Institut für Wirtschaftsforschung Halle
Halle Institute for Economic Research

Monetary Policy in a World Where Money (Also) Matters

Makram El-Shagi
Sebastian Giesen
Logan J. Kelly

July 2012 No. 6

IWH-Diskussionspapiere
IWH Discussion Papers

Authors: *Makram El-Shagi*
Halle Institute for Economic Research
Department of Macroeconomics
E-mail: Makram.El-Shagi@iwh-halle.de
Phone: +49 345 7753 835

Sebastian Giesen
Martin-Luther-University Halle-Wittenberg and
Halle Institute for Economic Research
Department of Macroeconomics
E-mail: Sebastian.Giesen@iwh-halle.de
Phone: +49 345 7753 804

Martin-Luther-University Halle-Wittenberg

Logan J. Kelly
University of Wisconsin – River Falls
E-mail: LoganKelly@uwrf.edu

Editor:
HALLE INSTITUTE FOR ECONOMIC RESEARCH – IWH
The IWH is a member of the Leibniz Association.

Address:	Kleine Maerkerstrasse 8, D-06108 Halle (Saale), Germany
Postal Address:	P.O. Box 11 03 61, D-06017 Halle (Saale), Germany
Phone:	+49 345 7753 60
Fax:	+49 345 7753 820
Internet:	http://www.iwh-halle.de

ISSN 1860-5303 (Print)
ISSN 2194-2188 (Online)

Monetary Policy in a World Where Money (Also) Matters

Abstract

While the long-run relation between money and inflation as predicted by the quantity theory is well established, empirical studies of the short-run adjustment process have been inconclusive at best.

The literature regarding the validity of the quantity theory within a given economy is mixed. Previous research has found support for quantity theory within a given economy by combining the P-Star, the structural VAR and the monetary aggregation literature. However, these models lack precise modelling of the short-run dynamics by ignoring interest rates as the main policy instrument.

Contrarily, most New Keynesian approaches, while excellently modeling the short-run dynamics transmitted through interest rates, ignore the role of money and thus the potential mid- and long-run effects of monetary policy.

We propose a parsimonious and fairly unrestrictive econometric model that allows a detailed look into the dynamics of a monetary policy shock by accounting for changes in economic equilibria, such as potential output and money demand, in a framework that allows for both monetarist and New Keynesian transmission mechanisms, while also considering the Barnett critique. While we confirm most New Keynesian findings concerning the short-run dynamics, we also find strong evidence for a substantial role of the quantity of money for price movements.

Keywords: monetary policy, P-Star, structural identification, Barnett critique

JEL Classification: E31, E52, C32

Monetary Policy in a World Where Money (Also) Matters

Zusammenfassung

Während die von der Quantitätstheorie vorhergesagte Langfristbeziehung zwischen Geld und Inflation gut dokumentiert ist, sind die Ergebnisse empirischer Studien zum kurzfristigen Anpassungsprozess wenig aufschlussreich.

Die diesbezügliche Literatur, die versucht, die Gültigkeit der Quantitätstheorie mit Zeitreihenmodellen innerhalb eines Landes zu bestätigen, kommt zu gemischten Ergebnissen. Aktuelle Forschungsarbeiten, in denen P-Star-Modelle mit strukturellen VAR-Modellen kombiniert werden und die die Erkenntnisse der Aggregationstheorie bezüglich der relevanten Geldmenge berücksichtigen, bestätigen die Quantitätstheorie. Allerdings vernachlässigen diese Modelle eine präzise Modellierung der kurzfristigen Inflationsdynamik, da die Zinssätze – als wesentliches Politikinstrument – nicht berücksichtigt werden.

Im Gegensatz dazu ignorieren die Neukeynesianischen Modelle, die bei der Kurzfristmodellierung sehr gut abschneiden, die Rolle der Geldmenge und vernachlässigen so die denkbaren mittel- und langfristigen Konsequenzen der Geldpolitik.

In diesem Papier stellen wir ein übersichtliches und dabei nur wenig restriktives ökonometrisches Modell vor, das einen detaillierten Blick auf die Dynamik nach einem geldpolitischen Schock erlaubt, indem es die Veränderung unbeobachtbarer Gleichgewichtsgrößen wie Produktionspotenzial und Geldnachfrage abbildet. Das ökonometrische Modell erlaubt so die Neukeynesianische wie auch monetaristische Transmission geldpolitischer Schocks und berücksichtigt gleichzeitig die Barnett-Kritik.

Die Schätzergebnisse bestätigen einerseits die meisten Neukeynesianischen Effekte für die kurze Frist, deuten aber gleichzeitig stark auf eine langfristig wichtige Rolle der Geldmenge für die Preisentwicklung hin.

Schlagwörter: Geldpolitik, P-Star, strukturelle Identifikation, Barnett-Kritik

JEL-Klassifikation: E31, E52, C32

1 Introduction

Ever since Sims (1980) cast doubt on the informational content of simple-sum monetary aggregates, the question of how monetary policy shocks propagate throughout the economy has been of interest to the profession for many years. But while the long run relation between money and inflation is well established, empirical studies of the short-run adjustment process have been inconclusive at best. There have been the three strands of literature that have attempted to reconcile the short-run adjustment process: the P-Star literature, the structural VAR literature and the monetary aggregation literature.

The P-Star literature, beginning with Hallman et al. (1991), has attempted to reestablish the role of money supply in explaining price movements as suggested by the quantity theory, which has often been validated using cross country data (see e.g. Teles and Uhlig, 2010, Herwartz and Reimers, 2006, McCandless and Weber, 1995). The most successful of these models follows the two-pillar Phillips Curve approach proposed by Gerlach and Svensson (2003), where a standard Phillips Curve framework is extended by including a measure of excess liquidity.[1] Movements of equilibrium velocity have proven to be a key obstacle to identifying excess liquidity, though. Most approaches that try to include nonlinear movements of velocity rely on explaining money demand either through the opportunity costs of holding money (see, e.g., Orphanides and Porter, 2000) or by accounting for the role of wealth and asset prices (see, e.g., Dreger and Wolters, 2009).

