission process to be completed? To be able to study the length of the transmission process we estimate a two pillar Phillips curve. The two pillar Phillips curve is related to the European Central Bank’s monetary policy strategy that divides the inflation process into different time horizons (i.e. short run, medium run and long run). By estimating the two pillar Phillips curve with the use of a bandspectrum regression (see Engle, 1974), we can identify the various time horizons and obtain an estimate of the length of the monetary transmission process.

We define that the transmission process has been completed once there is a one-to-one relationship between money growth and inflation. In total we explore the transmission process for five different inflation series, consumer price inflation, GDP deflator inflation, consumer food price inflation, house price inflation and share price inflation. In other words we use three price indices of the cost of present consumption (consumer inflation, GDP deflator and consumer food price inflation) and two asset prices (house price inflation and share price inflation).

We estimate the two pillar Phillips curve using a panel data model, the panel is used to increase the number of long run observations. In a sample from only one country commonly contains only a handful long run observations, but by pooling data from many individuals we can increase the number of observations sufficiently to be able to make inference of the regression results. The countries included in the panel are eight developed countries; Australia, Canada, Euro Area, Japan, Sweden, Switzerland, the United Kingdom and the United States covering the period 1976Q4 to 2008Q3.
The band spectrum regression is estimated with the help of a discrete wavelet transform (see e.g. Ramsey and Lampart, 1998; Percival and Walden, 2006). The discrete wavelet transform allows us to account for changes in monetary policy regimes and structural breaks that may have taken place within our sample period. The analysis is thus less sensitive than band spectrum regressions that are based on a Fourier transform.

The rest of the paper is organized as follows; in section 2 we discuss the relationship between monetary policy and inflation. Section 3 presents the estimation technique, the data and the regression results and Section 4 concludes the paper.

2. Monetary Policy and Inflation

2.1 The Quantity Equation

Monetary policy operates through many different transmission channels. Among these are the expectations channel, interest rate channel and the exchange rate channel. The relative importance of each channel may vary over time and one channel may be more relevant for one set of prices compared to another set of prices.

The duration of transmission process, furthermore, varies depending on how often prices are adjusted. Some prices, for example, asset prices are adjusted frequently and hence flexible, while other prices, for example, consumer prices are stickier and more likely to become misaligned from their equilibrium level (Woodford, 2003). Asset prices are therefore likely to respond quicker to monetary policy shocks while consumer prices are likely to be slower to respond. The complete transmission process is completed once all prices have responded with the same increase or decrease to the policy shock (Keynes, 1930).

Although monetary policy operates through many different channels, in the end a permanent increase in the price level cannot take place without a permanent increase in the money stock. Temporary fluctuations in the price level can take place without changes in the
money stock though. We can therefore use the quantity equation and the monetary aggregates to estimate the length of the transmission process.

According to the quantity equation, an increase in the money stock increases the price level one-to-one. The transmission process is, thus, completed once prices have responded one-to-one to a change in the money supply. This gives an identifying assumption that enables us to estimate the length of the transmission process.

In a model context it is possible to treat the money supply either as an exogenous variable and the main cause of inflation (see e.g. Friedman, 1963, 1968) or as an endogenous variable that just accompanies an increase in the price level (see e.g. Meyer, 2001; Woodford, 2003). Irrespective of whether money is an exogenous or endogenous variable, money and inflation are still correlated one-to-one in the long run, once the transmission process has been completed.

Consider the quantity equation,

\[ P_t Q_t = M_t V_t, \]  
(1)

where \( P \) is the price level, \( Q \) is the quantity of the products that are traded during a period, \( M \) the money stock and \( V \) money velocity. If we take the log of (1) we can obtain the following simple relationship for the logged price level,

\[ p_t = \log m_t - q_t + v_t, \]  
(2)

where small letters denote logs. Taking the first difference of equation (2) yields an expression for the inflation rate,

\[ \pi_t = \Delta m_t - \Delta q_t + \Delta v_t, \]  
(3)

where \( \pi_t \) is inflation. All things equal, an increase in the money stock hence crates inflation. It is important to note that the time period in the equations 1-3 as well as the inflation rate are theoretical concepts. This theoretical time period may be related to a calendar period (quarter or year), or it could be of some other length. The expression in equation (3) does thus not
necessarily hold over a calendar period and should be considered over some other period length where a one-to-one relationship exists.

