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ABSTRACT

Monetary Policy Misspecification in VAR Models*

We examine the effects of extracting monetary policy disturbances with semi-structural and structural VARs, using data generated by a limited participation model under partial accommodative and feedback rules. We find that, in general, misspecification is substantial: short run coefficients often have wrong signs; impulse responses and variance decompositions give misleading representations of the dynamics. Explanations for the results and suggestions for macroeconomic practice are provided.

JEL Classification: C32, C68, E32, E52
Keywords: general equilibrium, monetary policy, identification, structural vars

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NON-TECHNICAL SUMMARY

The high correlation between monetary and real aggregates over the business cycle has attracted the attention of macroeconomists for at least 40 years. Friedman and Schwartz (1960) were among the first to provide a causal interpretation of this relationship: they showed that the co-movements of money with output were not due to the passive response of money to the developments in the real and financial sides of the economy and argued that rates of exchange in money were good approximations to policy disturbances. Since their seminal work, several generations of macroeconomists have tried either to empirically refute Friedman and Schwartz's causal interpretation or to provide theoretical models that can account for the relationship.

The most recent theoretical branch of this literature has developed models where simple rules are used to characterize monetary policy and has focused attention on the channels of transmission of policy disturbances and on the persistence of the induced real effects.

In general, there has not been much discussion on whether the dynamics of macroeconomic variables change in response to policy shocks when alternative monetary rules are used.

The empirical side of the literature, on the other hand, has documented that unforecastable movements in money produce responses in macroeconomic variables, in particular interest rates that are difficult to interpret: i.e. they generate the so-called liquidity puzzle. To remedy these problems some authors suggested to use short-term interest rate innovations as indicators of monetary policy disturbances. Also in this case, the responses of certain macroeconomic variables to policy disturbances are difficult to justify (in particular, the response of the price level). As a consequence of these difficulties, the last ten years have witnessed a considerable effort in trying to identify monetary policy disturbances in the data using parsimoniously restricted multivariate time series models.

The methodology used in these exercises involves three steps: run unrestricted VAR models; identify monetary policy shocks by imposing exclusion restrictions on the matrix of contemporaneous impacts, typically justified by economic theory or informational delays; and measure the contribution of identified policy shocks to output fluctuations at different horizons. This literature has stressed the pitfalls of an incorrect choice of variables and identification schemes and carefully documented the type of central bank reaction function in place in various historical episodes. However, by concentrating on the issue of identification, this literature has disregarded the question of what mechanism induces the observed dynamic money-output correlation and has not paid much attention to possible feedbacks due to the general equilibrium nature of shocks.

In this Paper we attempt to bridge these two branches of the literature by asking the following three questions: how adequate are structural VARs in capturing the dynamics generated by a monetary policy disturbance when the underlying economy has general equilibrium features? Does the answer change when the theoretical economy features different monetary policy rules or, given one rule, different identification schemes are used? How confident should we be that reported statistics correctly characterize the importance of policy in producing real fluctuations?

To answer these questions we simulate a version of the limited participation model under two different monetary policy rules (a partially accommodative and a feedback one).

Using simulated data we then estimate a 4-variable VAR model for output, inflation, interest rates and real balances and identify structural disturbances by imposing exclusion restrictions on the contemporaneous impact of innovations according to two different schemes: a triangular one, and a non-recursive one. Both schemes impose stringent 'inertial' restrictions on the data: policy disturbances are assumed not to affect output and inflation contemporaneously and the static aggregate demand curve is assumed to cross a vertical aggregate supply.

We compare the theoretical and the estimated structural VAR representations using several statistics: impact coefficients, the impulse–response function, the variance decomposition and the time path of structural shocks. We find that VARs identified with inertial restrictions on the matrix of contemporaneous impacts provide a poor characterization of the DGP of the actual data. Both approaches fail to recover the features of our theoretical monetary policy disturbances, regardless of the policy rule employed. Misspecifications occur at all levels. Estimated short-run coefficients often have the wrong sign and, in the case of triangular identification schemes, are estimated to be the same regardless of the monetary rule generating the data. The sign and the significance of impulse responses differ across policy rules and identification schemes but there is a widespread tendency to misrepresent the true dynamics. The variance decomposition typically underestimate the importance of monetary policy shocks, as sources of variability for real variables and, in at least one case, attributes most of the fluctuations to the wrong source of disturbance.

Why are structural VARs so bad? We argue that the results are obtained because, in the theoretical economy, the effects of structural shocks on the variables of interest are highly interrelated and this makes them econometrically underidentified. That is, in the theoretical economy there is no 'sluggish' variable which can be used as instrument in policy and non-policy equations. To restate this concept in a different way, the model economy produces impact coefficients where there are not enough zeros to identify the underlying structural disturbances.

Semi-structural or structural VAR analyses that employ exclusion restrictions omit important variables from certain equations when estimating structural shocks. This omission biases the coefficients of the included ones, whenever included and excluded variables are correlated, which is precisely the case we are considering. Economies where the responses to shocks fully take place within one period are therefore not suited to be analysed with standard identification procedures because there is no natural 'inertial' restriction one can appeal to recover the disturbances. In models where price stickiness, adjustment costs or implementation lags do provide natural exclusion restrictions, it may still be impossible to identify structural disturbances because such models restrict the impact of *shocks* on particular variables, therefore leaving unresolved the inherent under-identification present in the data.

Compared with the large body of empirical VAR literature that claimed success in recovering structural disturbances, our exercise suggests that one of the following two conclusions must hold. Either the class of models considered in the theoretical literature provides such a poor characterization of real data in terms of richness of the dynamics, sources of shocks and contemporaneous impacts that our results, although interesting, represent a cautionary footnote which sophisticated VAR users can neglect in their analysis. While we have argued that the class of models considered here are consistent with some important features of post-war data for the G7, it is certainly the case that no one would hold them as a null hypothesis in a statistical sense. Nevertheless, the fact that current theoretical models imply a very small number of (intrinsically similar) contemporaneous exclusion restrictions provides a great challenge to researchers engaged in integrating identified VAR and dynamic general equilibrium analyses. The alternative conclusion is more constructive. If the general equilibrium effects of shocks kick-in much faster than one is led to expect; stickiness of prices and wages is not useful to differentiate the impact of different types of shocks; and informational delays are dubious or weak, our analysis suggests that great care should be used in interpreting VAR identified with inertial restrictions and, in general, the need to resort to identification schemes which more effectively use theoretical information to identify shocks. In the latter part of the Paper, we show that an approach which uses the sign of the conditional cross-correlation function of selected variables to extract the informational content of orthogonal shocks, does not face the problems that standard VAR analysis encounters when there are no natural inertial restrictions to be used. In particular, we show that the approach is able to identify structural shocks and to provide a correct characterization of the relative importance of various shocks to fluctuations in the variables of the system.

Monetary Policy Misspecification in VAR Models*

Fabio Canova[†]and Joaquim Pires Pina[‡]

October 1998,
This Revision, September 1999

Abstract

We examine the effects of extracting monetary policy disturbances with semi-structural and structural VARs, using data generated by a limited participation model under partial accommodative and feedback rules. We find that, in general, misspecification is substantial: short run coefficients often have wrong signs; impulse responses and variance decompositions give misleading representations of the dynamics. Explanations for the results and suggestions for macroeconomic practice are provided.

Key Words: General equilibrium, Monetary Policy, Identification, Structural VARs

JEL Classification No: C32, C68, E32, E52

Per questo non abbiamo niente da insegnare: su cio' che piu' somiglia alla nostra esperienza non possimao influire, in cio' che porta la nostra impronta non sappiamo riconoscerci. *Mr. Palomar, Italo Calvino*

1. Introduction

The high correlation between monetary and real aggregates over the business cycle has attracted the attention of macroeconomists for at least forty years. Friedman and Schwartz (1960) were among the firsts to provide a causal interpretation of this relationship: they showed that the comovements of money with output were not due

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to the passive response of money to the developments in the real and financial sides of the economy and argued that rate of changes in money were good approximations to policy disturbances. Since their seminal work, several generations of macroeconomists have tried either to empirically refute Friedman and Schwartz's causal interpretation or to provide theoretical models which can account for the relationship.

