

Money and Inflation: The Role of Persistent Velocity Movements

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Abstract

While the long run relation between money and inflation is well established, empirical evidence on the adjustment to the long run equilibrium is very heterogeneous. In the present paper we use a multivariate state space framework, that substantially expands the traditional vector error correction approach, to analyze the short run impact of money on prices in the U.S. between 1959Q1 and 2007Q4. The key contribution of this approach is that it allows to identify the impact of money growth on inflation without having to model money demand explicitly. The latter has proven to be one of the main obstacles to finding empirical evidence for the quantity theory of money. We solve this problem by capturing persistent movements of velocity - and thus implicitly of money demand - independent of their origin. Our results, that are proven to be robust to several modifications of the model, show a highly significant impact of money overhang on inflation in the US.

JEL-Classification: E31; E52; C32

Keywords: Velocity, multivariate state space model, exit strategy

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1 Introduction

Central banks all over the world increased money supply substantially in reaction to the current financial crises.¹ While this does not cause inflationary pressure at the moment due to the current business cycle environment, the question arises if and when excess liquidity endangers price stability.

While the long run relation between money and inflation is well established, empirical evidence on the transmission mechanism is very heterogeneous. Partially, this is due to the high dependency of the adjustment process on the current economic and institutional environment. This in turn induces strong volatility in the transmission from money to prices that renders current and lagged money growth ineffective in explaining inflation.

A key issue in the identification of the relation between money and prices is the identification of the “money overhang”. Since movements of money supply, that do not correspond to a matching money demand, first of all cause velocity to deviate from its equilibrium, this requires a decomposition of velocity into equilibrium and deviation.

First attempts in this direction have been undertaken by Orphanides & Porter (2000, 2001), who rely on the difference between velocity and the predicted velocity of a simple regression model for their decomposition.

Contrarily to their approach, we embed the decomposition in a full fledged macro econometric framework, that is inspired by the two pillar Phillips-curve P-Star-model developed by Gerlach & Svensson (2003).

While our paper is focused on explaining inflation, it relies on the long run assumptions that are commonly used in the money demand literature, where the long run validity of the quantity theory, is often taken for granted. Besides integrating the strands of literature that focus on the driving forces of inflation and money demand respectively, the present paper contributes to the literature in several ways:

First, we distinguish changes in money velocity that are due to institutional developments and thus do not induce inflationary pressure and changes that reflect transitory movements in money demand. Most notably we develop a multivariate state space model of velocity that allows a decomposition within a structural model, without applying restrictions on the causes of velocity development.

Then, we use our model to illustrate the consequences of the monetary

¹In the fourth quarter of 2008, immediately after the collapse of Lehman, the monetary base has been increased by roughly 50 percent in a single quarter. While the impact on M2 that is traditionally employed to analyze the relationship between money and prices is substantially smaller, the growth rates in 2008Q4 and 2009Q1 (3.5% and 3.0%) have been the highest rates observed since the 1970s.

policy that has been employed to mitigate the impact of the financial crisis. In addition to the simulation that is derived using the past behavior of the central bank, we discuss an alternate exit strategy.

The remainder of the paper is structured as follows. Section 2 further outlines the underlying theoretical concepts and relevant literature. Section 3 introduces the dataset that is used for our estimations. Section 4 presents the methodology that is used for velocity filtering. The corresponding results are found in section 5.1. The second subsection expands the core model with some robustness tests. Section 6 describes the policy scenarios based on our multivariate model. Section 7 concludes.

2 The link between money growth and inflation

Assuming that the long run equilibria of GDP and velocity are not dependent on money, the quantity theory of money predicts a positive relationship between monetary growth and inflation. Both, estimating the long term correlation of money and prices without risking the results to be driven by the common underlying trend, and estimating the short term impact of money growth on inflation, have been among the most frequently analyzed empirical problems of the last decades. Evidence from cross country studies strongly supports the one to one correlation of average money growth and average inflation that can be derived from the quantity theory, as noted by McCandless & Weber (1995) among others.

Nevertheless, the impact of money on prices is hard to identify within one country. De Grauwe & Polan (2005) have argued that the long run link between nominal money growth and inflation might be much looser than commonly assumed in countries which have operated in moderate inflation environments. This might explain the evidence supporting the quantity theory that is based on periods of volatile inflation, like. e.g. the study of Wahlroos (1985) covering Finland in the 1970s and early 1980s. However, in general the transmission process from money to prices seems to be strongly volatile. Nevertheless, some recent contributions argue that money growth does indeed affect inflation significantly if the correct measure of domestic monetary aggregates is chosen (Aksoy & Piskorski (2006)). Furthermore, most studies are not conclusive about the appropriate horizon over which money is related to inflation, see for instance Shapiro & Watson (1988) and Christiano, Eichenbaum & Evans (1999). Altogether, evidence whether present or lagged rates of money growth affect inflation is mixed at best. Since the

immediate impact of money growth on inflation strongly varies, an error correction approach that accounts for the total monetary growth that has not become inflation yet seems to be appropriate. For example, Lütkepohl & Wolters (2003) and Holtemöller (2004) find evidence for a long run relationship in a VEC approach where money and prices are considered to be $I(2)$ or $I(1)$ after a nominal to real transformation. Similar approaches have most prominently been used in the recent money demand literature. Especially P-Star-Models that have been proposed by Hallman, Porter & Small (1991) have been successful in explaining inflation in the Euro area, see Kaufmann & Kugler (2008), Svensson (2000) and references therein. Similar results have been obtained for Germany by Tödter (2002) and Tödter & Reimers (1994). However, the P-Star-approach has not yet been very successful in identifying the relationship between money and inflation in the US (Rudebusch & Svensson 2002). Many of these papers model movements in money demand that are due to a non-unity income elasticity of money demand or wealth.