In addition, prices in equations 1-3 relate to all prices in the economy, not just consumer prices. This theoretical price index includes prices of everything purchased or purchasable during a period (see e.g. Fisher, 1911; Lindahl, 1929). The quantity, \( q \), similarly relates to everything purchased during a period and is not necessarily related to real GDP. As a matter of convenience, however, it may be desirable to replace \( q \) with a measure of real GDP, \( y \), since \( q \) is more or less impossible to measure (Lindahl, 1929).

The price level \( p \) is also difficult to measure, but can be estimated with a great spectrum of different prices and price indices. Due to money neutrality, however, all prices will eventually respond one-to-one to a change in the money supply (see e.g. Friedman 1974; Vinning and Elwetowski, 1976). Individual prices may be affected by relative price changes that are uncorrelated with monetary policy. In any broader price index such relative price effects are likely to cancel out as some prices will grow at a faster rate than the average and some at a slower rate than the average. Any price index with relatively many prices is thus likely to capture the true rate of monetary inflation in the long run.

2.2 The Two Pillar Phillips Curve

The European Central Bank (ECB) defines its inflation target in terms of a consumer price index (the harmonized index of consumer prices; HICP). Its monetary policy strategy, furthermore, rests on two pillars; economic analysis and monetary analysis. The first pillar, is to be interpreted as the short- to medium term inflation determinants, while the second pillar contains the long run causes of inflation (see e.g. ECB, 2003b). The division of the policy strategy into two components may be interpreted as recognition that the relevant time period for the quantity equation with consumer prices as a measure of inflation is not necessarily related to a calendar period and may last longer.
Gerlach (2004) interprets the ECB’s monetary policy strategy as a two pillar Phillips curve. The two pillar Phillips curve can be written as,

$$\pi_t = \gamma_1 \left( \mu_t^{LR} - y_t^{LR} + \Delta v_t^{LR} \right) + \gamma_2 g_t + \eta_t,$$

where $\mu_t^{LR}$ is long run money growth (i.e. the horizon over which money neutrality holds), $y_t^{LR}$ long run real GDP growth (growth in potential GDP), $\Delta v_t^{LR}$ long run changes in money velocity, $g_t$ an output gap and $\eta_t$ a shock term. The output gap is per definition zero in the long run and thus a short to medium term inflation determinant and money growth is a long run estimate and hence represents the long run inflation determinants. The first pillar is hence, represented by the output gap (or an unemployment gap) and the second pillar, by long run estimates of the quantity equation.

The two pillar Phillips curve has been estimated by, among others, Neuman and Greiber (2004) and Assemacher-Wesche and Gerlach (2008 b) for the Eurozone and by Assemacher-Wesche and Gerlach (2008a) for Switzerland, using consumer prices as a measure of inflation. These studies find empirical support for the two pillar Phillips curve, although the length of the transmission process varies between five to eight years.

2.3 Expansion of the Two Pillar Phillips Curve

In this paper, we also estimate a two pillar Phillips curve, but we use more than the consumer price index to measure inflation. We also consider, a GDP deflator, consumer food price index, a house prices and share prices.

Alchian and Klein (1973) argues following the discussion in Fischer (1911) that asset prices should be included in the central banks price index, since monetary policy affects these prices too and these prices in turn affect the individual’s welfare. These arguments are based on the fact that the individuals welfare is not just a function of present flows of consumption, but also a function of future flows of consumption (see e.g. Konüs, 1939; Samuelson, 1961).
The consumer price index, which is a cost of living index, is thus not a measure of the purchasing power of money (or monetary inflation).

Naturally, it can be argued as in Woodford (2003), that the central bank should concentrate its monetary policy on sticky prices and ignore asset prices since these are among the most flexible, even if its increases the volatility in flexible prices. However, it is still interesting to consider the length of the transmission process for other prices and how much more volatile these may become due to an active monetary policy based on consumer price inflation.