The most recent theoretical branch of this literature (see e.g., Lucas (1990), Christiano (1991), Fuerst (1992), Cooley and Quadrini (1997)) has developed models where simple rules are used to characterize monetary policy and has focused attention on the channels of transmission of policy disturbances and on the persistence of the induced real effects (see e.g. Chari, Kehoe and McGrattan (1996)). In general, there has not been much discussion on whether the dynamics of macroeconomic variables change in response to policy shocks when alternative monetary rules are used (one exception is Christiano, Eichenbaum and Evans (1997a)).

The empirical side of the literature, on the other hand, has documented that unforecastable movements in money produce responses in macroeconomic variables, in particular interest rates, that are difficult to interpret - i.e. they generate the so-called liquidity puzzle (see Leeper and Gordon (1991)). To remedy these problems Sims (1980), Bernanke and Blinder (1992) suggested to use short term interest rate innovations as indicators of monetary policy disturbances. Also in this case, the responses of certain macroeconomic variables to policy disturbances are difficult to justify (in particular, the response of the price level (Sims (1992)). As a consequence of these difficulties, the last ten years have witnessed a considerable effort in trying to identify monetary policy disturbances in the data using parsimoniously restricted multivariate time series models (see Gordon and Leeper (1994), Christiano, Eichenbaum and Evans (1996), Bernanke and Mihov (1998), Uhlig (1999)).

The methodology used in these exercises involves three steps: run unrestricted VAR models; identify monetary policy shocks by imposing exclusion restrictions on the matrix of contemporaneous impacts, typically justified by economic theory or informational delays; and measure the contribution of identified policy shocks to output fluctuations at different horizons. This literature has stressed the pitfalls of an incorrect choice of variables and identification schemes and carefully documented the type of central bank reaction function in place in various historical episodes [1]. However, by concentrating on the issue of identification, this literature has disregarded the question of what mechanism induces the observed dynamic money-output correlation and has not payed much attention to possible feedbacks due to the general equilibrium nature of shocks (one exception is Canova and De Nicoló (1998)).

In this paper we attempt to bridge these two branches of the literature by asking the following three questions: how adequate are structural VARs in capturing the dynamics generated by a monetary policy disturbance when the underlying economy has general equilibrium features? Does the answer change when the theoretical economy features different monetary policy rules or, given one rule, different identification schemes are used? How confident should we be that reported statistics correctly characterize the importance of policy in producing real fluctuations ?

[1] A related literature, attempting to represent the behavior of the monetary authority, has developed on the side in the last five years, see e.g. Clarida, Gertler and Galí (1999).

To answer these questions we simulate a version of the limited participation model of Christiano, Eichenbaum and Evans (1997b) under two different monetary policy rules (a partially accommodative and a feedback one). Such an economy displays several desirable features (see Sims (1998)): the liquidity effect produced by a contractionary monetary shock reduces output by means of increases in nominal interest rates; nonpolicy shocks producing inflation induce movements in interest rates which are larger than those obtainable under a policy of fixing the money stock; most of the variations in the policy instrument are accounted for by responses of policy to the state of the economy, not by random disturbances to the policy behavior. In addition, depending on the policy rule used, the response of real variables to monetary shocks can be made either modest or sizable.

Using simulated data we then estimate a 4-variable VAR model for output, inflation, interest rates and real balances and identify structural disturbances by imposing exclusion restrictions on the contemporaneous impact of innovations according to two different schemes: a triangular one, as in Christiano, Eichenbaum and Evans (1996), and a non-recursive one as in Sims and Zha (1996) or Leeper, Sims and Zha (1996), Both schemes impose stringent "inertial" restrictions on the data: policy disturbances are assumed not to affect output and inflation contemporaneously and the static aggregate demand curve is assumed to cross a vertical aggregate supply.

We compare the theoretical and the estimated structural VAR representations using several statistics: impact coefficients, the impulse response function, the variance decomposition and the time path of structural shocks. We find that VARs identified with inertial restrictions on the matrix of contemporaneous impacts provide a poor characterization of the DGP of the actual data. Both approaches fail to recover the features of our theoretical monetary policy disturbances, regardless of the policy rule employed. Misspecifications occur at all levels. Estimated short run coefficients often have the wrong sign and, in the case of triangular identification schemes, are estimated to be the same regardless of the monetary rule generating the data. The sign and the significance of impulse responses differ across policy rules and identification schemes but there is a widespread tendency to misrepresent the true dynamics. The variance decomposition typically underestimate the importance of monetary policy shocks, as sources of variability for real variables and, in at least one case, attributes most of the fluctuations to the wrong source of disturbance.

Why are structural VARs so bad? We show that the exact features of the theoretical economy, including the specification of the policy rule, do not matter for the results. We also show that small sample sizes, the failure to include a state variable in the VAR representation of the system and the statistical features of the shocks can not account for the poor behavior of structural VAR analyses. We argue that the results obtain because, in the theoretical economy, the effects of structural shocks on the variables of interest are highly interrelated and this makes them econometrically underidentified. That is, in the theoretical economy there is no "sluggish" variable which can be used as instrument in policy and nonpolicy equations. To restate this concept in a different way, the model economy produces impact coefficients where there are not enough zeros to identify the underlying structural disturbances.

Semi-structural or structural VAR analyses which employ exclusion restrictions omit important variables from certain equations when estimating structural shocks. This omission biases the coefficients of the included ones, whenever included and excluded variables are correlated, which is precisely the case we are considering. Economies where the responses to shocks fully take place within one period are therefore not suited to be analyzed with standard identification procedures because there is no natural "inertial" restriction one can appeal to recover the disturbances. In models where price stickiness, adjustment costs or implementation lags do provide natural exclusion restrictions, it may still be impossible to identify structural disturbances because such models restrict the impact of *all* shocks on particular variables, therefore leaving unresolved the inherent underidentification present in the data.

Compared with the large body of empirical VAR literature which claimed success in recovering structural disturbances, our exercise suggests that one of the following two conclusions must hold. Either the class of models considered in the theoretical literature provides such a poor characterization of real data in terms of richness of the dynamics, sources of shocks and contemporaneous impacts that our results, although interesting, represent a cautionary footnote which sophisticated VAR users can neglect in their analysis. While we have argued that the class of models considered here are consistent with some important features of postwar data for the G7, it is certainly the case that no one would hold them as a null hypothesis in a statistical sense. Nevertheless, the fact that current theoretical models imply a very small number of (intrinsically similar) contemporaneous exclusion restrictions provides a great challenge to researchers engaged in integrating identified VAR and dynamic general equilibrium analyses. The alternative conclusion is more constructive. If the general equilibrium effects of shocks kick-in much faster than one is led to expect; stickiness of prices and wages is not useful to differentiate the impact of different types of shocks; and informational delays are dubious or weak, our analysis suggests that great care should be used in interpreting VAR identified with inertial restrictions and, in general, the need to resort to identification schemes which more effectively use theoretical information to identify shocks. In the latter part of the paper, we show that the approach suggested by Canova and De Nicoló (1998), which uses the sign of the conditional cross correlation function of selected variables to extract the informational content of orthogonal shocks, does not face the problems that standard VAR analysis encounters when there are no natural inertial restrictions to be used. In particular, we show that the approach is able to identify structural shocks and to provide a correct characterization of the relative importance of various shocks to fluctuations in the variables of the system.