However, even if inflation truly was 'always and everywhere a monetary phenomenon' in the long run, as stated by Friedman in his seminal 1963 book, a conventional vector cointegration approach - that includes some of the major driving forces of money demand - does not necessarily identify the long run relation between money and prices correctly, because it neglects the structural development of the velocity of money. Since excess supply and demand of money are captured by transitory movements of velocity in a world where real and nominal rigidities prevail, the identification of excess liquidity, that endangers price stability, is tied to the identification of equilibrium velocity. Thus, in our paper we try to investigate the behavior of velocity in more detail, to capture more information that might be relevant for the determination of future inflation. Most notably, we decompose velocity in a transitory and a persistent component within a macroeconomic framework that supplies the necessary identifying restrictions.

There have been first approaches to distinguish between equilibrium and current velocity by Orphanides & Porter (2000, 2001). Their models use the difference between velocity and the predicted velocity of a simple regression model that explains movements in velocity with the opportunity costs of holding money as an indicator for monetary pressure in their version of the P*-framework. This simple decomposition approach already allows substantial improvements in the identification of the impact of money on prices.²

²Research in a similar direction has been done by Bruggeman et al. (2005) who apply some frequency filtering techniques to velocity. Also out of the narrow field of money demand analysis, there has been increasing interest in the behavior of velocity recently. Benk, Gillman & Kejak (2010) for instance, embed money velocity in a DSGE model that is calibrated to US data. Serletis & Shahmoradi (2006) analyze the driving forces of the

Instead of using just a simple univariate regression to explain movements in money velocity we adopt a multivariate unobserved components decomposition of velocity, that allows the identification of the long run equilibrium velocity while applying less restrictive assumptions on specific driving forces of velocity. Contrarily to the P-star-approach that Orphanides & Porter use, we want to analyze through which channels the adjustment of velocity to its equilibrium happens. However, since the deviation of velocity from equilibrium is defined to be the part of velocity that is explained by the deviation of the opportunity costs of holding money from their equilibrium by Orphanides & Porter, the channel of adjustment is predefined in their approach. As these opportunity costs are mostly caused by central bank policy, money growth would be favored as channel of adjustment by construction. Thus, we choose an approach where we merely have to assume that an equilibrium exists, where deviations can be eroded by the growth of money, prices or production.³ Essentially, we do not only test, whether money velocity v_t exhibits a tendency to return to a long run equilibrium velocity v_t^* or not, but also through which channels this adjustment occurs.⁴

Unlike the bulk of the previous literature, we do not treat $m - p$ or $m - p - y$ as a single endogenous variable, but instead regress inflation, output growth and money growth on the “error correction term”, i.e. the transitory component of velocity, separately.

The model works with unadjusted money velocity and thus is similar to the setup used for example by Dreger & Wolters (2009) who impose a long run income elasticity of money demand of one.⁵ That is, we assume that velocity, albeit following a trend, is not driven by income in the short run. This differs from other recent approaches e.g. by Herwartz & Reimers (2006).⁶ While this assumption imposes a short run elasticity of money de-

US velocity of money in a GARCH-M Model. There is a related strand of literature that deals with the nonlinearities of money demand, see e.g. Calza & Zaghini (2009).

³Anyhow, we do find that monetary policy does indeed drive a large share of adjustment. Hence, our results are more or less in line with Orphanides & Porter as discussed in detail in the results section.

⁴Since the deviation of velocity from its long run equilibrium is mostly a short term adaptation to monetary policy, we refer to this deviation as ‘money overhang’ in the remainder of this paper. This roughly follows the idea of Gerlach & Svensson (2003) since our concept of non equilibrium velocity adopts the role of their money gap. The key difference is, that we only consider those parts of money supply to be an “overhang” that have not yet had an impact on prices.

⁵This assumption is not uncontroversial, but has been confirmed for some countries. See Wolters, Teräsvirta & Lütkepohl (1998) for the case of Germany.

⁶However, the decomposition we perform should identify the correct structural component of velocity independent of its causes.

mand on income of one on the model, it does not impose this restriction in the long run. Persistent changes of any potential driving force of velocity are by construction attributed to the persistent velocity component. Thus, a change in velocity that is caused by a persistent change of income is correctly identified as non-transitory. The same holds true for developments that are caused by institutional change as financial innovation, wealth and other factors that are discussed in the corresponding literature. This high flexibility of our model allows a parsimonious specification in terms of further controls. Anyhow, we test the income elasticity of money demand explicitly in our robustness section.