While the P-star literature deals mostly with the question of whether excess liquidity causes inflation, the structural VAR literature deals with the identification of monetary shocks and transmission of those shocks throughout the economy.[2] In the last decade, sign restrictions have become a popular method of identifying structural shocks (see, e.g., Faust, 1998, Canova and De Nicoló, 2002, and Uhlig, 2005). This technique also allows us to embed a more convincing economic explanation into structural econometric models than does the standard Cholesky decomposition.

Finally, the simple-sum aggregates, used in many of the studies in the both the P-star and

[1]While these models have been applied, there have been difficulties fitting these models to the United States samples that include the Great Moderation, P-star models have been particularly successful in explaining inflation in Europe (see e.g. Kaufmann and Kugler (2008), Svensson (2000), and Tödter (2002)).

[2]This includes the seminal contributions of Gordon and Leeper (1994), Leeper et al. (1996), Bernanke and Mihov (1998), Christiano et al. (1996), and Christiano et al. (1999).

the Structural VAR literatures, have no theoretical link to the monetary services flow (see, e.g., Barnett 1980, Barnett and Serletis 2000 and Barnett and Chauvet 2011), significantly overstate the money stock (Barnett, Chae, and Keating 2005 and Barnett, Keating, and Kelly 2008), and mask the dynamics of the relationship between money and interest rates (Kelly 2009 and Kelly, Barnett, and Keating 2011). The problem stems from an internal inconsistency between the assumption made in the macroeconomic model and the and the aggregator functions used to produce the monetary aggregate data supplied by central banks. This internal inconsistency can cause serious distortions in the estimated dynamics of the macroeconomic model. Chrystal and MacDonald (1994, p. 76) first called this issue the "Barnett Critique." Thus, Kelly, Barnett and others argue that much of the difficulty understanding short run relationship between money and the rest of the economy is the result of the measurement error exhibited by simple-sum monetary aggregates.

The "Barnett Critique" remains an important issue as Belongia and Ireland (2011, p. 1) state, "[D]espite this widespread appreciation of the advantages of Divisia monetary aggregation...throughout the past three decades and down to the present day, analysts have continued, overwhelmingly, to rely on the readily available but conceptually flawed simple-sum measures."

Though the literature regarding the short-run adjustment process to monetary policy shocks within a given economy is mixed, El-Shagi, Giesen, and Kelly (2011) have found support for quantity theory within the U.S. economy by combining these strands of literature.While this framework improves the the identifications of money supply shocks by estimating long-run money demand, they were unable to account for short-run fluctuations of money demand.

In this paper, we create a parsimonious model that allows a detailed look into the dynamics of a monetary policy shock by identifying persistent and non-persistent money demand and supply shocks by building upon the framework established by El-Shagi et al. (2011). This is crucial because previous research has found that there exists a time inconsistency problem in monetary policy, since monetary policy has short-run benefit, i.e. current monetary policy affects GDP in the short-run, and long-run costs, i.e. money overhang affects prices in the long-run (see, e.g., Nicolini, 1998 and Taylor, 1993). To evaluate monetary policy appropriately, we have to take great care when identifying what part of a shock coming from the money market truly is a policy shock. Therefore, the model must (i) include a variable that is as close as possible to the actual policy variable, Effective Federal Funds Rate in our model, (ii) be at a frequency that closely mirrors the the policy decisions of the central bank, monthly in our model, and (iii) be able to to distinguish between policy and non-policy shocks in both the long-run and in the short-run.

The key contribution of this approach is to provide a common ground for the fully structural DSGE models and the purely data driven VAR approaches. By explicitly modeling the latent variables driving the economy and thereby allowing to correctly identify transitory disequilibria and their adjustment, we are able to capture the dynamics of the economy not unlike DSGE models. Actually, the estimation of DSGE models usually relies on reduced form state space models similar to our own (see Ireland, 2004). However, we impose far less restrictions on the data, since we do not have to assume specific functional forms of the underlying concepts, such as utility and production functions. Thus, similar to the VAR literature, we can truly allow the data to speak, providing impulse responses that might be closer to what we observe in the real world.

2 Connecting the Divisia Index to the Quantity Theory

The methodology employed in this paper is rooted in the Quantity Theory of Money, and fundamental to the Quantity Theory is the so called equation of exchange. In this section, we provide a theoretical foundation for connecting the equation of exchange to Divisia monetary aggregates. To do so, we begin by reviewing a money demand framework derived by Barnett and Zheng (2011).[3] This is a non-trivial exercise given that the traditional equation of exchange contains a measure of the money stock where Divisia monetary aggregates measure service flow.

Following Barnett and Zheng (2011), let the representative agent choose consumption, C_t, real

[3] See also Belongia and Ireland (2011), who develop a similar DSGE framework that attempts to account for the "Barnett Critique" by carefully integrating the monetary aggregator function into the DSGE model, and Alvarez et al. who do not account for the "Barnett Critique" but are able to establish a relationship between the money stock and prices in an inventory model of money demand.

monetary service flow, M_t/P_t and labor supply, N_t, to maximize its life-time utility function,[4]

$$E_0 \sum_{t=0}^{\infty} \beta^t H_t\left(C_t, \frac{M_t}{P_t}, N_t\right), \tag{1}$$

such that for all $t = 0, 1, 2, \ldots$

$$\int_0^1 P_t(i)C_t(i)di + B_t + \int_0^1 M_t(j)dj = \\ Q_{t-1}B_{t-1} + \int_0^1 R_{t-1}(j)M_{t-1}(j)dj_t + W_tN_t - T_t \tag{2}$$

where

$C_t(i) =$ the quantity of the household's consumption of good i during period t,

$M_t(j) =$ the quantity of monetary asset j held by the household in period t,

$P_t(i) =$ the price of consumption good i in period t,

$R_t(j) =$ the gross return on monetary asset j held in period t,

$B_t =$ the quantity of bonds held by the household in period t,

$Q_t =$ the gross return on bonds held in period t,

$W_t =$ the nominal wage rate in period t,

$T_t =$ the nominal amount of taxes paid by the household in period t.