Several works have examined misspecification problems in identified VARs (see e.g. Sargent (1984), Cooley and LeRoy (1985), Sargent and Hansen (1991)). Recently Rudebusch (1998) has provided a number of reasons for why structural VARs are inadequate for monetary policy analyses. Our work looks at misspecification from a different perspective. While Rudebush claims that the estimated policy reaction function and the estimated structural shocks have little to do with the policy reaction function used by Fed and the structural shocks perceived by financial market participants, we show that standard identifying assumptions are inconsistent with the restrictions implied by a large class of general equilibrium monetary models. In other words, our critique is not directed to the VAR methodology per-se but on a particular type of identifying restrictions routinely used in applied work. In fact, we demonstrate that when theory is used to provide restrictions on the sign of the pairwise cross correlation function of variables in response to shocks, identified VARs correctly recover structural shocks and the dynamics of the model without explicitly estimating the policy reaction function.

The rest of the paper is organized as follows. Next section presents the model, its calibration and discusses the properties of the theoretical economy. Section 3 describes the results obtained using identified VAR analyses on data simulated from the artificial economy. Section 4 examines some explanations for the results. Section 5 provides an alternative identification approach which copes with the inherent underidentification of the data. Section 6 concludes.

2. Model

The artificial economy we use is a version of the limited participation model used by Christiano, Eichenbaum and Evans(1997b). We chose this model as our workhorse because it displays desirable theoretical features and seems to be able to quantitatively reproduce important aspects of aggregate US time series (see King and Watson (1996); Chari, Kehoe and McGrattan (1996); Christiano, Eichenbaum and Evans (1997b)).

Our setup has four types of shocks: technology, monetary policy, government expenditure and preference shocks. We use a richer stochastic structure than it is typically assumed to have a data generating process with more realistic features and an economy which has the same number of shocks as the variables we will consider later on in the VAR. Also, there are five different types of agents (households, firms, a bank, a government and the monetary authority) and we assume that all markets are competitive.

2.1. Households

The economy is populated by a continuum of homogeneous infinitely lived households. The representative household maximizes the expected discounted sum of instantaneous utilities (with discount factor $\beta \in (0,1)$) derived from consuming an homogenous good, C_t and from enjoying leisure. The timing of the decision is the following: agents choose deposits, I_t, at the beginning of the period out of money held, M_{t-1} before observing the shocks ; then all the shocks are realized, and the monetary injection, X_t^A, is fed into the bank. At this point households choose the number of hours to work, and how much capital to rent to firms. The time endowment is normalized to one; capital is in fixed supply and normalized to one. At the end of production time, households collect the wage payment, W_tN_t, and uses it with the money left, $M_{t-1} - I_t$, to buy goods. After goods are purchased agents receive income from holding one-period government bonds, $R_t^bB_{t-1}$, from renting capital to the firm, r_tK_{t-1}, from owning shares in the firms and in the bank, and from deposits, $R_t^MI_t$ and pay taxes, where R_t^M is gross return on money deposits (and credit) and R_t^b is gross nominal return on bonds. Out of disposable income the household decides the composition of its portfolio (money, capital and bonds) to be carried over next period. The program solved is

$$Max_{\{C_t,I_t,N_t,K_t,M_t,B_t\}} E_0 \sum_0^{\infty} \beta^t [\xi_t(\ln(C_t)) + \gamma \ln(1-N_t)] \tag{2.1}$$

subject to

$$P_t C_t \leq M_{t-1} - I_t + W_t N_t \tag{2.2}$$

$$\begin{aligned} M_t + P_t K_t + B_t &\leq W_t N_t + P_t r_t K_{t-1} + R_t^M (I_t + X_t) + R_t^b B_{t-1} + M_{t-1} \\ &- I_t - P_t(C_t + T_t) \end{aligned} \tag{2.3}$$

where $\ln(\xi_t) = (1-\psi)\ln(\xi) + \psi \ln(\xi_{t-1}) + u_t$, with $u_t \sim iid(0, \sigma_u^2)$, $|\psi| < 1$, M_{-1}, B_{-1}, K_{-1} are given and E_0 is the expectation conditional on information at time 0. Equation (2.2) is the cash-in-advance constraint and equation (2.3) is the budget constraint faced by households. Given local nonsatiation, both constraints are assumed to hold with equality.

2.2. Firms

There exists a continuum of identical firms, facing a constant returns to scale technology perturbed by an exogenous technology shock v_t. Each firm maximizes profits subject to the given technology and to a cash-in-advance constraint, since wages are paid before the firm collects revenues from the sales of the product. Profits at each t are measured by the difference between the receipts from selling the good, Y_t, at price P_t, and the costs associated with renting capital, $P_t r_t K_t$, and paying wages, $(1 + R_t^M) W_t N_t$. The problem solved by the firm is

$$Max_{\{N_t,K_t\}} \text{Profits}_t = P_t Y_t - (1 + R_t^M) W_t N_t - P_t r_t K_t \tag{2.4}$$

subject to

$$W_t N_t \leq I_t + X_t \tag{2.5}$$

$$Y_t \leq v_t N_t^{\alpha} K_t^{1-\alpha} \tag{2.6}$$

We assume $\ln(v_t) = (1-\rho)\ln(v) + \rho \ln(v_{t-1}) + \vartheta_t$, with $\vartheta_t \sim iid(0, \sigma_\vartheta^2)$, $|\rho| < 1$, $\alpha \in [0, 1]$. Also here we assume that the constraints (2.5)-(2.6) hold with equality.

2.3. Financial intermediary

We abstract from financial intermediation issues, since these are of marginal importance for the topic of the paper, and give the financial intermediary a trivial problem. It collects money from the households in the form of deposits, I_t^A and pay R_t^M of gross interest. It also receives X_t^A from the monetary authority, issued at zero cost and supplied at zero price. It then rents these funds to firms at the price R_t^M. The profits from financial intermediation, $R_t^M X_t^A$, are paid-out to the household in the form of dividends. (The superscript A indicates aggregate variables).

2.4. Government

The government in this economy plays a simple role. Government consumption G_t^A, is financed by issuing one-period bonds, B_t^A, after repaying outstanding debt, $R_t^b B_{t-1}^A$, and lump sum taxes. That is, $P_t(G_t^A - T_t) = B_t^A - R_t^b B_{t-1}^A$. We assume $\ln(G_t^A) = (1-\theta)\ln(G^A) + \theta\ln(G_{t-1}^A) + \varphi_t$, with $\varphi_t \sim iid(0, \sigma_\varphi^2)$, $|\theta| < 1$.

2.5. Monetary authority

The monetary authority issues cash at no costs every period and transfers to the bank are in the form of an "helicopter drop" of money. In deciding how much to issue it follows one of two possible monetary policy rules: a partial accommodation rule or a feedback rule. At this stage, we specify the policy rule in an implicit form as $f(R, M, P, Y, \varepsilon) = 0$ and monetary injections are defined as $X_t^A = M_t^A - M_{t-1}^A$ where $\ln(\varepsilon_t) = (1-\phi)\ln(\varepsilon) + \phi\ln(\varepsilon_{t-1}) + \omega_t$, with $\omega_t \sim iid(0, \sigma_\omega^2)$, $|\phi| < 1$.