3 Dataset

To investigate our research question we analyze quarterly data from the United States. Our sample covers the period from 1959Q1 until 2007Q4. While data until 2009Q3 is available, we want to exclude the current crisis, since strong movements at the end of a sample, as they were recently observed in the development of GDP and the monetary aggregates, are known to strongly distort the filtering techniques we use. The vector of interest is $x = [m, p, y]$. In our preferred specification the price indicator p chosen is the consumer price index (CPI). As alternate measures we use core inflation, i.e. CPI excluding certain items that face volatile price movements, notably food and energy, and the implicit price deflator in the robustness tests. The monetary aggregate m used in the baseline specification is M2. However, we also test our econometric models using an alternate specification based on a more narrow definition of money, M0. Production y is defined as GDP throughout the paper.

Table 1: Dickey-Fuller tests

Dickey-Fuller	Money Base	M2	Output	CPI
Test Statistic	-10.28	-6.13	-7.04	-2.85
1%	-3.46	-3.46	-3.46	-3.46
5%	-2.88	-2.88	-2.88	-2.88
10%	-2.57	-2.57	-2.57	-2.57

The individual series have been tested to be difference stationary, at least at a ten percent significance level. Thereby, we used the augmented Dickey-Fuller test; see table 1. Results based on a more powerful test proposed by Ng & Perron (2001), can be found in the appendix (tables A.1, A.2, A.3,

A.4). All data series are seasonally adjusted. Graphs of all time series used in the basic setup are found in the appendix (see Figure A.1).

4 Model and Methodology

The starting point for our analysis is the quantity theory:

$$m_t + v_t = y_t + p_t, \quad (1)$$

where m , p , y and v are the natural logarithms of money, prices, output and velocity and t is a time index.

If real money supply exceeds the real money demand that corresponds to the current output level, this is initially reflected by decreased velocity of money since the prices (and thus real money supply) are not able to adjust instantly. The efforts of economic agents to adjust their liquidity position and spending behavior to match their preferences, cause a return of the velocity to its equilibrium and a simultaneous increase of the price level. Therefore, real money supply decreases until it once again matches the real money demand that corresponds to the output level. In this quantity theory framework, the mismatch of real money supply and real money demand is reflected in deviations of velocity from its equilibrium. One of the key driving forces of inflation can thus be written as follows:

$$-\tilde{v}_t = m_t - p_t - y_t + v_t^*. \quad (2)$$

By definition $-\tilde{v}_t$ is supposed to return to its equilibrium value of zero. Since a negative deviation of the velocity from its equilibrium is the consequence of real money supply exceeding real money demand, we interpret $-\tilde{v}_t$ as money overhang following Gerlach & Svensson (2003). Therefore, to allow the intuitive interpretation of our results in line with the quantity theory, all our models use $-\tilde{v}_t$ instead of \tilde{v}_t to analyze the consequences of the deviation of velocity from equilibrium.

Under certain conditions $-\tilde{v}_t$ could be interpreted as the error correction term of a cointegration relationship between money, output and prices. However, classical cointegration analysis is only able to cope with this framework, if the equilibrium level of velocity meets some criteria: If equilibrium velocity is constant or follows a linear trend this can be captured by conventional CVEC models with constant and trend in the cointegration relationship. The unobservable equilibrium level of velocity v^* then is implicitly modelled as the constant term and the time dependent component of the error correction specification. A linear dependency of the equilibrium velocity on output (or

any other variable included in the cointegration relation) can be included in the cointegration vector that would else be set to $[1, -1, -1]$.

However, these assumptions are fairly restrictive. Velocity is driven by a number of factors, that are partly unobservable or hardly observable at least. Most notably, the change of the institutional, economic and technological framework that affects velocity can neither be measured nor assumed to follow a linear trend. Furthermore, financial innovation and other events that cause equilibrium velocity to change possibly occur too often to be modeled as structural breaks.

Therefore, we recommend an approach where equilibrium velocity is treated as an unobservable variable in a multivariate state space model, that embeds the attempted decomposition of velocity into equilibrium and deviations from equilibrium into a standard macroeconomic framework. That is, we simultaneously estimate the deviation from equilibrium and the macroeconomic consequences of this deviation on prices, nominal money supply and output.

The major advantage of this approach is, that the decomposition of velocity into a persistent component, i.e. equilibrium velocity, and a transitory component, i.e. money overhang, allows to capture any persistent change of equilibrium velocity independent of its origin. The effects of wealth or income on money demand that are discussed in the literature are thus implicitly included. This allows for a very parsimonious model specification, that is restricted to the key variables of interest.

Methodologically, our approach follows Gerlach & Smets (1999) who embed the unobserved components decomposition of GDP into a multi-equation system that takes a New Keynesian Phillips Curve into account. Our state space model then takes the following form.