The dynamic programing problem implied by this general setup results in the following first order conditions,

$$\frac{H_{Ct}}{P_t} = Q_t\beta E_t\left\{\frac{H_{Ct+1}}{P_{t+1}}\right\} \tag{3}$$

$$\frac{H_{Mt}(j)}{H_{Ct}} = \frac{Q_t - R_t(j)}{Q_t}, \forall j \in [0,1] \tag{4}$$

$$-\frac{H_{Nt}}{H_{Ct}} = \frac{W_t}{P_t}, \tag{5}$$

where (4) is the household's period t demand for monetary asset j. It is easy to see that the right hand side of (4) is the period t user cost of monetary asset j.

[4]This model does not begin with the representative agent's elementary utility function, since it contains aggregate money. However, if money has positive value in equilibrium, then there exists a derived utility function containing money (Arrow and Hahn, 1971). The money in the utility function technique allows us to remain agnostic as to the specific motive for holding money.

To find the demand for aggregate money, sum the marginal utility of the individual monetary assets to get

$$\frac{\int_0^1 U_t(j)M_t(j)dj}{M_t} = \frac{H_{mt}}{H_{Ct}}, \tag{6}$$

which by Fisher's factor reversal reduces to

$$\Psi_t = \frac{H_{Mt}}{H_{Ct}}, \tag{7}$$

where Ψ_t is the aggregate user cost of money in period t.[5] Now, to find a closed form for the money demand function, assume the representative agent's utility function is the CES, then (7) becomes

$$\Psi_t = \left(\frac{\theta}{1-\theta}\right)\left(\frac{P_tC_t}{M_t}\right)^{\nu}. \tag{8}$$

Rearranging (8) yields

$$\frac{P_tC_t}{M_t} = \omega\left(\Psi_t\right)^{\frac{1}{\nu}}, \tag{9}$$

where

$$\omega = \left(\frac{\theta}{1-\theta}\right)^{-\frac{1}{\nu}}.$$

Note that the left hand side of (9) looks very much like the traditional formulation of velocity with the exception that $M_t$is the monetary service flow and not the money stock. Thus, with the form (9) we can formulate a flow version of the equation of exchange, i.e.

$$M_tV_t^f = P_tC_t, \tag{10}$$

where

$$V_t^f = \omega\left(\Psi_t\right)^{\frac{1}{\nu}}$$

is service flow velocity. This model focuses on the behavior of the representative consumer. There is no government, business or foreign expenditure, therefore the right hand side of (10) can be interpreted as nominal GDP. While the richness of the model above could be improved by

[5]Note that $\int_0^1 U_t(j)M_t(j)dj$ is the total expenditure on monetary assets; therefore by Fisher's factor reversal the price aggregate Ψ_t can be found by dividing by the quantity aggregate M_t.

adding more complexity, additional complexity would not change the point being illustrated that there exists a quantity theory like relationship between the monetary service flow and nominal GDP. The only difference would be the functional form of V^f. This is not a major problem for our econometric model because, provided a flow velocity exists and has economic meaning, our method can estimate V^f without specifying the functional form. Thus, our econometric approach is not dependent on any underlying assumption about the aggregate utility or production functions and is robust to the assumptions made in this illustration.

More important to our model is the fact that V^f can be represented as a function of structural parameters and the user cost of money. Because there is an equilibrium user cost, there also exists a equilibrium velocity, V^*, such that deviations from V^*, i.e. monetary overhang, are economically meaningful and must be compensated for by an adjustment in money, prices or output. For the remainder of this paper we omit the superscript f on the velocity variable. We will, however, continue to define velocity as in (10).

3 Data and Descriptive Analysis

3.1 Data Selection

For our analysis, we use monthly U.S. data that includes a monetary aggregate, price level, output and an interest rate from 1967M1 to 2006M2. The system of variables we choose has a long history in the analysis of monetary policy shocks. Leeper and Gordon (1992), for example, examine a very similar system. The sample period was chosen because calculation of the new monetary aggregate begins in 1967M1, and we choose to exclude the financial crisis because its magnitude and position in the sample causes it to have an exaggerated influence on the parameter estimates. Variables used are as follows.

The monetary aggregate, m, is the log of the revised monetary service index at the M2 level of aggregation (MSI2) produced by the Federal Reserve Bank of St. Louis (see Anderson and Jones 2011). We conducted our empirical analysis using monetary aggregates of various levels of aggregation. Our results were robust to the choice of monetary aggregate. The revised MSI2 is the Tornqvist-Theil discrete time approximation of the the Divisia monetary aggregate first developed by Barnett (1978) and Barnett (1980), adjusted for retail sweeps (See Anderson and Rasche (2000) and Dutkowsky and Cynamon (2003) for further explanation of the issues of retail sweeps). The price aggregate, p, is the log of personal consumption expenditures price deflator (PCE), which we obtain from the Bureau of Labor Statistics. As a robustness check, the analysis is also conducted using the Consumer Price Index, which does not cause meaningful changes in our results. Output, y, is the log of real Gross Domestic Product (GDP), which we obtain from the Bureau of Economic Analysis. We interpolate monthly observations of the first difference of GDP, then the cumulative sum of the differences is reported (see Bernanke, Gertler, Watson, Sims, and Friedman 1997 and Mönch and Uhlig 2004a). An explanation of this process is provided in section 3.2. The interest rate, i, is the monthly average of the effective Federal Funds rate, which we obtain from the Federal Reserve Board of Governors. We also used the Federal Funds target rate. Our results were robust to the choice of interest rate.