2.6. Equilibrium

The competitive equilibrium for this economy is defined by the following conditions:

$$C_t = C_t^A;\ N_t = N_t^A \quad \text{and} \quad K_t^A = 1;\ Y_t = Y_t^A \tag{2.7}$$

$$Y_t^A = C_t^A + G_t^A = z_t N_t^{A\alpha} K_{t-1}^{A(1-\alpha)} \tag{2.8}$$

$$I_t^A + X_t^A = W_t N_t^A \tag{2.9}$$

$$M_{t-1}^A + X_t^A = P_t C_t^A \tag{2.10}$$

$$X_t^A = M_t^A - M_{t-1}^A \tag{2.11}$$

$$f(R_t, M_t, P_t, Y_t, \varepsilon_t) = 0 \tag{2.12}$$

$$P_t(G_t^A - T_t) = B_t^A - R_t^b B_{t-1}^A \tag{2.13}$$

$$R_t^b = R_t^M = r_t \frac{p_{t+1}}{p_t} \tag{2.14}$$

together with the four laws of motions for the shocks

$$\ln(\xi_t) = (1-\psi)\ln(\xi) + \psi\ln(\xi_{t-1}) + u_t, \text{ with } u_t \sim iid(0, \sigma_u^2), |\psi| < 1$$

$$\ln(v_t) = (1-\rho)\ln(v) + \rho\ln(v_{t-1}) + \vartheta_t, \text{ with } \vartheta_t \sim iid(0, \sigma_\vartheta^2), |\rho| < 1$$

$$\ln(\varepsilon_t) = (1-\phi)\ln(\varepsilon) + \phi\ln(\varepsilon_{t-1}) + \omega_t, \text{ with } \omega_t \sim iid(0, \sigma_\omega^2), |\phi| < 1$$

$$\ln(G_t) = (1-\theta)\ln(G) + \theta\ln(G_{t-1}) + \varphi_t, \text{ with } \varphi_t \sim iid(0, \sigma_\varphi^2), |\theta| < 1$$

the three intratemporal conditions and the Euler equation

$$r_t = (1-\alpha)\frac{Y_t}{K_{t-1}} \tag{2.15}$$

$$\frac{W_t}{P_t} = \frac{\gamma C_t}{(1-N_t)\xi_t} \tag{2.16}$$

$$\frac{R_t W_t}{P_t} = \alpha \frac{Y_t}{N_t} \tag{2.17}$$

$$\frac{\xi_t}{C_t} = E_t \left[\frac{\beta R_t}{(P_{t+1}/P_t)} \frac{\xi_{t+1}}{C_{t+1}} \right] \tag{2.18}$$

2.7. A Monetary Shock: Impact Responses

It is useful to provide some intuition on how the endogenous variables instantaneously respond to a monetary policy shock. Using the constraints (2.2)- (2.5) we obtain

$$\frac{W_t N_t^A}{P_t C_t^A} = \Gamma_t = \frac{I_t^A + X_t^A}{M_{t-1}^A + X_t^A} \tag{2.19}$$

If deposits are smaller than money held, i.e. $I_t^A < M_{t-1}^A$, a monetary injection increases Γ_t. Clearly, this is larger the smaller is I_t^A relative to M_{t-1}^A. Combining the labor supply equation (2.16) with the left-hand side of (2.19) we have

$$\Gamma_t = \frac{N_t^A}{(1 - N_t^A)\xi_t} \gamma \tag{2.20}$$

In equation (2.20) hours worked are positively related to monetary injections. Hence also output and consumption will be positively correlated with X_t^A. From the labor demand equation (2.17) we have

$$R_t = \frac{\alpha}{\Gamma_t} \frac{1}{1 - \frac{G_t^A}{v_t N_t^{A\alpha} K_{t-1}^{A1-\alpha}}} \tag{2.21}$$

so that the nominal interest rate decreases following a monetary injection (therefore generating a liquidity effect). Since a monetary injection reduces the costs of borrowing funds, it will induce firms to hire more workers. The magnitude of the increase in hours worked depends on the share of labor, α, and the labor supply elasticity (which is negatively related to γ). The response of prices to a monetary injection is

$$P_t = \frac{M_{t-1}^A + X_t^A}{v_t N_t^{A\alpha} K_{t-1}^{A1-\alpha} - G_t^A} \tag{2.22}$$

Hence, the extent of the price increase depends on how total hours respond to the shocks. If the share α is large and/or labor supply is very elastic, prices will endogenously be sticky. From the labor supply equation (2.16) the real wage

$$\frac{W_t}{P_t} = \gamma \frac{v_t N_t^{A\alpha} K_{t-1}^{A1-\alpha} - G_t^A}{(1 - N_t^A)\xi_t} \tag{2.23}$$

is likely to rise with X_t^A and this implies that the nominal wage will rise as well.

To summarize, a contractionary monetary disturbance increases nominal interest rates, contracts employment, output and consumption, decreases real and nominal wages and prices. The extent and the timing of the decline in prices depends on the parameter configurations used. We take this combined set of circumstances to be a distinctive feature of monetary policy disturbances in this type of economy.

2.8. Calibration and Computation of Equilibrium

To generate time series out of the model, we choose a standard parametrization. The time unit of the model to be a quarter. The five free parameters are fixed as follows:

$\bar{N}$	α	$\overline{\Pi}$	β	$\overline{c}/\overline{y}$
0.30	0.65	1.00	0.99	0.80

where $\overline{c}/\overline{y}$ is the share of consumption in output, $\bar{N}$ is hours worked and $\overline{\Pi}$ is gross inflation in the steady states, α is exponent of labor in the production function, β is the discount factor. These parameters imply that in steady-state the gross real interest rate is 1.01, output is 0.46, deposits are 0.29, real balances 0.37, the real wage 0.88, the share of leisure in utility is 0.65, and $\gamma = 1.86$, which are in line with those used in the literature.

We parametrize the stochastic processes for the four shocks to all have the same persistence and the same standard deviation. We show later that our qualitative conclusions are robust to exact choice of these parameters. In the benchmark case we set:

υ	ε	ξ	ρ	ϕ	ψ	θ	σ_ϑ	σ_ω	σ_u
1.0	1.0	1.0	0.95	0.95	0.95	0.95	0.71	0.71	0.71

where υ, ε, ξ are the steady state value of the shocks, ρ, ϕ, ψ, θ are the AR parameters and σ_ϑ, σ_ω, σ_u are the standard deviations for the shocks. Using the resource constraint in the steady-state we have that $\bar{G^A} = \bar{y} - \bar{m} = 0.09$. We choose the standard deviation of G shocks so that the coefficient of variation is the same as for other processes, i.e., $\sigma_\varphi = G^A * 0.71 = 0.06$. Note that this parsimonious selection ties our hands since it reduces the number of degrees of freedom we have to fine tune the data to the idiosyncracies of the various identification schemes.

To solve the model we transform the variables in real terms (with lower case letters denoting real variables). This ensures, along with the assumed parametrization, stationarity of simulated data. We specify the policy rule to be of the form

$$m_t^{\delta_0} = \kappa \Pi_t^{\delta_1} R_t^{\delta_2} y_t^{\delta_3} \varepsilon_t \tag{2.24}$$

where κ is a constant. In percentage deviation from steady state, a partial accommodation rule is obtained setting $\delta_2 = -1, \delta_0 = -0.3, \delta_1 = \delta_3 = 0$; and a feedback (Taylor) rule is obtained by setting $\delta_2 = -1.0; \delta_1 = 0.5; \delta_3 = 0.1, \delta_0 = 0$. Note that in both cases the supply of real balances is upward sloping in the (m, R) space.

A solution to the model is obtained by log-linearizing the equilibrium conditions around the steady state using the approach of Uhlig (1997).

2.9. Policy rules and the dynamics of the model

Inspection of the equilibrium policy functions along with the dynamics generated by the model provides useful information on the characteristics of our economy under the two monetary policy rules. We present the equilibrium policy functions in table 1. Figure 1 plots the impulse responses to the four shocks in an economy with a partial accommodative rule and figure 2 presents the responses of the endogenous variables following a persistent monetary policy shock under the two different policy rules. Table 2 reports the theoretical variance decomposition at the 16-periods horizon for output, inflation, nominal interest rate and real balances for each of the two rules.