3. Empirical Analysis

3.1 Bandspectrum Regression

Engle (1974) proposed an estimation technique for models that contain more than one time horizon. The first step to estimate such a model is to decompose the time series into different frequencies. The individual frequencies (or frequency bands) from such a decomposition can directly be related to different time horizons. A high frequency, for example, represents the short run, while the low frequencies close to the zero frequency represent the long run. By regressing on a limited set of frequencies instead of all frequencies at the same time, it is hence possible to explore relationships at different time horizons.

To be able to explore long run relationships, though, a fair amount of data is necessary. Consider, for example, the case where the short and medium run (the duration of the business cycle) lasts approximately six to eight years. Under such circumstances, a sample of some thirty years of observations only contains between five and six long run observations, which is too few to make any inference on. To be able to study the long run, more long run observations is needed. One possible method to obtain more data is to use a panel where data from many countries can be pooled. We consider a panel data model with data from eight
developed countries: Australia, Canada, Euro Area, Japan, Sweden, Switzerland, the United Kingdom and the United States. The sample covers the period 1976Q4 to 2008Q3.

The band spectrum regression that Engle introduces uses a Fourier transform to decompose the data into different frequency components. However, the Fourier transform is not the only transform that can be used. All that is required is that the transform decomposes the time series into different frequencies such that the various time horizons can be indentified. The disadvantage with the Fourier transform is that it assumes that the time series are stationary, not just in the sense that they are I(0), but that the series do not include any outliers or structural breaks (see e.g. Percival and Walden, 2006). Non-recurring events may cause leakages between the frequency bands whereby it is difficult to separate the various time horizons from each other.

An alternative to the discrete Fourier transform is the discrete wavelet transform. The discrete wavelet transform can decompose non-stationary time series, both series that are I(1) and series that contains non-recurring events. The discrete wavelet transform is thus a more appropriate transform to decompose economic time series (see e.g. Brockwell and Davis, 1998; Percival and Walden, 2006; Crowley, 2007).

The disadvantage with the discrete wavelet transform is that it can only decompose the time series if the number of observations equals a certain number; in this case we either have to choose between 64 observations, 128 observations or 256 observations. 64 observations is too few to be able to explore the long run if we have quarterly data (assuming that the business cycle lasts at least five year), and we cannot obtain 256 quarterly observations for all countries. Therefore we settle for 128 quarterly observations covering the period 1976Q4 to 2008Q3.

To use the discrete wavelet transform one has to chose a set of basis functions. The Fourier transform uses sine- and cosine functions, but the wavelet transform can be based on a
great spectrum of different functions. In this paper we use the Haar-wavelet. The Haar-wavelet is chosen with the respect to the length of the data series available, and due to practical implementation problems that may arise when alternative wavelet functions are used, i.e. boundary problems (see Percival and Walden, 2006).

3.2 Regression Model

The estimated inflation model is,

\[ \pi_{if} = \alpha_i \mu_{if} + \alpha_2 y_{if} + \alpha_3 u_{if} + \alpha_4 g_{if} + \varepsilon_{if}, \]  

where \( i \) denotes the country, \( f \) is the frequency band, \( \mu \) is money growth, \( y \) is real GDP growth, \( u \) is the unemployment rate (which at all frequencies except the low frequency represents an unemployment gap), and \( g \) is the output gap.

The residuals are modelled using a fixed effects model,

\[ \varepsilon_{if} = \begin{cases} v_{if} & \text{if } 0 < f < 1 \frac{1}{2}, \\ \lambda_i + v_{if} & \text{if } f = 0 \end{cases}, \]

where \( \lambda_i \) is an individual specific fixed effect and \( v_{if} \) is i.i.d. \( (0, \sigma^2_{if}) \). The idiosyncratic component is allowed to be both heteroskedastic within individuals and between individuals. The model is thus estimated using a GLS and not an OLS.

All frequency components, except the zero frequency component, have a zero mean, it is therefore not possible to use a random effects model for these frequencies. We could assume a random effects model for the long run (zero frequency), but we have too few long run observations to be able to estimate such a model. We thus assume a fixed effects model.