3.2 Data preparation

Interpolation of monthly data While money supply, prices and interest rates are available in monthly frequency, GDP is only available quarterly. While industrial production, being the only monthly available production side indicator, is too noisy to replace GDP in a dynamic model, a spline interpolation of DP (cubic or otherwise) removes too much of the dynamics of GDP to be useful in identifying contemporaneous effects of (policy) shocks. We thus follow Mönch and Uhlig (2004b) in interpolating the dynamics of monthly GDP by modeling GDP growth as an ARMA(1,1) process using the additional information provided by industrial production and unemployment.[6]

To do so, we estimate the simple state space model, defined by the signal equation

$$y_t - y_{t-3} = \sum_{i=0}^{2} \Delta \bar{y}_{t-i} \tag{11}$$

and the state equations

[6]An added advantage of this method is that it closely models the actual behavior of the Federal Reserve in that policy makers use industrial production as an indicator of the less volatile GDP.

$$\bar{y}_t = \alpha + \beta \bar{y}_{t-1} + \gamma \Delta ip_t + \theta ur_t + v_t \tag{12}$$

$$v_t = v_{t-1} + \varepsilon_t,$$

where y denotes logged GDP, $\bar{y}$ denotes the latent monthly growth rate of GDP, ip is (logged) industrial production, ur is the unemployment rate, v is an MA(1) process with errors denoted by ε; t is a time index, and α,β, γ and θ are parameters.

The model is estimated using a Kalman filter with ML estimation, where Kalman updates are only performed in months 3, 6, 9 and 12 of each year, i.e. if there is data on y actually available. The logged level at time t is then approximated by the cumulative sum of growth rates (i.e. log differences) up to period t.

Detrending All variables used in the model except interest rates are linearly detrended. Interest rates are mean adjusted. Thus our model does not need to include a constant term in the first difference equations, nor a time trend in the level equations. Moreover, this specification makes our model depict the difference to equilibrium growth rates rather than actual growth rates, making the interpretation of impulse responses particularly easy.

4 Empirical Methodology

4.1 The model

Our model explains the log differences of money, prices, GDP and interest rates based on their own past and an error correction term, estimated using a Kalman filter approach, that enforces the return to the equilibrium that has been theoretically outlined in section 2. Thus, the model then takes the form:

$$\begin{bmatrix} \Delta m \\ \Delta p \\ \Delta y \\ \Delta i \end{bmatrix}_t = A(m_t - p_t - y_t^* - v_t^*) + \psi \Delta y_t^* + \phi \Delta v_t^* + B y_{t-1}^* + C(L) \begin{bmatrix} \Delta m \\ \Delta p \\ \Delta y \\ \Delta i \end{bmatrix}_t + \varepsilon_t \quad (13)$$

$$\begin{bmatrix} y_t^* \\ v_t^* \end{bmatrix} = \begin{bmatrix} y_{t-1}^* \\ v_{t-1}^* \end{bmatrix} + u_t, \quad (14)$$

where m, p and y are the logged levels of money, prices and GDP; v is adjusted velocity; A, B, $C(L)$, ψ and ϕ are coefficient vectors or matrices (C(L) being a lag polynomial); u and ε are the error term vectors of signal and state equations respectively; and t again is the time index. The star denotes persistent, i.e. random walk, components. Since we use detrended data, there is no drift term in the persistent components of velocity and GDP.

4.1.1 Reducing the number of parameters

State space models of this size quickly become unfeasible to estimate when the lag order increases due to the huge number of parameters. Using monthly data, we want to use a lag order of at least 12 to capture the key dynamics that are ongoing. Since this would result in more than 200 parameters we propose to restrict the matrix C(L) to zero, where the correlation coefficient is unlikely to matter.

We obtain a first approximate estimate of the model by replacing the Kalman filtered cyclical components of GDP and velocity, respectivel,y by their HP filtered counterparts. We then identify the least significant parameter in C(L), restrict it to zero and reestimate, until all remaining parameters are significant at the 10% level or only 50 entries of C(L) remain unconstrained. The state space model is then estimated using these zero restrictions. Since the entries of C(L) are particularly robust to minor misspecification of the cyclical components, this allows us to reduce the number of parameters substantially, without strongly affecting the model.[7]

[7] We tested the statistical significance of the difference between coefficients obtained from the (constrained) regression model using HP filtered cycles and coefficients obtained from our state space model. While the improved estimation of latent variables by the state space approach does lead to different estimates in the corresponding coefficients, in both modelswe find no statistically significant parameters in C(L), i.e. in the autoregressive

4.2 Sign restrictions

To identify our structural innovations, we adopt the sign restriction approach introduced by Canova and De Nicoló (2002), Uhlig (2005), and Fry and Pagan (2010). We consider only those responses where the following sign restrictions hold:

$$\begin{bmatrix} + & + & + & + \\ * & + & + & - \\ + & - & + & - \\ - & + & + & + \end{bmatrix}. \tag{15}$$

We do not, however, prevent the response of any variable to any shock from being zero. Thus, we never impose that a particular response to a shock must happen, but rather allow for the possibility that they may happen.

Monetary Policy Shock An expansionary monetary policy shock, which is a negative shock on interest rates, has a positive contemporaneous effect on the money supply and GDP. The contemporaneous effect on price level is unconstrained. Remaining agnostic about the contemporaneous response of price level allows for the possibility of a price puzzle. Restricting the contemporaneous response of real output to be positive allows for the possibility that money is non-neutral in the short-run, though our model does impose long-run money neutrality. Finally, restricting the contemporaneous response of money to be positive simply imposes a downward sloping demand for money, eliminating a liquidity puzzle. [8]

Cost Shock A cost shock has positive contemporaneous effect on the money supply, price level, and interest rates, and a negative contemporaneous effect on the real output. Costs have a positive impact on prices and a negative impact on real GDP; as in Leeper et al. (1996). To justify a positive contemporaneous effect on the money supply and the interest rate, consider that since

behavior of the vector of endogenous variables, using a t-test.

[8]As a robustness test, we imposed an alternate set of restrictions that left the response of money to a monetary policy shock unconstrained. In order to identify shocks, we imposed an additional restriction on the relative size of the shocks, since the sign restrictions would no longer guarantee linearly independent shocks. We restricted the largest shocks to interest rates, prices and GDP to be provided by the monetary policy, cost and demand shocks, respectively. While this is not our preferred specification, it gave us a means to determine how restrictive our no-liquidity-puzzle assumption is. Even under this alternative specification, we found a clearly positive contemporaneous effect of the monetary policy shock on money.

the money supply process is at least partially endogenous, when price level increases, interest rates increase, inducing lenders to temporarily lend more. In other words, because neither lenders nor the central bank can react to the change in price level instantly, the new price level causes demand for money to shift to the right before money supply can change, causing a temporary increase in m and i.