Table 1 presents some interesting features. First of all, the dynamics generated with a feedback (FB) rule are richer than those obtained with a partial accommodative (PA) rule. In particular, in the FB economy, real balances, real deposits, output, employment and real wages are negatively related to last period real balances - higher real balances last period imply that current interest rates and inflation will be higher-while this is not the case in the PA economy. Second, the sign of certain impact coefficients is different in the two economies. In particular, in the PA rule a technology disturbance decreases hours on impact, while in the FB rule the instantaneous response of hours is positive although small. This differential behavior of equilibrium employment can be easily explained by examining the reaction of nominal interest rates to technology shocks. When interest rates react positively to the shock, agents are richer and the wealth effect of the shock, together with the higher wage costs for the firms, make employment decline. When the interest rate decreases in response to the shock, the expansionary effect generated by lower costs of production dominates the negative wealth effect of the shock. Third, in the FB rule, the instantaneous response of the nominal interest rate to a monetary policy shock is much smaller in magnitude. That is, nominal interest rates are worse indicators of the stance of monetary policy with a FB rule than with a PA rule (see also Bernanke and Blinder (1992)). Finally, note that all disturbances produce contemporaneous impacts on all the variables of the system with both rules. This feature should be kept in mind when discussing the results obtained from identification schemes which impose "inertial" restrictions on the contemporaneous effect of certain shocks.

From figure 1 we see that a technology shock has the standard effects on output, inflation, real wage, real balances and real deposits while the dynamics of hours are dominated by the wealth effect [2]. A positive preference shock represents an outward shift in the labor supply: it increases all variables but inflation and the real wage which decline for a few periods after the disturbances. A (contractionary) monetary shock generates a persistent increase in the nominal interest rate and produces long lasting depressive effects on output, hours worked, real wage, inflation, real balances and

[2] We have also experimented with an economy where capital accumulation is allowed. In this economy hours increase by approximately the same amount as output. Because none of the other dynamics are altered, and the introduction of a third state considerably complicates the computation of the solution of the model without improving our understanding of the issues of interest, we only present results obtained from a model with fixed capital. The interested reader is invited to consult Pina (1999).

real deposits [3]. Finally, an unexpected increase in government expenditure increases output and inflation (this latter variable only for one quarter), makes agents work harder and deposit more and this decreases real wage and real balances held.

Figure 2 indicates that the responses to a monetary policy disturbance is qualitatively similar in the two economies. The dynamics in the PA economy are well characterized by a linear AR(1) process, while in the FB economy peaks or through responses occur with a lag of two quarters. Note also that the magnitude of the responses is more pronounced in the FB economy, in particular for inflation and the nominal interest rate.

Most of the dynamics at the 4-years horizons are due to technology and monetary shocks, regardless of the policy rule used. Preference disturbances account for a small portion of the variance of output and real balances, but they have no measurable impact on interest rates. Government expenditure shocks explain a small percentage of inflation variance in a PA economy, but otherwise they have negligible effects in the system. Finally, note that monetary shocks explain a larger portion of the variability of output in the FB economy then in the PA economy (35% vs. 14%) and that interest rate movements are largely driven by monetary disturbances in both economies.

To summarize, the dynamics generated by monetary policy disturbances are qualitatively independent of the policy rule. A contractionary disturbance, persistently increases nominal interest rates, has contemporaneous and long lasting negative effects on output and makes inflation first decline and then increase. Monetary shocks account for a substantial portion of the variance of nominal rates at long horizons, and varying amount of inflation variance. Consistent with the characterization offered by Sims and Zha (1996) and Uhlig (1999), the percentage of the variance of real variables explained by policy disturbances in the PA economy is modest. In the FB economy monetary disturbances account for one-third of the variance of real variables.

While the model specification is far from being a good null hypothesis as far as fitting actual data, it is able to qualitatively produce those features which the empirical literature has uncontroversially found in the data (see e.g. Gordon and Leeper (1994) and Sims (1998)). Our task in the next few sections is to examine whether identified VAR models are able to recover this set of fundamental features.

3. VAR Models

3.1. Specification

We represent the simulated economy of section 2 with a set of linear dynamic equations of the form

$$A_0 z_t = A(L) z_{t-1} + e_t \tag{3.1}$$

where L is the lag operator, $A(L)$ is a matrix polynomial in L, $e_t = [v_t, \xi_t, \varepsilon_t, G_t]$ is assumed to have a mean of zero and a diagonal covariance matrix Σ_e. We assume that A_0 is invertible so that the VAR representation of the system is

$$z_t = B(L) z_{t-1} + \zeta_t \tag{3.2}$$

[3] The persistence of these effects is due to the AR(1) nature of the shocks.

where $\zeta_t = A_0^{-1} e_t$ has covariance matrix Σ_ζ.

Our task will be to estimate VAR model like (3.2) using data simulated with the two different monetary policy rules, use the fact that $A_0^{-1}\Sigma_e A_0^{-1'} = \Sigma_\zeta$ and exclusion restrictions on A_0 to provide the minimal set of constraints needed to identify the various sources of structural disturbances. Then we examine (i) whether the sign and the magnitude of the coefficients of the estimated monetary policy rule replicate those of the generating economy, (ii) whether the estimated dynamics in response to a policy shock mimic those of the generating economy, (iii) whether the variance decomposition of a vector of variables matches the one of the theoretical economy.

Since our model has four structural shocks, we use a four variable VAR model with output, inflation, real balances and nominal interest rates as our basic structure. The choice of these variables, as opposed to their nominal counterpart, is dictated by the fact that their true dynamics are stationary and this makes our comparison exercise meaningful. Because the theoretical dynamics of the data are different under the two different rules, we estimate a VAR(1) model with data from the PA economy and a VAR(2) model with data from a FB economy[4].

As in the literature, we assume that the monetary policy rule is of the form

$$R_t = f(\Theta_t) + q_t \tag{3.3}$$

where f is a linear function of Θ_t, the available information set, and q_t is the monetary policy innovation. We consider two different specifications for Θ_t. The first, in the spirit of Christiano, Eichenbaum and Evans (1996) (CEE) assumes that Θ_t includes current and lagged values of output and inflation, in addition to lagged values of real balances and interest rates. In other words, we assume a contemporaneous relationship between monetary policy shock and shocks to inflation and production of the same type as the one described by the FB rule. To complete the identification of the other disturbances (which we call for simplicity, aggregate supply, aggregate demand and money demand) we assume that output contemporaneously reacts only to its own innovations, that inflation responds contemporaneously to output and inflation innovations and that real balances are contemporaneously affected by innovations in all the variables. These restrictions imply a recursive structure on the matrix A_0 with the variables in the VAR ordered as output, inflation, interest rates and real balances. The second identification scheme is in the spirit of Sims and Zha (1996) (SZ) and Leeper, Sims and Zha (1996). It assumes that Θ includes current and lagged values of real balances, in addition to lagged values of the interest rate, of inflation and of output. Hence the policy equation recovered with this scheme is characterized by the same type of contemporaneous feedbacks we obtain with a PA rule. To complete the identification of the other structural disturbances we assume as before that output and inflation are not contemporaneously affected by monetary policy shocks, that inflation reacts to output and inflation innovations contemporaneously and that real balances respond contemporaneously to innovations in the other three variables.

[4] AIC and SIC criteria also pick one and two lags for the two data sets. Increasing the lag length of the estimated VAR does not change the essence of the results we present.

3.2. The Results

We generate 250 data points for the variables for each of the two economies and use the last 150 as our data set. VAR models are estimated by OLS, equation by equation, and for each data set we apply the two identification schemes, for a total of 4 combinations. Contemporaneous impact coefficients are estimated with the Bernanke procedure in WinRATS after a preliminary search for initial conditions has been conducted with a simplex algorithm. Table 3 presents estimates of the non-zero coefficients obtained. In parenthesis, we report asymptotically normal standard errors.