The discrete wavelet transform decomposes the data into seven different frequency bands. These frequency bands have a periodicity of respectively, 1 quarter to 2 quarters; 2 quarters to 1 year; 1 year to 2 years; 2 years to 4 years; 4 years to 8 years; 8 years to 16 years and 16 years and beyond.
When we estimate the model, we begin by estimating a separate model for each of the seven horizons (frequency bands). In these regressions we include all the variables that are considered to affect inflation. We then test whether some variables are insignificant; if they are we remove them from the model and re-estimate it. Once we have obtained one model for each frequency band, we test whether some frequency bands can be represented by the same model. If they can we combine these frequency bands and re-estimate the model such that the parameter estimates are based on as much information as possible.

For share price we assume a slightly different model compared to the other price series (consumer prices, GDP deflator, consumer food prices and house prices). In the share price model we also include the long run government bond yield to capture substitution effects between different investment possibilities. The expected relationship between real GDP growth and share prices is, furthermore, expected to differ compared to the other price indices. An increase in real GDP increases future profit possibilities for the firms and is therefore expected to increase share prices. According to the quantity equation an increase in real GDP has a negative effect on inflation, but since share prices is expected future profits it should have a theoretically positive effect.

The estimated share price model is;

\[ \rho_{gf} = \beta_1 \mu_{gf} + \beta_2 y_{gf} + \beta_3 g_{gf} + \beta_4 u_{gf} + \beta_5 i_{gf} + \eta_{gf}, \]  

(7)

where \( i_{gf} \) is the long run government bond yield (10 year bond). The residuals, \( \eta_{gf} \), are assumed to follow a similar one way fixed effects model as in equation (6).

3.3 Data

Data for real GDP, consumer prices, GDP deflator, consumer food prices share prices, unemployment rate, long term government bond yield and money are collected from Thomson Financial Data Stream. We use a broad monetary aggregate, M3, for all countries
except the US where no M3 data exists after 2006, instead we use M2. Similarly no M3 data exists for the United Kingdom for the early part of the sample, and we hence use M4 for the United Kingdom. House prices are collected from the Bank of International Settlements (BIS).

All series are quarterly growth rates, except the long term government bond yield which is the yearly yield divided by four to represent quarterly rates and house price inflation which is given on a yearly frequency. House price inflation is thus the yearly growth rate divided by four to represent quarterly growth rates. Since we do not have quarterly data for house prices we cannot explore the 1 quarter to 2 quarters and 2 quarters to 1 year horizons for this inflation rate. The discrete wavelet transform is however unaffected by the difference in data frequency

All frequency components except the zero frequency are per definition stationary (see e.g. Percival and Walden, 2006). However, the zero frequency (i.e. long run) components may be non-stationary. We therefore test the integration order using a panel integration test by Im et al. (2003) where we allow for serially correlated errors. We reject the null hypothesis of a unit root in the time series using a 5%-significance level except for the long term government bond yield; see Table 1. A closer examination of individual test statistics for each individual and each data series reveals that we can reject a unit root in all time series except, for the Japanese GDP deflator. However, since Japanese money growth is stationary and all other GDP deflators are stationary, we conclude that in all likelihood, it is stationary too.
### Table 1: Unit Root Tests

<table>
<thead>
<tr>
<th>Variable</th>
<th>Test Statistic</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer Price Inflation</td>
<td>-2.468</td>
<td>0.007</td>
</tr>
<tr>
<td>GDP Deflator Inflation</td>
<td>-1.729</td>
<td>0.042</td>
</tr>
<tr>
<td>Consumer Food Price Inflation</td>
<td>-4.088</td>
<td>0.000</td>
</tr>
<tr>
<td>House Price Inflation</td>
<td>-4.844</td>
<td>0.000</td>
</tr>
<tr>
<td>Share Price Inflation</td>
<td>-6.421</td>
<td>0.000</td>
</tr>
<tr>
<td>Money Growth</td>
<td>-5.522</td>
<td>0.000</td>
</tr>
<tr>
<td>Real GDP Growth</td>
<td>-2.883</td>
<td>0.002</td>
</tr>
<tr>
<td>Unemployment</td>
<td>-3.801</td>
<td>0.000</td>
</tr>
<tr>
<td>Output Gap</td>
<td>-9.251</td>
<td>0.000</td>
</tr>
<tr>
<td>Long Term Interest Rate</td>
<td>-0.972</td>
<td>0.166</td>
</tr>
</tbody>
</table>

Since inflation is stationary and the long term yield is non-stationary, the interest rate cannot be related in the long run, but they can be related in the short to medium term. We thus exclude the long term yield from all long run regressions.