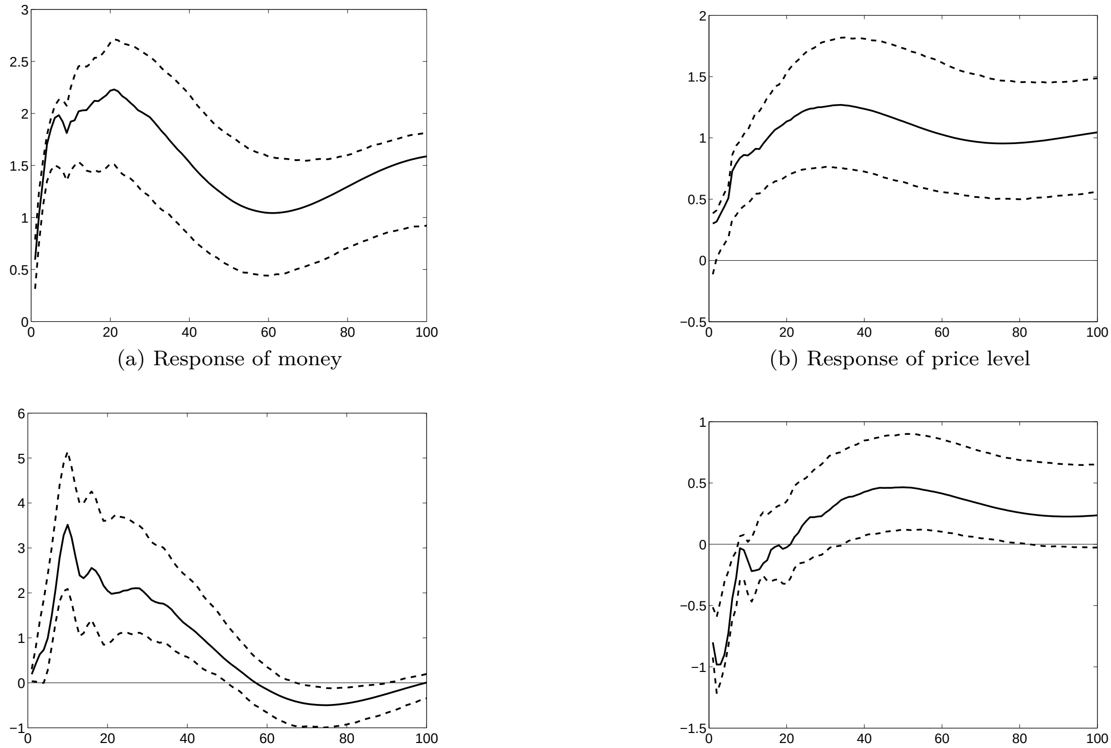
Demand Shock An increase in aggregate demand causes an increase in both output and price level. Both higher price level and increased volume of trade causes demand for money change before money supply can respond, leading to a temporary increase in m and i. Thus, a demand shock has a positive contemporaneous effect on money, prices, GDP and interest rates.

Money Demand Shock An increase in money demand leads to an increase in interest rates, which in turn lowers aggregate demand causing prices and output to fall. Thus, a money demand shock has a positive contemporaneous effect on money and interest rates and a negative contemporaneous effect on prices and GDP.

5 Results

Monetary policy shock. Figure 1 presents the impulse responses to a positive monetary policy shock. A positive monetary policy shock induces a strongly significant and persistent positive response in money and a strongly negative response in the Federal Funds rate that lasts about 12 months. We see a strongly positive response in real GDP that lasts about 44 months, but the exploiting monetary policy is not without cost. While real GDP peeks at 10 months, price level continues to grow until 34 months after the initial shock. The Federal Funds rate eventually responds to inflationary pressure, and exhibits considerable persistence, i.e. remains significantly above pre-shock level nearly 40 months. Inflation is stationary by construction, so this persistence indicates that the inflation expectations remain higher then pre-shock level long after the actual inflationary effects of the monetary policy shock have dissipated.

Cost shock. Initially, a positive cost shock induces a significant increase in price level and a decrease in real GDP, which is consistent with theoretical expectations, see figure 2. The