It is worth concentrating our discussion first on the estimates of the policy equation with the two identification schemes. Recall that in the PA economy, the interest rate responds to real balances and the contemporaneous coefficient is 0.3. The SZ scheme correctly captures the sign of this coefficient but the point estimate is insignificantly different from zero. With the CEE scheme estimates of the coefficients on output and inflation, which should be theoretically equal to zero, are negative and significant. That is, estimates obtained with the CEE scheme imply that monetary policy is leaning against output and inflation innovations while this is not the case in the model economy. In the FB economy, the coefficients on output and inflation innovations in the policy equation are equal to 0.1 and 0.5, respectively. Our estimates with the CEE scheme instead suggest that these coefficients are negative and significant. Interestingly, short run estimates of the policy parameters are very similar across data sets with the CEE identification scheme. With the SZ identification scheme the sign of the coefficient on interest rate innovations is negative and significant so that, in this case, this scheme fails to recover a (positively sloped) supply function for real balances.

There are several other interesting aspects of table 3. First, regardless of the identification scheme used, the parameters of the money demand function are similar across data sets with the CEE scheme. Second, the magnitude of the parameter in the aggregate demand equation changes with the data set and it is larger with data generated by PA rule with both identification schemes. Finally, in all but one case estimated coefficients are significant both statistically and economically.

To summarize, in 3 out of the 4 experiments, identification obtained by imposing inertial restrictions on the contemporaneous effects of the shocks fails to capture the true monetary policy rule and provides a distorted picture of the impact coefficients in all the equations. In the remaining case, the estimated coefficient in the policy rule has the right sign but it is insignificant.

Figure 3 presents the estimated dynamics in response to interest rate shocks under the CEE scheme and in response to a monetary policy shock under the SZ scheme for the two data sets. Each figure presents 68% confidence bands obtained by Monte Carlo methods together with the theoretical responses we have presented in figure 2, scaled so that shocks in the theoretical economy and in the VAR have the same variance. For the just-identified CEE system, Monte Carlo bands are constructed using the standard WinRATS procedure. For over-identified SZ system we follow Sims and Zha (1998), draw replications from the joint posterior distribution of the autoregressive parameters, the variance-covariance matrix of the residuals and of the matrix of the structural parameters; use importance sampling to weight draws with different information and antithetic methods to speed up the calculations. We report small sample confidence bands obtained by drawing 1000 replications for each data set, as opposed to their asymptotic approximations, to allow for asymmetries in the distribution of impulse responses, if they exist.

Consider first the responses obtained with the CEE scheme. The responses of inflation and interest rates to what we have identified as monetary policy (interest rate) shock are similar across data sets. Hence, not only estimates of the contemporaneous parameters are insensitive to the underlying monetary policy rule with this identification scheme, but also the dynamics appear to inherit this feature. There are notable differences in the response of output and real balances in the two economies: a contractionary monetary policy shock (an increase in interest rate) generates median responses that are significant and positive in the PA economy, and significant and negative (after two steps) when we use data generated by a FB economy. Quantitatively, true responses differ from the estimated ones and for interest rates and inflation they are typically outside the estimated standard error bands. Note also, that with both data sets, the estimated time that the economy needs to adjust to the policy shock is long and the dynamics have not yet completely settled 16 periods after the shock.

With a recursive identification scheme, it is possible that disturbances to real balances also capture important aspects of monetary policy shocks. We do not report these responses here because there is very little difference in how the system react to interest rates and real balances shocks. In the PA economy, they are exactly identical apart from a sign change in all the responses. In the FB economy output and real balances median responses are significantly positive while inflation and interest rates median responses are insignificant. In general, true responses fall outside the bands except in the FB economy, but only for a few periods.

The median responses obtained with SZ identification scheme are qualitative similar to those obtained with the CEE scheme, regardless of the monetary policy rule. The bands, however, are very large and typically asymmetric reflecting the non-normality of estimated parameters in small samples. Overall, we find that in the PA economy, output and real balances responses are wrong and the entire band lies on the other side of zero; the one of inflation is somewhat misspecified, as the negative impact on inflation is missing. Finally, the bands for interest rates turns persistently negative after two quarters while in the model economy this is never the case. In the FB economy the major misspecification concerns the initially positive responses of inflation - a reminiscent of the "price puzzle" (see Sims (1992)) - and the fact that interest rate responses turn negative after 3 quarters. Notice that in this case, output and real balances responses do have the correct sign. Quantitatively speaking, true responses are occasionally inside the estimated bands but there is no substantial improvement relative to the CEE scheme.

In conclusion, both identification schemes fail to capture the contractionary consequences on output and the dynamics of inflation following a tightening of monetary policy in the PA economy. In the FB economy both schemes are better but also in this case they fail to reproduce the persistence of inflation and interest rate responses in the medium run.

We next turn to the variance decomposition (see table 4). Recall that in the theoretical economy monetary shocks play an important role as sources of fluctuations in the economy and explain, depending on the data set, between 14 and 35% of the variance of output and real balances, between 50 and 93% of the variance of inflation and between 87 and 97% of the variance of interest rates.

With the CEE identification scheme, interest rate innovations explain negligible portions of the variance of all four variables at the 16 periods horizon for both data sets. Interestingly, and contrary to what the theoretical decomposition suggested, inflation innovations are the only significant source of variations in interest rates at the 16 periods horizon with both data sets. Hence, this identification scheme produces the erroneous impression that the liquidity effect of monetary policy shocks are short lived and the expected inflation effects dominate the variability of interest rates in the long run. In general, this scheme produces monetary policy shocks which greatly underestimate the true contribution of these disturbances to the variance of real and monetary variables, regardless of the data set used. Note also that contrary to what occurred in the model, with a FB rule aggregate supply (output) innovations fail to explain a significant portion of inflation variability and with the PA rule aggregate demand (inflation) innovations fail to generate significant long run variations in output and real balances. Quantitatively, the true values are outside the error bands appearing in table 4.

With SZ identification scheme monetary policy innovations explain large and significant portions of the variability of real variables in both economies. With this identification scheme long run variations in interest rates appear to be driven, at least partially, by monetary policy innovations suggesting that the liquidity effect of a policy shock is much more long lived than with the CEE scheme. As with CEE scheme, aggregate demand (inflation) innovations explain small but significant portions of the variability of all variables while money demand (real balances) innovations play a negligible role with all data sets. Contrary to what was obtained in the theoretical economy, aggregate supply (output) innovations account for an insignificant portion of the variability of real variables which are now driven by aggregate demand and policy shocks. Finally, quantitatively speaking, the 68% bands do not in general include the true values presented in table 2.

In conclusion, with the CEE scheme the liquidity effects of a monetary policy shock are estimated to be short lived and this type of disturbances is estimated to have negligible importance in explaining real fluctuations regardless of the data used. With the SZ scheme the opposite occurs. The liquidity effects of monetary shocks have longer lasting repercussions on interest rates and this type of disturbances explain sizeable portion of the variance of output (between 17 and 52% in the PA economy and between 22% and 55% in the FB economy).

We have conducted several experiments to examine the sensitivity of the results to parameter choices in the theoretical economy. In particular, we have change the variances and the persistence of the structural shocks: we cut by half the variance of monetary innovations, we have calibrated their persistence to US data or made them iid. We have also varied the coefficient in partial accommodation rule from 0.0

(which correspond to a interest rate rule) [5] to 0.8 and changed the parameter on inflation in the feedback rule from 0.5 to 1.2. (see Sims and Zha (1998) and Taylor (1993) for an empirical justification of these ranges). We found that the extent of the misspecification is robust to variations of the parameters within these ranges even though, as we approach an interest rate rule, the results obtained with the SZ scheme worsen. We have also examined an identification scheme in the spirit of Sims (1992) where the estimated policy rule is characterized as a interest rate rule, i.e. where the nominal interest rate is assumed to respond only to its own innovations; real balances respond to innovations in the nominal rate; inflation is responding to innovations in the nominal rate and in real balances and output responds to innovations in all variables. The extent of the misspecification is reduced by this alternative ordering of the variables but the qualitative effects we report are still present [6].