### 3.4 Regression Results

#### 3.4.1 Consumer Price Inflation

Following Gerlach (2004), Neuman and Greiber (2004) and Assenmacher-and Wesche (2008a, b) we begin by estimating a two pillar Phillips curve using consumer price inflation as the inflation measure. We then use these regression results as a benchmark to which we compare the results from the other regression models.

The regression results are presented in Table 2. These results are the final regression results where we have excluded insignificant variables (we use a 5%-significance level). Even if we pool countries the number of observations is relatively few in the long run models and the degrees of freedoms are quickly reduced by including too many variables. We therefore exclude the insignificant variables.

We consider both an unemployment gap and an output gap as a measure of the business cycle. The output gap is estimated using an HP-filter and Eviews 5.1 standard settings.
(λ=100). The higher frequencies from the discrete wavelet transform represent an unemployment gap. It is thus possible to interpret the unemployment rate at the higher frequencies as an unemployment gap.

One star in the table represents a significance level of 1%, two stars a 5% significance level and three stars a 10% significance level.

<table>
<thead>
<tr>
<th></th>
<th>Short Run 1 quarter – 2 years</th>
<th>Medium Run 2 years – 8 years</th>
<th>Long Run &gt;8 years</th>
<th>Long Run &gt;16 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Money Growth</td>
<td>---</td>
<td>---</td>
<td>0.756***</td>
<td>1.090***</td>
</tr>
<tr>
<td>Real GDP Growth</td>
<td>---</td>
<td>-0.256***</td>
<td>-0.494***</td>
<td>-1.823***</td>
</tr>
<tr>
<td>Unemployment Rate</td>
<td>-0.278***</td>
<td>-0.130***</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Output Gap</td>
<td>---</td>
<td>0.174***</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Degrees of Freedom</td>
<td>895</td>
<td>93</td>
<td>30</td>
<td>14</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.047</td>
<td>0.480</td>
<td>0.813</td>
<td>0.962</td>
</tr>
</tbody>
</table>

Table 2: Regression Results - Two Pillar Phillips Curve

The regression results implies that the consumer price inflation process can be decomposed into three time horizons, a short run, a medium run and a long run time horizon. We define the long run as the horizon over which no measure of the business cycle have any statistically significant effect on inflation. The medium run is defined as the horizon where the business cycle affects inflation, and the short run as the horizon where, in principle, none of our variables considered can explain the variation in the inflation rate.

Considering the regression results, we define the short run as the one quarter to two year period. The unemployment gap is significant in these regressions, but the \( R^2 \) is almost zero; 0.047. Because so little of the variation is explained by the unemployment gap we defined this horizon as the short run.

The medium run inflation model has a higher \( R^2 \) value; 0.480. The model includes three significant variables, which all can be interpreted as representing a measure of the business
cycle; temporary GDP growth, the output gap and the unemployment gap. All parameter values have the theoretically correct signs for this interpretation. If we remove one of the gaps, output gap or unemployment gap, the parameter estimate before the other gap increases slightly, in absolute values, to about 0.25, $R^2$ is, however, reduced to between 0.3 and 0.35.

The medium run lasts approximately two to eight years; following this horizon no gap has any significant effect on inflation. We thus define the eight years and beyond as the long run. The estimated parameter estimate for money is 0.75, which is below the by quantity equation expected value of one. However, if we also exclude the eight years to sixteen years horizon the parameter estimate increases to one. The complete transmission process thus lasts somewhere between eight to sixteen years for consumer prices.

These regression results are in line with the results obtained by Gerlach and Neuman and Greiber, although the long run horizon is slightly longer than the results by Assenmacher-Wesche and Gerlach (2008b) indicate for the Euro Area.

The conclusion is that monetary policy affects inflation through an output and unemployment gap in the medium run (up 8 years), but money has no direct effect. In the long run, there is a stable long run relationship between inflation and money growth. The length of the complete transmission process is about one decade.