(a) Response of money

(b) Response of price level

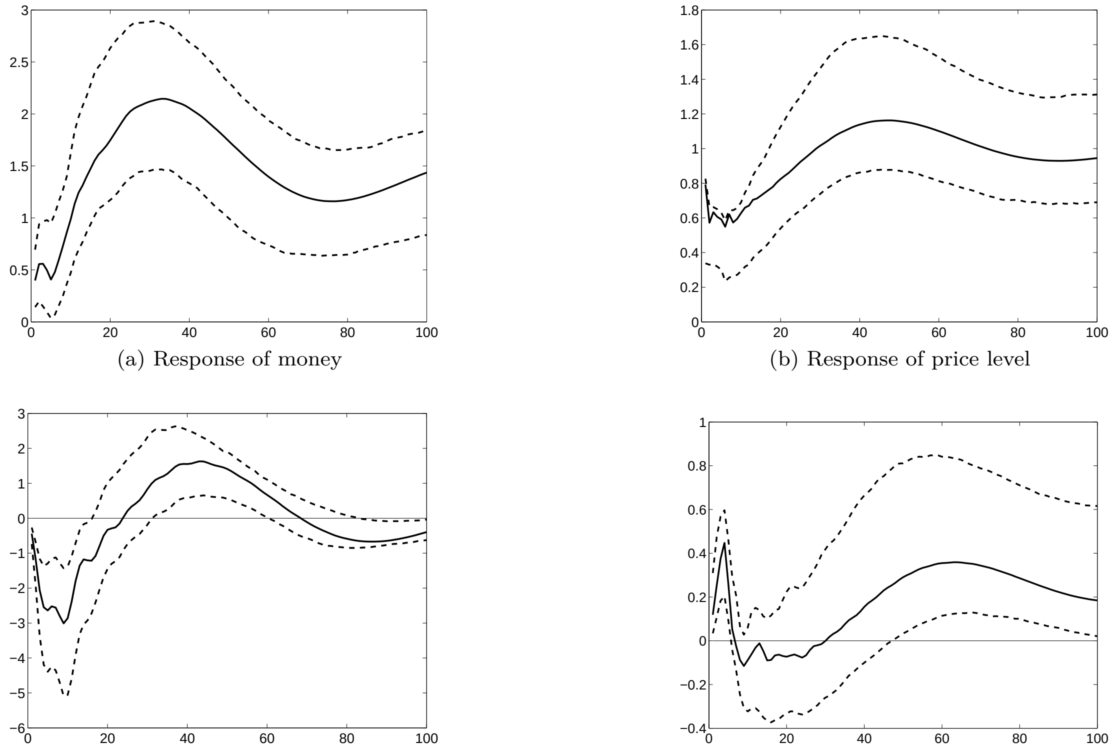
(c) Response of real GDP

(d) Response of interest rates

Figure 1: Impulse responses to a positive monetary policy shock.

central bank's response, on the other hand, is more interesting. For the first 12 months after the shock, the central bank appears to be mostly concerned with the price level increase as the Federal Funds rate immediately increases. Price level falls in response, but remains significantly above the pre-shock level. After the 12th month, the central bank changes course, dropping the Federal Funds rate to its original level and strongly increasing money. Real GDP begins to recover and price level starts rising. The monetary stimulus causes real GDP to over shoot potential, leading the central bank to increase the Federal Funds rate. Real GDP eventually comes back to potential, and as GDP returns to potential, the Federal Funds rate returns to its pre-shock level. Price level and money, however, remain at a permanently higher level.

Demand shock. A positive demand shock induces a significant positive response in real GDP and price level, but a insignificant contraction in money and a strongly significant response of the Federal Funds rate dissipates the price level increase quickly, see figure 3. The upswing in real



(a) Response of money

(b) Response of price level

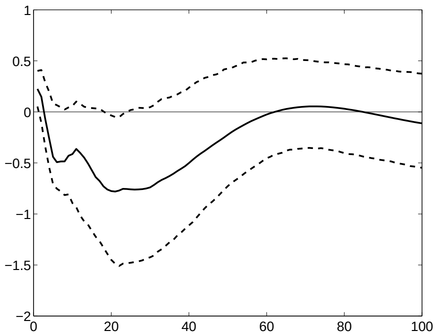
(c) Response of real GDP

(d) Response of interest rates

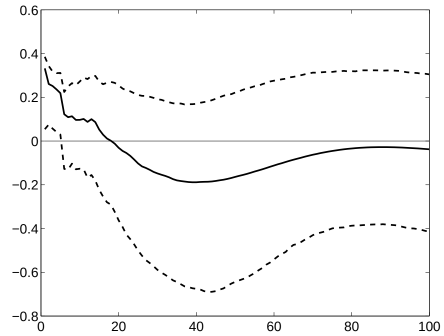
Figure 2: Impulse responses to a positive cost shock.

GDP lasts approximately 24 months. The central bank's response to the shock is quite small, i.e. there is an insignificant decline in money. However, the Federal Funds rate increase is quite strong. Thus, the increased transactions volume leads to an increase in money demand that is not accommodated by monetary policy, and the Federal Funds rate is permanently increased. This result begs the question: Why should the Federal Funds rate remain permanently above the pre-shock equilibrium, even after the other variables, including prices, have returned to the their pre-shock levels? The permanent increase in the Federal Funds rate indicates that the demand shock has a permanent affect on preferences, that is aggregate demand has a permanent propensity toward a higher level. Thus, the Federal Funds rate remains above pre-shock levels as a check on excess aggregate demand.

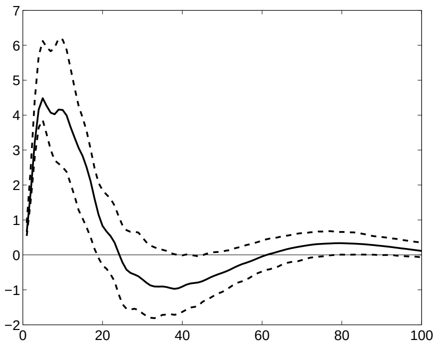
Money demand shock. The economic response to a positive money demand shock is complex, see figure 4. We first observe an immediate increase in the Federal Funds rate and a decrease