4. Explanations

The results we have presented are somewhat surprising and contradict the conventional wisdom that (semi)-structural identification in VAR models can recover, when appropriately performed, the true dynamics of the data. It is therefore worth investigating why the results of our experiments go against this commonly held perception.

One possible reason for why both identification schemes fail to capture the features of the monetary policy rule in the generating economy is the small sample of the data. That is, structural VAR estimates are so far away from the truth because the sample is too short for any asymptotic approximation to hold. While this explanation has the potential to reconcile our results with the existing VAR evidence, we find it hard to believe that small samples may be the reason for the outcomes. After all, small samples typically imply that estimated contemporaneous parameters are insignificant and error bands include zeros, which is not necessarily the case in our experiments. Moreover, our sample size corresponds approximately to the size of quarterly US data used in almost all empirical exercises. Despite this a-priori skepticisms, we conducted two experiments to detect how important the problem is. In the first one, we generated 700 data points and kept the last 600 for estimation. The qualitative features of the results are unchanged. The coefficients of the policy function estimated under the CEE scheme are wrong and their magnitude is independent of the data generating process. With the SZ identification scheme the sign of the coefficient on real balances in the policy function is still wrong in the FB economy while the coefficient obtained with data generated in the PA economy is positive and now significantly different from zero. The remaining features of the impact coefficients remain and the qualitative features of the variance decomposition are also very similar to those of table 4.

In the second experiment, we artificially gave to the VAR econometrician the exact specification of the variance covariance matrix of reduced form VAR residuals (computed analytically from the theoretical VAR representation) and ask him/her

[5] Note that the price level is determined even when $\delta_0 = 0.0$ because in the model the fiscal and monetary authorities are separated.

[6] An appendix, available on request, contains the results of these and other experiments mentioned in the paper.

to estimate the free parameters with the two identification schemes. We present the estimated reduced form and the true covariance matrices in table 5. It is clear that the estimated covariance matrix approximates quite well the true one even with only 150 data points. When we input the true covariance matrix in the routine to estimate impact coefficients, we find no changes with the CEE scheme while with the SZ scheme the coefficient on real balances in the monetary policy rule for the PA economy is positive and significant. Also, the qualitative features of the variance decomposition are unchanged. Hence, the elimination of estimation and/or small sample problems helps to get more precise estimates of the coefficient of the policy rule in the PA economy with the SZ identification scheme but has no effect with the CEE scheme. Even in these ideal conditions, both schemes fail to capture the true contemporaneous interdependencies among the variables in the FB economy and misrepresent the dynamics following a monetary policy disturbance in all cases [7].

We have conducted a number of other robustness checks to examine whether the results are due to possibly improper assumptions we have made at the estimation stage. In particular, we have reestimated the VAR using money, prices in place of real balances, inflation and we have taken into account that, based on the policy rules presented in table 1, the inflation equation in the VAR is misspecified - there is a state variable (lagged deposits) which is omitted. In both cases, no significant changes in the qualitative features of the results are obtained. Hence, what is the reason for the poor performance of identified VARs?

To understand why VARs have hard time to capture the true dynamics of the data is worth turning back to the equilibrium policy functions and consider only the subset of the impact coefficients which correspond to the four variables used in the VAR. It is easy to check that in both cases the system is econometrically underidentified. That is, the model produces impact responses which are inconsistent with the inertial restrictions imposed by the two identification schemes. Imposing false zero restrictions implies an omitted variable bias and, because of the correlations present in the theoretical model, the non-zero coefficients will capture, to a large extent, the effect of omitted innovations. Hence, for example, the negative coefficients on inflation and output in the policy rule obtained with the CEE scheme result from the omission of monetary policy shocks from the aggregate supply and the aggregate demand equations.

Misspecification (both in terms of sign and magnitude) of the impact coefficients may translate in distorted estimates of the dynamics, since the matrix of contemporaneous effects enters the matrices of estimated structural lagged coefficients. This may explain why both the variance decomposition and the impulse responses are far from the true ones and, for example, why estimates of the contribution of monetary policy shocks to the variance of output is so different from the theoretical one.

[7] In private conversation Tao Zha pointed out to us that the Bernanke procedure in RATS may often lead to wrong ML estimates in overidentified models. While this is clearly a concern, we do not believe that this is the reason for the poor performance of the SZ scheme with the FB economy. Estimation with other packages gave similar results.

5. An alternative identification approach

The task of this section is to show that in economies like the one presented in section 2, where the matrix of impact coefficients is econometrically underidentified, VAR analysis **can** correctly recover structural disturbances. But for this to happen one should use identification schemes which do not require inertial restrictions on the contemporaneous impact coefficients. In the last few years there has been a number of papers providing methods to identify VAR using sign and shape restrictions (see Canova and De Nicoló (1998), Uhlig (1999) and Faust (1998)) and such methods work in economies like ours. To show that this is the case we employ a variant of the procedure suggested by Canova and De Nicoló. The basic idea of the method is simple. Economic theory does not typically provide information on the timing of the reaction of variables to shocks - which are the basis for the inertial-type restrictions appearing in the CEE or SZ schemes - but has something to say about the sign of the cross correlation function of VAR variables, in response to specific shocks. Here to identify structural disturbances we use the minimal set of restrictions shared by a large class of dynamic models (including flexible prices, sticky prices and indeterminacy-type models) which achieves the purpose. For example, we have seen that regardless of the exact specification of the policy rule, the theoretical economy (and many other specifications) implies that a contractionary monetary policy shock produces an increase in interest rates, a decrease in real balances and output and causes inflation to first decline and then increase (see figure 2). That is, an orthogonal shock can be termed "a monetary policy disturbance", if it generates a cross correlation function for interest rates and real balances and for interest rates and output that is negative for leads and lags and a cross correlation function for interest rates and inflation which is negative for leads and positive for lags of the interest rate.

To make this idea operative, we first find an orthogonal decomposition of the covariance matrix of the reduced form shocks, for example, of the type $\Sigma_\zeta = PDP'$ where P is a matrix of eigenvectors and D a diagonal matrix of eigenvalues, and then use the theoretical information about the joint response of the variables of the system in response to a monetary policy disturbance to see whether any of the four orthogonal shocks produces the required cross-correlation pattern. Since the matrix P does not have any zeros and is not subject to the misspecifications we have mentioned in the previous section. If with the proposed decomposition there is no shock which fits the theoretical pattern, one can try an alternative orthogonal decomposition and repeat the exercise. Since there is an infinite number of orthogonal decompositions which can be obtained from a symmetric matrix Σ_ζ, all differing by an (orthonormal) rotation matrix Q, it may be the case that many orthogonalizations produce the required pattern. When this is the case, we select the decomposition which come closest to reproduce the sign and the magnitude of a selected number of terms of the vector of theoretical pairwise cross correlation functions [8].

To illustrate the approach we present in the top panel of table 6 few terms of the theoretical cross correlation function of interest rates with inflation and real balances

[8] The reader interested in the technical details concerning these alternative decompositions may consult Canova and De Nicoló (1998).

in the two economies following a monetary policy disturbance. In the bottom panel we report the cross correlation function of the same variables following the shock we have identified to be the monetary policy disturbance. It is easy to check that the cross correlations for the two pair variables have the right sign; are approximately of the same magnitude of the theoretical ones and leads and lags correlations decay to zero, roughly, at the right speed.

In figure 4 we present impulse responses to the orthogonalized shock which we have termed monetary policy disturbance in the two economies. The sample size used to estimates the parameters is 150 and the VAR is estimated as in section 3. In both cases such a shock represents an expansionary monetary policy shock since it decreases interest rates, increases real balances and output and makes inflation first increase and then decline. None of the other shocks generate this special set of circumstances. Note that the response of output to monetary disturbances was not used to extract the policy shock from the data and therefore can be used to independently check the outcomes of the identification approach. It is therefore remarkable that the method produces output responses with persistence which match the theoretical one (68% bands include theoretical responses at almost all steps).