The signal equations are given by:

$$\begin{bmatrix} \Delta m \\ \Delta p \\ \Delta y \end{bmatrix}_t = A(-\tilde{v}_{t-1}) + B(L) \begin{bmatrix} \Delta m \\ \Delta p \\ \Delta y \end{bmatrix}_t + u_t \quad (3)$$

$$v_t = \tilde{v}_t + v_t^*$$

The two state equations that describe the behavior of the components of velocity are given by:

$$v_t^* = v_{t-1}^* + \alpha_1 + \varepsilon_{1t} \quad (4)$$

$$\tilde{v}_t = \phi(L)\tilde{v}_t + \varepsilon_{2t}.$$

In here, A is a coefficient vector, $B(L)$ is a lag polynomial of coefficient matrices, $\phi(L)$ is a lag polynomial of autoregressive coefficient vectors, and u_t and ε_{it} are vectors containing i.i.d. error terms. This state space representation where the evolution of the signal variables is explained by the (unobserved) states is estimated using the Kalman-filter.⁷ For a given initial state and given coefficient matrices the Kalman-filter provides recursive estimates for the state in period t and its variance using the newly arrived information of the signal variable and the lagged estimated states. The coefficient matrices are then estimated with standard MLE by numerically optimizing the likelihood that can be derived from the prediction error decomposition of the Kalman-filter. To enforce our concept of an equilibrium velocity, a stationarity condition is enforced regarding the transitory component of velocity, i.e. money overhang.⁸

5 Results

5.1 Results of the baseline model

The reported results use five lags, as suggest by the AIC (see table 2).⁹

Table 2: Information Criteria

Lags	AIC	BIC	HQ
2	-15.5026	-15.1821*	-15.3727
3	-15.6407	-15.1581	-15.4450*
4	-15.6470	-15.0010	-15.3850
5	-15.6864*	-14.8758	-15.3576
6	-15.6350	-14.6584	-15.2389

Notes: The minimum is denoted with a *.

⁷A detailed survey regarding state space methods can be found in Durbin & Koopman (2001) and Harvey (2006).

⁸There is a cluster of parameter combinations with a high likelihood that satisfies this condition, where most of the volatility of the velocity of money is attributed to the trend rather than to the cycle. Since this is economically implausible we exclude this region of the parameter space.

⁹Owing to the resulting complexity of the likelihood function we use different optimization procedures to rule out possible local maxima. Therefore, we used a slightly adapted version of the genetic optimization algorithm developed by El-Shagi (2010), and the simplex routine provided by the Matlab optimization toolbox. Both routines produce similar results. The ones presented here are based on the Matlab routine.

BIC and Hannan-Quinn both indicate fewer lags. However, in specifications with less than 4 lags there is a high degree of residual serial correlation as seen in table 3. The first AR coefficient of the cyclical component is higher than one. This is presumably driven by the strong autoregressive process of inflation and money growth. While strong deviations from the long run equilibrium cannot be sustained for too long, the momentum in the dynamics of money and inflation can cause extended periods of growing deviation until the monetary pressure finally overtakes. Thus, models with less than two lags do not allow to estimate a stationary cyclical component without adding very strict additional assumptions.

According to a Portmanteau test there is no residual serial correlation in the preferred model specification (see table 3).

Table 3: Portmanteau test for autocorrelation of residuals

Lags	Lagorder of Model		
	2	3	5
1	NaN	NaN	NaN
2	NaN	NaN	NaN
3	0.0000	NaN	NaN
4	0.0000	0.0051	NaN
5	0.0001	0.0182	NaN
6	0.0002	0.0678	0.2920
7	0.0004	0.0980	0.3634
8	0.0001	0.0446	0.2118
9	0.0001	0.0192	0.0986
10	0.0002	0.0583	0.2547

Notes: The listed values are p-values.

The residuals are normally distributed according to both a Cramer-von-Mises test and a Watson test (see table 4). Figure 1 provides a visual inspection of the transitory and the trend component of velocity that is derived using the preferred five lag specification.

The multivariate Kalman-filter already identifies a slight monetary overhang at the end of the sample, i.e. before the financial turmoil. This is mostly driven by the huge increase in money supply that followed the collapse of the dot-com-bubble. The subsequent reduction in money overhang - that is often held responsible for the end of the real estate boom, is also

Table 4: Empirical Distribution Tests

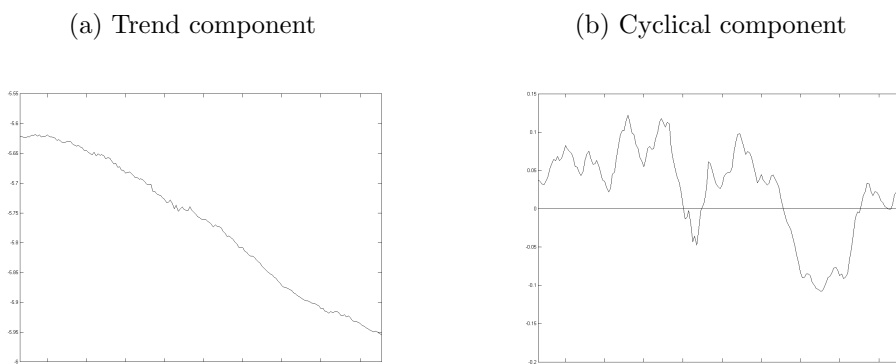
	U1	U2	U3
Watson-Test	0.0705	0.150	0.6692
Cramer von Mises	0.0735	0.119	0.591

Notes: Both tests consider the null of normality. The listed values are p-values.

visible. However, it is not sufficient to bring the monetary overhang back to zero.