3.4.2 GDP Deflator

The second set of prices we consider is the GDP deflator. Regression results with deflator inflation are presented in Table 3. We use the definitions of the short run, medium run and long run from the previous section thought out the paper to avoid confusion. The short run, defined in Section 3.4.1, can in these regressions be decomposed into two parts; one representing one quarter to six months, and one representing, six months to two years. For the first short run period no variables have any statistically significant effect on deflator inflation. In the second period, both money and real GDP growth affects inflation. The explanatory
power of the model is relatively high, $R^2$ is 0.557. Neither the unemployment gap nor the output gap has any influence on short run deflator inflation.

<table>
<thead>
<tr>
<th></th>
<th>Short Run 1 quarter – 2 quarters</th>
<th>Short Run 2 quarters – 2 years</th>
<th>Medium Run 2 years – 8 years</th>
<th>Long Run &gt;8 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Money</td>
<td>---</td>
<td>0.174*** (0.039)</td>
<td>0.224*** (0.048)</td>
<td>0.966*** (0.017)</td>
</tr>
<tr>
<td>Real GDP</td>
<td>---</td>
<td>-0.393*** (0.019)</td>
<td>-0.454*** (0.062)</td>
<td>-0.635*** (0.163)</td>
</tr>
<tr>
<td>Unemployment (gap)</td>
<td>---</td>
<td>---</td>
<td>-0.218*** (0.032)</td>
<td>---</td>
</tr>
<tr>
<td>Output Gap</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>---</td>
<td>382</td>
<td>93</td>
<td>30</td>
</tr>
<tr>
<td>$R^2$</td>
<td>---</td>
<td>0.557</td>
<td>0.230</td>
<td>0.800</td>
</tr>
</tbody>
</table>

Table 3: Regression Results – GDP Deflator Inflation

In the medium run, two years to eight years, the parameters for money growth, real GDP growth and the unemployment gap are significant. The parameter value for money growth is not significantly different from estimated parameter value for the second short run period; 0.224 compared to the short run value 0.174. In the long run, eight years and beyond, money growth and real GDP are significant and there is a one-to-one relationship between money growth and inflation. No other variable is significant.

These regression results implies that money have a direct effect on inflation already following a six month period, although the parameter estimate is below one. The transmission process is, furthermore, completed following an eight year period, which is quicker than the transmission process for consumer prices.

3.4.3 Consumer Food Prices

We can obtain a sub-set of consumer prices, food prices, for all countries except the Euro Area. The following food inflation regressions are hence based on all countries except the Euro Area. The regression results for food price inflation are presented in Table 4.
The only variables that have any effect on inflation are money growth and real GDP growth. Neither of the business cycle variables, unemployment gap and output gap, have any effect on food price inflation at any horizon. Food prices are hence insensitive to business cycle fluctuations.

None of the variables we consider are able to capture any of the short term fluctuations in food prices. In the medium run model, only money growth is significant; the estimated parameter is 0.256. This parameter estimate is close to the medium run estimate for money growth in the GDP deflator regressions. $R^2$ is low for the medium run model compared to the consumer price inflation model and the deflator inflation model; only 0.166.

In the long run model, the estimated parameter for money growth is 1.006 and for GDP growth -0.280. $R^2$ is also in this regression relatively low 0.449 for being estimates of the long run. Part of the long run fluctuations we cannot explain may be related to relative price changes.

In conclusion, money growth affects food price one-to-one in the long run and begins to affect food price over the medium term. These prices are hence among the more flexible consumer prices and may be used as an early indicator of the future developments of other consumer prices.
3.4.4 House Price Inflation

The fourth price index is a House price index that is obtained from the Bank of International Setlements (BIS). Creating a house price index is difficult and different countries use different methodologies. The house price index from the BIS is a collection of different national house price indices, more information about these house price indices can be obtained in Arthur (2005).

The results of the house price inflation regressions are available in Table 5.