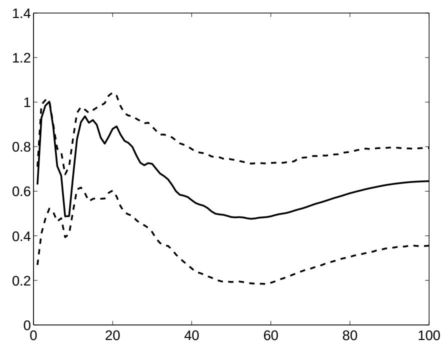
(a) Response of money



(b) Response of price level



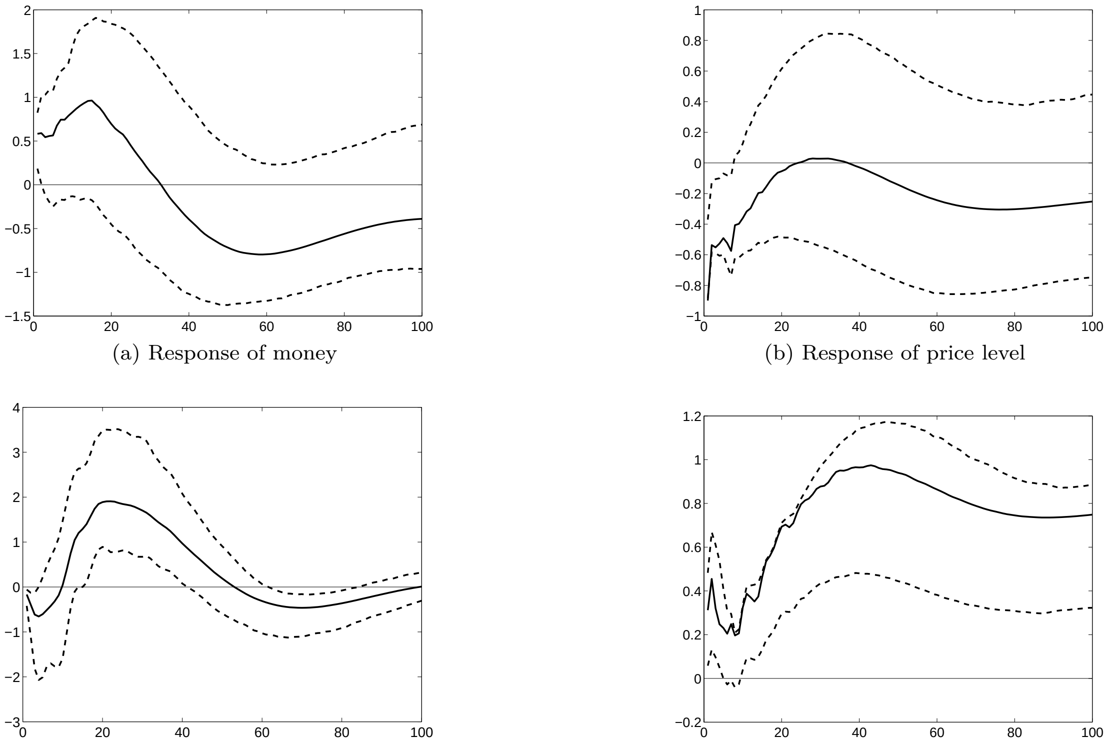
(c) Response of real GDP



(d) Response of interest rates

Figure 3: Impulse responses to a positive demand shock.

in real GDP, which is perfectly consistent with a leftward shift in the LM curve triggered by the money demand shock. However, real GDP quickly begins to recover and is significantly above potential from about 18 to 40 months after the initial shock. To explain this, consider that, because of the increased scarcity of money, we see an immediate decrease in price level that remains significant for about 12 months. This price level decrease creates a Pigou wealth effect that drives the recovery (see Pigou, 1912 and Pigou, 1917). This Pigou effect is further evidenced by a decline in the Federal Funds rate which coincides with the timing of the strongest increase in real GDP. During the business cycle upswing, price begins to rise, reducing the Pigou effect, bringing real GDP back to potential. We see little, if any, attempt by the central bank to accommodate the increased money demand, evidenced by the insignificant response of money, and so interest rates remain at a permanently higher level.



(a) Response of money

(b) Response of price level

(c) Response of real GDP

(d) Response of interest rates

Figure 4: Impulse responses to a positive money demand shock.

6 Conclusion

In this paper, we create a parsimonious model that allows a detailed look into the dynamics of a monetary policy shock. By applying shock identification to an econometric model that allows us to track equilibria such as potential output and money demand, we are able to combine some of the major advantages of DSGE models, which fully account for the driving forces of economic development, and VAR approaches, which allow the data to speak. Doing so, we can make the following observations.

First, we see a positive relationship between money growth and real income. With a monetary policy shock (i.e. a reduction of the Federal Funds rate), we see an immediate positive response of money and real income. This positive relationship between money and real income can be observed in the other shocks as well, though with a lag that is sometimes insignificant. Second, there is a positive relationship between money and prices. Across all four shocks, we see a positive correlation between the impulse response of money and the impulse response of prices. Third, there is a short run negative correlation between money and interest rates, but that relationship reverses in the long run. After a monetary policy shock, we initially observe a negative relationship between money and interest rates, lasting approximately three months.After these three months, though money continues to grow, interest rates begin to rise. The increase in interest rates becomes significantly positive after approximately 36 months. And lastly, we find that an increase in money can come from various sources, i.e. our econometric model - although being in the tradition of the quantity theory - allows for partly endogenous money. We see significant money growth resulting from both monetary policy and cost shocks, and insignificant money growth for approximately 18 months resulting from a money demand shock.

Thus, while we find that monetary easing can stimulate real output in the short run, ignoring money in monetary policy, which is generally done today, presents some substantial long-run risks. Given the inertia exhibited by inflation, failure to control the quantity of money can cause inflationary pressure strong enough to outweigh the original gain of monetary easing. Moreover, the long-run upward pressure on interest rates created by excessive money growth may have even more persistent impacts on the economy through decreased investment.

Finally, our approach allows us to model money growth that is independent of the Federal Reserve's monetary policy decisions. Thus, ignoring money in monetary policy becomes even more perilous as we see ill effects of excessive money growth can be precipitated by environmental change beyond the control of monetary policy makers. Moreover, excess or deficit liquidity may well be the only warning indicator capable of signaling the need for policy change in certain circumstances. A subject for further research is whether or not monetary overhang could have provided an early warning of the 2008 financial crisis.

Acknowledgements

The authors are indebted to Jane Binner, Walter Hyll and Gunner Pippel and Hans-Eggert Reimers for valuable comments and suggestions. We also thank the participants of the Scottish Economic Society Annual Conference 2012.

References

Alvarez, F., Atkeson, A., Edmond, C., 2009. Sluggish Responses of Prices and Inflation to Monetary Shocks in an Inventory Model of Money Demand. The Quarterly Journal of Economics 124 (3), 911–967.

Anderson, R., Rasche, R., 2000. Retail sweep programs and bank reserves, 1994–1999. Working Paper Series.

Anderson, R. G., Jones, B. E., September/October 2011. A comprehensive revision of the monetary services (divisia) indexes for the united states. Federal Reserve Bank of St. Louis Review, 325–359.

Arrow, K. J., Hahn, G. H., 1971. General Competitive Analysis. San Francisco: Holden-Day.

Barnett, W., Chauvet, M., 2011. How better monetary statistics could have signaled the financial crisis. Journal of Econometrics 161 (1), 6 – 23.

Barnett, W. A., 1978. The user cost of money. Economics Letters 1 (2), 145–149.

Barnett, W. A., 1980. An application of index number and aggregation theory. Journal of Econometrics 14, 11–48.

Barnett, W. A., Chae, U., Keating, J. W., July 2005. The discounted economic stock of money with VAR forecasting. Annals of Finance 2 (2), 229–258.