The knowledge of the money overhang before the crisis is essential to estimate the total money overhang that has been accumulated due to the recent monetary policy. We do not include the crisis period into the estimation since state space models of the suggested type are sensitive to outliers at the end of sample.

Figure 1: Velocity components



Furthermore, the filter finds evidence for an increased speed in the development of equilibrium velocity in the middle of the sample. This roughly corresponds to the results of Orphanides & Porter (2001).

Our model shows a clear and significant positive impact of money overhang on inflation. The correlation coefficient of 0.014 implies a change of quarterly inflation of about 0.32 percentage points (in annualized rates) if the money overhang changes by one standard deviation. Neither money growth nor output growth react significantly to the monetary overhang.

Table 5: Error Correction Estimates

Trend Specification	Error Correction		
	Δ CPI	Δ M	Δ GDP
Linear trend	0.006 (2.853)	-0.004 (-1.145)	0.0001 (0.015)
Kalman-filtered trend	0.014 (2.464)	-0.008 (-0.908)	0.018 (1.696)

Notes: t-values are given in parentheses.

To summarize, we clearly find that the return of velocity to its long run equilibrium is strongly driven by inflation. Due to the caveat that we partially enforce stationarity of money overhang, this does not necessarily prove that inflation is driven by money supply. However, the results strongly support this hypothesis and show that the data is absolutely in line with the assumption that money drives inflation. The key results are summarized in table 5. The table includes the adjustment coefficients, i.e. the vector A , and the corresponding t-statistics for the specifications outlined above. To give a reference point that allows comparability, the table also reports the results obtained using a standard vector error correction model with a trend in the cointegration relation.

5.2 Robustness and Extensions

To strengthen our arguments we impose several robustness tests that generally brace the validity of our results.

Different variables As a first robustness check we incorporated different proxies for money and prices. In addition to M2 that is used in our baseline specification the model is tested with the monetary base (M0) that is closer to monetary policy. GDP deflator and core CPI are used as alternative price measures. The first one is more closely related to our production measure since it includes all products. The latter allows to exclude prices for commodities like oil, which are rather driven by short term dynamics on international markets than by domestic monetary policy.

Both, the impact of money overhang on inflation and the impact of money overhang on the growth of the money stock itself are quite robust. As can be seen in table 6, all specifications using M2 and the clear majority of

specifications using M0 we find an impact of money overhang on inflation of roughly the same magnitude.

Table 6: Robustness Check - Different Variables

Money	Prices	δM	ΔP	ΔY
MB	cpi	-0.11 (-3.76)	0.03 (1.72)	0.06 (1.53)
MB	core cpi	-0.04 (-2.34)	0.02 (1.61)	0.04 (1.65)
MB	ipd	-0.04 (-2.63)	0.01 (2.02)	0.01 (0.67)
M2	cpi	-0.01 (-0.90)	0.02 (2.50)	0.02 (1.40)
M2	core cpi	-0.02 (-2.03)	0.01 (2.20)	0.02 (1.48)
M2	ipd	-0.01 (-1.45)	0.01 (1.93)	0.02 (1.55)

Notes: t-values are given in parentheses.

The adjustment coefficient describing the impact of the monetary overhang on inflation is slightly larger in the setups, where velocity is computed based on the monetary base. However, this is mostly due to the higher volatility of M2-velocity. In terms of the inflation movement that is caused by a one standard deviation change of velocity both specifications yield very similar results.

Furthermore, the impact of cyclical velocity on prices is more significant if the monetary base is used as money measure. This reflects the proximity of monetary base to actual monetary policy actions. Contrarily, M2 reacts to monetary policy only after a while and might be driven by other investment issues. A reaction of M2 to inflation which might partially stem from the central banks reaction to inflationary tendencies is thus obfuscated by more noise and therefore less significant. On the other hand, M2 contains more information about the relevant liquidity endowment of the economy. This might explain, why the reaction of prices is more significant if velocity is computed based on M2.