<table>
<thead>
<tr>
<th></th>
<th>Short Run</th>
<th>Short Run</th>
<th>Medium Run</th>
<th>Long Run</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 quarter – 1 year</td>
<td>1 year – 2 years</td>
<td>2 years – 8 years</td>
<td>&gt;8 years</td>
</tr>
<tr>
<td>Money</td>
<td>---</td>
<td>---</td>
<td>0.369***</td>
<td>1.196***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.018)</td>
<td>(0.030)</td>
</tr>
<tr>
<td>Real GDP</td>
<td>---</td>
<td>---</td>
<td>-0.337***</td>
<td>-0.682***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.045)</td>
<td>(0.064)</td>
</tr>
<tr>
<td>Unemployment (gap)</td>
<td>---</td>
<td>-0.457***</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.066)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output gap</td>
<td>---</td>
<td>---</td>
<td>0.690***</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.021)</td>
<td></td>
</tr>
<tr>
<td>Degrees of Freedom</td>
<td>---</td>
<td>127</td>
<td>93</td>
<td>30</td>
</tr>
<tr>
<td>$R^2$</td>
<td>---</td>
<td>0.187</td>
<td>0.310</td>
<td>0.935</td>
</tr>
</tbody>
</table>

Table 5: Regression Results - Two Pillar Phillips Curve House Price Inflation

Similar to the GDP deflator, we can decompose the short run into two periods; the first covers the one quarter to one year horizon and the second covers one year to two years horizon. In the first short run period, no variable has any statistically significant effect on house prices. In the second period the unemployment gap has a relative large effect compared to the other considered inflation rates.

In the medium run, money is significant, 0.369, real GDP growth -0.337, and the output gap 0.690. The parameter estimate for the output gap is relatively high compared to consumer price inflation and deflator inflation. House prices thus appear to be more sensitive to business cycle fluctuations than the other inflation rates.
The explanatory power for the short- and medium run models are modest; between 0.187 and 0.310. For the long run model $R^2$ is much higher 0.935, which is among the highest $R^2$ obtained for any of the considered regressions.

### 3.4.5 Share Price Inflation

The final set of prices that are considered are share prices. Share prices are modelled with a slightly altered two pillar Phillips curve, namely equation (7).

The short run regression results for the share inflation model are given by Table 6. The medium and long run estimates are presented in Table 7. Unlike consumer prices, the data generating process for these prices can be decomposed into four time horizons; 1 quarter to 1 year; 1 year to 4 years; 4 years to 8 years and beyond 8 years (alternatively one additional horizon can be added, 16 years and beyond).

The explanatory powers of the regression models are relatively low; 0.050 for the shortest horizon, 0.160 for the next and 0.267 for the 4 years to 8 years horizon. Share prices are in other words highly volatile due to other factors than those studied in this paper.

There is a negative relationship between long run government bond yields and share prices in the short run, indicating that there are substitution effects between the two. There are similar, although weaker, substitution effects in the other short and medium run horizons.

<table>
<thead>
<tr>
<th></th>
<th>1 quarter – 6 months</th>
<th>Short Run</th>
<th>1 year – 2 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>6 months</td>
<td>1 year</td>
</tr>
<tr>
<td>Money</td>
<td>---</td>
<td>0.271***</td>
<td>1.434***</td>
</tr>
<tr>
<td></td>
<td>(0.036)</td>
<td>(0.451)</td>
<td></td>
</tr>
<tr>
<td>Real GDP</td>
<td>---</td>
<td>0.292***</td>
<td>0.523***</td>
</tr>
<tr>
<td></td>
<td>(0.054)</td>
<td>(0.161)</td>
<td></td>
</tr>
<tr>
<td>Unemployment (gap)</td>
<td>1.472***</td>
<td>1.589***</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>(0.420)</td>
<td>(0.328)</td>
<td></td>
</tr>
<tr>
<td>Output Gap</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Long Term Interest Rate</td>
<td>-7.972***</td>
<td>-6.158***</td>
<td>-1.884***</td>
</tr>
<tr>
<td></td>
<td>(1.143)</td>
<td>(0.918)</td>
<td>(0.190)</td>
</tr>
<tr>
<td>Degrees of Freedom</td>
<td>510</td>
<td>252</td>
<td>125</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.162</td>
<td>0.168</td>
<td>0.103</td>
</tr>
</tbody>
</table>

*Table 5: Regression Results – Short Run Stock Price Inflation*
The unemployment has a positive effect on stock prices for the horizons 1 quarter to 4 years. This result may seem counter intuitive since a higher unemployment gap implies a recession, but similar results have been found by Boyd et al. (2001) who argues that share prices includes a forward looking component, news of higher unemployment implies that the central bank will reduce interest rates in the future due to the weakening conditions of the economy, which has a positive effect on share prices.