Barnett, W. A., Keating, J. W., Kelly, L. J., 2008. Toward a bias corrected currency equivalent index . Economics Letters 100 (3), 448–451.

Barnett, W. A., Serletis, A., 2000. The Theory of Monetary Aggregation. Contributions to Economic Analysis, vol. 245. Amsterdam: Elsevier.

Barnett, W. A., Zheng, M., 2011. Monetary policy implications of a new-Keynesian DSGE model with theoretically coherent monetary aggregation.

Belongia, M., Ireland, P., 2011. The barnett critique after three decades: A new keynesian analysis. Boston College Working Papers in Economics.

Bernanke, B., Gertler, M., Watson, M., Sims, C., Friedman, B., 1997. Systematic monetary policy and the effects of oil price shocks. Brookings papers on economic activity 1997 (1), 91–157.

Bernanke, B. S., Mihov, I., 1998. Measuring Monetary Policy. The Quarterly Journal of Economics 113 (3), 869–902.

Canova, F., De Nicoló, G., 2002. Monetary disturbances matter for business fluctuations in the G-7. Journal of Monetary Economics 49 (6), 1131–1159.

Christiano, L., Eichenbaum, M., Evans, C. L., 1999. Monetary Policy Shocks: What have we Learned and to what End? In: Handbook of Macroeconomics. Vol. 1. Elsevier.

Christiano, L. J., Eichenbaum, M., Evans, C., 1996. The Effects of Monetary Policy Shocks: Evidence from the Flow of Funds. The Review of Economics and Statistics 78 (1), 16–34.

Chrystal, K., MacDonald, R., 1994. Empirical evidence on the recent behavior and usefulness of simple-sum and weighted measures of the money stock. Review -Federal Reserve Bank of Saint Louis 76, 73–73.

Dreger, C., Wolters, J., 2009. Money Velocity and Asset Prices in the Euro Area. Empirica 36 (1), 51–63.

Dutkowsky, D., Cynamon, B., 2003. Sweep programs: The fall of m1 and rebirth of the medium of exchange. Journal of Money, Credit, and Banking 35 (2), 263–279.

El-Shagi, M., Giesen, S., Kelly, L. J., Apr. 2011. The quantity theory revisited: A new structural approach. IWH Discussion Papers 7, Halle Institute for Economic Research.

Faust, J., 1998. The robustness of identified VAR conclusions about money. Carnegie-Rochester Conference Series on Public Policy 49, 207–244.

Fry, R., Pagan, A., 2010. Sign Restrictions in Structural Vector Autoregressions: A Critical Review. Working Paper 22/2010, CAMA.

Gerlach, S., Svensson, L. E. O., 2003. Money and Inflation in the Euro Area: A Case for Monetary Indicators? Journal of Monetary Economics 50 (8), 1649–1672.

Gordon, D. B., Leeper, E. M., 1994. The Dynamic Impacts of Monetary Policy: An Exercise in Tentative Identification. The Journal of Political Economy 102 (6), 1228–1247.

Hallman, J. J., Porter, R. D., Small, D. H., 1991. Is the Price Level Tied to the M2 Monetary Aggregate in the Long Run? American Economic Review 81 (4), 841–858.

Herwartz, H., Reimers, H.-E., 2006. Long-Run Links among Money, Prices and Output: World-wide Evidence. German Economic Review 7 (1), 65–86.

Ireland, P. N., 2004. A method for taking models to the data. Journal of Economic Dynamics and Control 28 (6), 1205–1226.

Kaufmann, S., Kugler, P., 2008. Does Money Matter for Inflation in the Euro Area? Contemporary Economic Policy 26 (4), 590–606.

Kelly, L. J., 2009. The stock of money and why you should care. Emerald Group Publishing Limited.

Kelly, L. J., Barnett, W. A., Keating, J. W., 2011. Rethinking the liquidity puzzle: Application of a new measure of the economic money stock. Journal of Banking and Finance.

Leeper, E., Gordon, D., 1992. In search of the liquidity effect. Journal of Monetary Economics 29 (3), 341–369.

Leeper, E. M., Sims, C. A., Zha, T., 1996. What Does Monetary Policy Do? Brookings Papers on Economic Activity 1996 (2), 1–78.

McCandless, G. T., Weber, W. E., 1995. Some Monetary Facts. Federal Reserve Bank of Minneapolis Quarterly Review 19, 2–11.

Mönch, E., Uhlig, H., 2004a. Towards a monthly business cycle chronology for the euro area. CEPR Discussion Paper No. 4377.

Mönch, E., Uhlig, H., 2004b. Towards a monthly business cycle chronology for the euro area. CEPR Discussion Paper No. 4377.

Nicolini, J., 1998. More on the time consistency of monetary policy. Journal of Monetary Economics 41 (2), 333–350.

Orphanides, A., Porter, R., 2000. P* Revisited: Money-Based Inflation Forecasts with a Changing Equilibrium Velocity. Journal of Economics and Business 52 (1-2), 87–100.

Pigou, A., 1912. Wealth and welfare. Macmillan and co., limited.

Pigou, A. C., 1917. The value of money. Quarterly Journal of Economics 32, 38–65.

Sims, C. A., 1980. Comparison of interwar and postwar business cycles: Monetarism reconsidered. American Economic Review 70 (2), 250 – 257.

Svensson, L. E. O., 2000. Does the P* Model Provide any Rationale for Monetary Targeting? German Economic Review 1 (1), 69–81.

Taylor, J., 1993. Discretion versus policy rules in practice. In: Carnegie-Rochester conference series on public policy. Vol. 39. Elsevier, pp. 195–214.

Tödter, K. H., 2002. Monetary Indicators and Policy Rules in the P-Star Model. Bundesbank Discussion Papers (18/02).

Teles, P., Uhlig, H., 2010. Is Quantity Theory Still Alive? Working Paper No. w16393, NBER.

Uhlig, H., 2005. What are the effects of monetary policy on output? Results from an agnostic identification procedure. Journal of Monetary Economics 52 (2), 381–419.