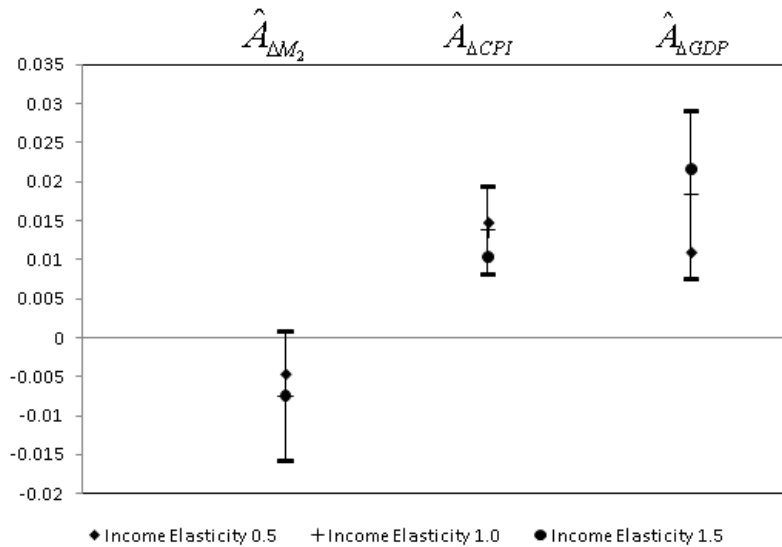
Robustness to different specifications of the income elasticity of money demand Since the impact of income on velocity is mostly of long run nature, it should correspondingly be captured by our persistent velocity component. However, to make sure that a potential stable short run correlation of income and velocity, that cannot be ruled out definitely, does not distort our results, we test a battery of models where income elasticity of money demand is explicitly modeled.

Essentially this is done by replacing money velocity with an adjusted velocity that is given by:

$$v_t^{adj} = m_t - p_t - \gamma y_t. \quad (5)$$

This alternative setup is then estimated in our multivariate approach for a range of γ s between 0.3 and 1.5, that covers most values for the income elasticity of money that are found in the previous empirical literature or derived in the respective theoretical papers (Knell & Stix 2005).

Figure 2: Estimates of the Adjustment Coefficients with varying γ

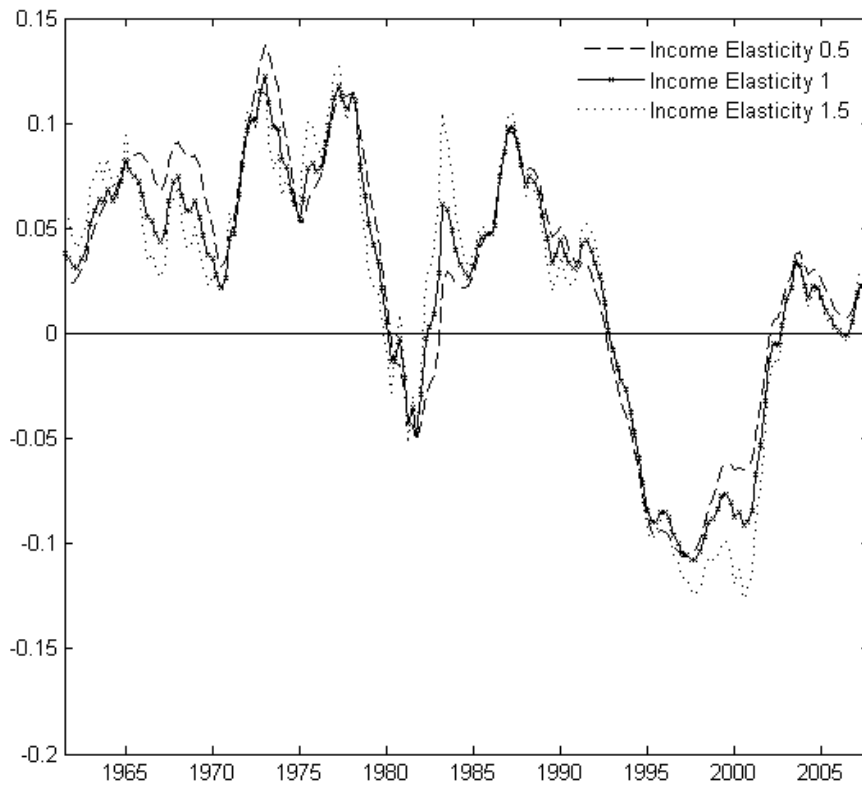


Note: $\hat{A}_{\Delta M_2}$, $\hat{A}_{\Delta CPI}$, $\hat{A}_{\Delta GDP}$ refer to the components of the estimates of the coefficient vector A . The horizontal bars represent one standard error around the estimate in the baseline model with $\gamma = 1$.

The likelihood surface along the γ -dimension is very flat and does not allow to distinguish the likelihood of the different setups with reasonable certainty. Anyhow, the results vary only marginally. Figure 2 summarizes

the adjustment coefficients from models using income elasticities of $\gamma = 0.5$, $\gamma = 1.0$ and $\gamma = 1.5$. It can easily be seen that the coefficient estimates are barely affected by the choice of γ .

Figure 3: Cyclical components of velocity for selected γ s



Similarly, the cyclical component of velocity is virtually identical for all models as can be seen in Figure 3. Due to this ability of the model to deduct a reasonable estimate of money overhang even if the income elasticity of money demand is misspecified (within a certain limit), the model is inappropriate to estimate this elasticity precisely. Residuals - and hence likelihood - would only differ substantially between the models if the state variable estimates differed.

6 Consequences of the monetary reaction on the financial crisis

Our model allows simulations that are based on different policies. Since the recent monetary policy creates a substantial challenge for future monetary policy, this is of major interest.