What is interesting is that there is a strong effect of money growth already in the six months to one year horizon, a relationship which becomes a one-to-one relationship already in the one to two year horizon. This one-to-one relationship is maintained throughout the other horizons.

It should be noted though that the relationship between money growth and inflation is reduced to 0.223 for the eight years and beyond horizon, however if we exclude the 8 years to 16 years horizon we obtain the same one-to-one relationship as before. The low parameter value for the eight years and beyond horizon, may be due to data problems, or because we have so few long run observations. Since this horizon stands out as the exception compared to the other horizons, we conclude that share prices respond one-to-one to monetary policy shocks already following a one year period.

The overall result from these regressions are that money causes share price inflation already following a six month period and that it is a one-to-one relationship following one year. Temporary fluctuations in money growth thus increase the volatility of share prices.
4. Conclusions

Most central banks use a consumer price index as their main price index. However, monetary policy affects all prices in an economy and it thus interesting to study how different price series respond to monetary policy shocks. In this paper we consider five different price indices; consumer prices, GDP deflator, consumer food prices, house prices and share prices. We find that consumer prices are sticky and the complete transmission process lasts between eight to sixteen years. Share prices are the most flexible and respond already following a six month period. The other inflation series respond to monetary policy shocks directly following a one to two years period.

Fischer (1911) and Alchian and Klein (1973) have argued that the central bank should be concerned about the purchasing power of money. Purchasing power of money is a different concept compared to the cost of living that the consumer price index measures (Wynne, 1999). Difference between the two is that the purchasing power of money measures the cost of maintaining a certain level of welfare, the cost of living measures the cost of maintain a
certain consumption basket. Welfare depends on present and future consumption and there may thus be differences between the two inflation rates, at least in the short to medium term.

Our regression results indicate that in the long run, the two may be the same since all inflation rates we have considered respond one-to-one to monetary policy shocks. However, in the short to medium run they are not the same. The consumer price index is thus not a good measure of the purchasing power of money at these horizons.

The stickiness of consumer prices makes it difficult to use these prices to measure the complete effect of monetary policy on the economy. An alternative measure that is quicker to respond are share prices. These prices respond already following a six month period, but they are very volatile due to other non-monetary factors and thus have a low signal-to-noise ratio. The GDP deflator is slightly more informative than consumer prices and less volatile than share prices and thus perhaps one of the better inflation indicators for the central bank.

Issing (2003b) argues that money growth itself is a good indicator of the rate of monetary inflation (purchasing power inflation). Our regression results indicate that if we exclude the one quarter to one year horizon, then money growth creates inflation one-to-one at least in one the inflation series. Money growth may thus contain information about the true rate of monetary policy induced inflation that an individual price series does not.
References


ECB (2003a) Background Studies for the ECB’s Evaluation of its Monetary Policy Strategy, European Central Bank, Frankfurt am Main, Germany.


LINDAHL E. (1929) Om Förhållandet Mellan Pennigmängd och Prisnivå, Almqvist & Wiksell's Boktryckeri AB, Uppsala, Sweden.


VICKERS J. (1999), Asset Price and Monetary Policy, Lecture at Money, Macro and Finance Group 31st Annual Conference, Oxford University, 22 September 1999.


We also tried other wavelet functions to test the sensitivity of our results. We tested two other wavelet functions, Daubechie (4) wavelet and Daubechie (6) wavelet functions. The regression results are similar, when we use the Daubechie wavelets instead of the Haar wavelet, the parameter estimate for money growth increases slightly for the medium run for consumer price inflation and becomes significant at the 5% level. Furthermore, the unemployment gap tends to become less significant in all inflation models. Otherwise the results do not significantly change.

The discrete wavelet transform is unaffected since we use a Haar-wavelet.