6.1 The baseline simulation

For our simulations we extend the dataset to the current end of the available data (2010Q2). However, since outliers at the sample end would distort the results, we take the parameter estimates that are obtained from our general sample (i.e using data ranging from 1959Q1 to 2007Q4). Essentially this exercise is similar to common impulse response functions, with the key difference that the shock is not applied to a single variable but is given by the actual developments that could be observed since the end of the estimation window.

Since Δm is determined endogenously the model, the scenario that is presented in this section includes the implicit assumption that the exit strategy of the Federal Reserve mirrors the previous policy for the reduction of excess liquidity. Although this implies an annual cutback in M2 that has not been seen in the past decades, the model predicts an inflationary wave with annual inflation rates (quarter over quarter) above the 5% threshold for 2 years, peaking at roughly 6%.

Inflation rates of this magnitude for more than a single quarter have the last time been observed during the oil crisis.

The quite broad confidence bands that can be seen in Figure A.2 (appendix) are mostly due to high degree of uncertainty in output growth that subsequently causes high uncertainty in future inflation that depends on growth.

6.2 Alternate policy scenarios

Due to the monetary policy in response to the crisis excess liquidity and the corresponding inflationary pressure reached a magnitude that is unique in post stagflation period. Thus, the behavior of central banks that could be observed in the past possibly is no valid estimate for the exit strategy of the Federal Reserve.

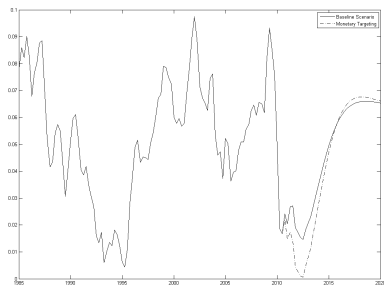
We simulate our model with an alternative approach to combat excess liquidity more drastically.

Our model does not include an explicit policy instrument as interest rates. Assuming for simplicity that the central bank can roughly control money supply, we thus employ Δm as a substitute policy variable. Since the key issue, we want to tackle with our forecast, is the size of a possible inflationary wave rather than its precise timing, a possible lag between monetary policy actions and money growth is of limited importance. Thus, this simplification is feasible, if the central bank can control M2 growth in the medium run.

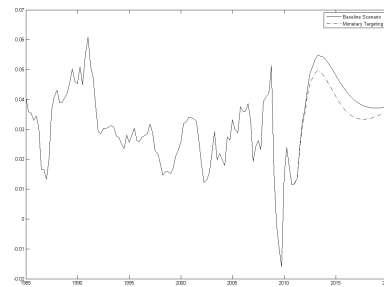
We substitute the original regression coefficient of money overhang in the money growth equation by an alternative value of three times the size. The constant in the money growth equation is correspondingly adjusted to maintain the original steady state inflation rate. This roughly corresponds to the idea of monetary targeting if we assume that the central bank aims to correct for past 'mistakes'.

Figure 4: Policy simulation

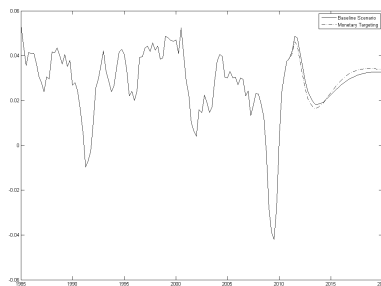
(a) Money Growth Simulation



(b) Inflation Simulation



(c) Output Simulation



Albeit this change of the policy seems quite strong, the model shows

that this is not sufficient to prevent the inflationary “wave” that is seen in the baseline model. Even though the impact on inflation is limited, we can see that the negative impact on growth in the quarter in which the money overhang is removed is slightly more pronounced.

This shows that the options of the central bank to cut back money supply to the desired level are limited. Since it is not only money stock but also money growth that affects output growth, a quick return to the pre crisis liquidity endowment comes at a cost, even if the liquidity is not needed any longer for its original purpose of stabilizing the financial sector. As a caveat, it has to be said that total growth possibly will be slightly higher due to the closing output gap that is not included in this model. Since this does not affect the difference between the scenarios, these results nevertheless emphasize the substantial costs that are associated with the exit strategies that are necessary to avoid high inflation.

Figure 4 shows the 40 period ahead forecasts from the baseline model and the the monetary targeting scenario. Albeit knowing that a 40 period ahead forecast has to be taken with caution, we want to present the full dynamics of the system until the relevant part of the response to the policy shock has died out.

7 Conclusion

Altogether we find clear evidence that inflation is heavily influenced by money overhang, once velocity is appropriately taken care of in the underlying definition of money overhang. The changes in the growth rate of long run equilibrium velocity seem to be one of the major problems of previous attempts to analyze the role of money for inflation. These results could only be achieved by including velocity in a structural model that nevertheless does not impose any restrictions on possible driving forces of velocity. However, one caveat of our approach is that the (rarely doubted) existence of a long run equilibrium of velocity has to be exogenously imposed on the econometric model. Conditional on this existence we can strongly support the thesis of inflation as a monetary phenomenon.

Our simulations built on the estimates suggest, that a period of higher inflation should come once the real economy recovers, even if the central bank withdraws liquidity from the market much stronger than it did in the past.

To avoid high inflation or the problems that might arise if excess liquidity is reduced by negative money growth, it seems most feasible to stabilize the current level of velocity, i.e. to deliberately render the transitory change in velocity persistent. A substantial part of the current velocity can most

likely be explained by the increased risk aversion of banks in response to the current crisis and the corresponding deleveraging. Since the risk preference of banks in the pre crisis period is widely considered as too high, a banking regulation that prevents the banks to return to their old behavior might not only prevent inflationary pressure but also reduce the systemic risk of the financial sector.

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A Graphics and Tables

Figure A.1: Data series

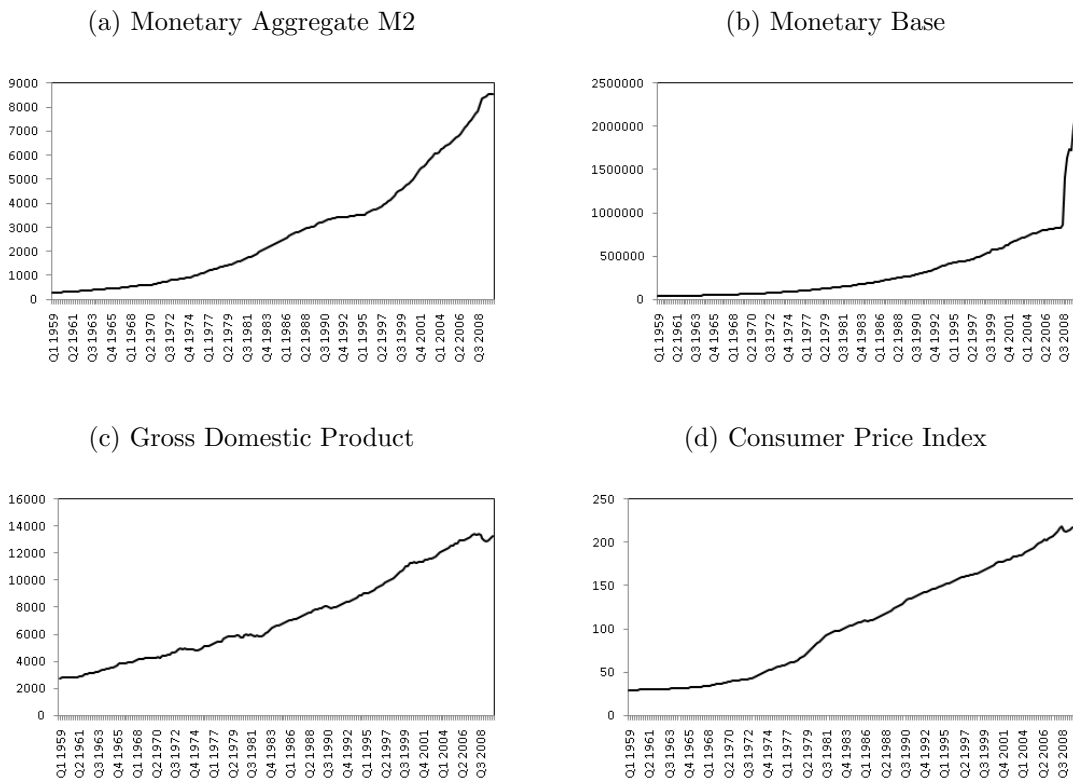


Figure A.2: Inflationary reaction with 80 percent confidence bounds

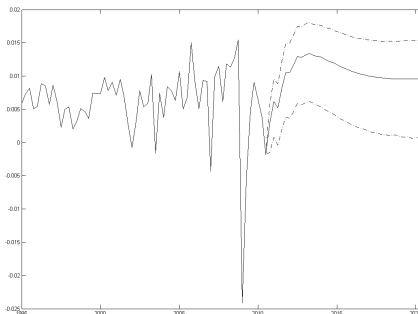


Table A.1: Ng-Perron Test for CPI

Ng-Perron	MZa	MZt	MSB	MPT
Test Statistic	-8.07	-2.01	0.25	3.03
1%	-13.80	-2.58	0.17	1.78
5%	-8.10	-1.98	0.23	3.17
10%	-5.70	-1.62	0.28	4.45

Table A.2: Ng-Perron Test for real GDP

Ng-Perron	MZa	MZt	MSB	MPT
Test Statistic	-8.09	-1.96	0.24	3.21
1%	-13.80	-2.58	0.17	1.78
5%	-8.10	-1.98	0.23	3.17
10%	-5.70	-1.62	0.28	4.45

Table A.3: Ng-Perron Test for M2

Ng-Perron	MZa	MZt	MSB	MPT
Test Statistic	-29.12	-3.72	0.13	1.14
1%	-13.80	-2.58	0.17	1.78
5%	-8.10	-1.98	0.23	3.17
10%	-5.70	-1.62	0.28	4.45

Table A.4: Ng-Perron Test for MB

Ng-Perron	MZa	MZt	MSB	MPT
Test Statistic	-87.52	-6.61	0.08	0.30
1%	-13.80	-2.58	0.17	1.78
5%	-8.10	-1.98	0.23	3.17
10%	-5.70	-1.62	0.28	4.45