In figure 5 we present theoretical and estimated monetary policy shocks extracted with CEE, SZ and the alternative identification scheme for the two data sets. While innovations obtained with the CEE scheme for the PA economy have often the wrong sign and slightly different dynamics (contemporaneous correlation is 0.05), they are much more congruent with the true ones with the SZ scheme and the alternative identification scheme (contemporaneous correlations 0.96 and 0.98). For the FB economy the numbers are very similar even though estimated shocks lead actual ones.

How much of the variance of output, inflation, interest rates and real balances are explained by identified policy disturbances? Table 7 presents this information. For reference, we also repeat those of the theoretical economy. Although the importance of policy disturbances in explaining output and real balances is slightly overstated and their importance for inflation and interest rates slightly understated, 68% bands are not that far from the correct percentages. Moreover, qualitatively, identified shocks reproduce the basic features of theoretical monetary policy shocks. For example, in the PA economy, orthogonalized shocks to inflation explain in the median 24% of the variance of output, 63% of the variance of inflation, 95% of the variance of interest rates and 23% of the variance of real balances, while in the theoretical economy these percentages were 14%, 50%, 88%, and 14% respectively.

In conclusion, an approach which uses the sign of the conditional cross correlation function of a set of variables to identify structural disturbances does not suffer from the shortcomings affecting CEE and SZ approaches. Contrary to identification procedures that (wrongly) impose inertial restrictions on the contemporaneous impact of shocks, such an approach is able to properly identify the monetary policy disturbance without explicitly estimating any policy rule, mimics their dynamic effects on real variables and correctly measure their importance as source of fluctuations in the economy. It is important to stress that these results are obtained using the same sample size, the same variables, the same VAR specification and applying the same estimation approach employed in section 3. Hence, we confirm that small samples, the omission of a state variable, the nature of the variables used in the VAR are not crucial ingredients to explain why standard approaches fail. What matters is how complicated the matrix of impact multipliers is. When the underlying economy is of a dynamic general equilibrium type it is rarely the case the inertial restrictions imposed by structural VAR econometricians have appealing theoretical content.

6. Conclusions

This paper examined whether identified VAR models are able to capture crucial features of theoretical monetary policy disturbances. We have seen that, whenever a general equilibrium economy of the limited participation type is used to generate the data, identification approaches which employ inertial restrictions on the contemporaneous effects of certain structural shocks, produce misleading answers. Impact coefficients are mismeasured; the sign and the shape of impulse response function misspecified; the contribution of monetary shocks to the variability of real variables distorted; and these outcomes obtain even when the estimated policy rule correctly recognizes the variables entering in the theoretical policy rule.

We have seen that the reason for these outcomes is that the system of contemporaneous equations used to estimate impact coefficients is econometrically underidentified. The imposition of zero restrictions on an underidentified system causes an omitted variable problem which biases estimates of impact coefficients and the misrepresent the dynamics in response to structural shocks. We have also shown that in situations like these, VAR analyses conducted with a different style of identification may still be useful. When identification is obtained by means of sign restrictions on the cross correlation function of certain variables in response to shocks, as described in Canova and De Nicoló (1998), estimated policy shocks produce dynamics which mimic the theoretical ones and correctly characterize their importance for movements in real variables regardless of the policy rule employed.

We have argued that the results are essentially robust to the choice of policy rules and, to a large extent, identification schemes. In particular, the presence of more or less rich dynamics in the data generating process is not crucial and structural identification schemes a-la Sims and Zha (1996) are not necessarily better than semi-structural ones a-la Christiano, Eichenbaum and Evans (1997), except for estimating impact coefficients.

Standard statistics measuring the contribution of shocks to the dynamics of the endogenous variables may give an erroneous representation of reality when inappropriate identification schemes are used. Our results show than even when estimated impact coefficients are approximately correct, the dynamics in response to monetary policy shocks may be farfetched. Hence, crucial economic questions - how long lived are the liquidity effects of monetary policy? how important are monetary policy innovations in explaining the variability of real variables - may receive the incorrect answers. In our example, we have found that both types of misspecifications occur. In particular, the importance of monetary policy shocks for the variability of real variables may be underestimated, and this may explain why many authors (e.g. Uhlig (1999)) have questioned the importance of monetary policy disturbances as sources of output fluctuations. When an alternative identification procedure along the lines of Canova and De Nicoló (1998) is used these problems vanish. The contribution of various shocks to the variability of the four variables is correctly ranked, the dynamics in response to the structural shocks have the right qualitative features and, to a large extent, the correct magnitude.

Most of these conclusions should not surprise sophisticated users of structural VAR models. The idea that the omission of variables correlated with those included in a regression causes biases and distortions is as old as econometrics, as is the statement that economic systems which are underidentified can not be estimated using exclusion restrictions. What we have shown here is an example in which there is no variable reacting "sluggishly" to shocks which can be used as instrument in estimating contemporaneous effects. One may be tempted to argue that the result is specific to the model we use and do not carry over to specifications where sticky prices, adjustment costs or implementation lags may produce some zeros in the matrix of impact coefficients. While it is true that such specifications do produce sluggish responses of certain variables to shocks, it is also the case that they are not helpful for identification. This is because, for example, sticky prices imply that inflation will be sluggish in response to all shocks (not only monetary policy shocks) and this will translate in a column of zeros in the matrix of contemporaneous impacts. Clearly this set of zeros is not useful to identify various shocks. We have experimented with several variations of the theoretical economy and we have not been able to produce an example in which all four equations of our VAR would be simultaneously identifiable using inertial restrictions on contemporaneous coefficients (see also Sims and Zha (1996)). That is to say, the class of models which may produce an underidentified matrix of impact coefficients is probably larger we ourselves originally thought. Clearly, this does not mean that the information acquired in the last 10 years of VAR analyses on the effects of monetary policy should be expurgated from the body of knowledge available to applied macroeconometricians. If the class of theoretical models currently used in monetary economics has little bearing with the real world, precisely in determining the timing of the responses of variables to shocks, our exercise provides an important cautionary warning for those engaged in applied work in the field. However, whenever there are doubts about the extent of sluggishness of variables in reaction to disturbances, our alternative identification approach offers a safe bet against possible misrepresentations. The suggestion of moving away from using VAR identified using restrictions on contemporaneous coefficients is present in a latent form in the most recent literature (see e.g. Sims (1998)) and recent contributions by Canova and De Nicoló (1998), Faust (1998) and Uhlig (1999) make the task possible.

References

[1] Bernanke, B. and Blinder, A., 1992, "The Federal Funds Rate and the Channels of Monetary Transmission", *American Economic Review*, 901-921.

[2] Bernanke, B. and Mihov, I, 1998, "Measuring Monetary Policy", *Quarterly Journal of Economics* 113, 869-902.

[3] Canova, F. and De Nicoló,G., 1998, "Did You Know that Monetary Shocks Matter for Output and Inflation Cycles? Evidence form the G-7", CEPR working paper 2028.

[4] Chari, V. V., Kehoe, P. and McGrattan, E., 1996, "Sticky Price Models of the Business Cycle: Can the Contract Multiplier Solve the Persistence Problem?", *Federal Reserve Bank of Minneapolis Staff Report 217*, forthcoming, Econometrica.

[5] Christiano, L., 1991, Modelling the Liquidity Effect of a Monetary Shock, *Federal Reserve Bank of Minneapolis, Quarterly Review*, Winter, 1-24.

[6] Christiano, L., Eichenbaum, M. and Evans, C., 1996, "The Effects of Monetary Policy Shocks: Some Evidence from the Flow of Funds", *Review of Economics and Statistics* LXXVIII, pp. 16-34.

[7] Christiano, L., Eichenbaum, M. and Evans, C., 1997a, "Modeling Money", Northwestern University, manuscript.

[8] Christiano, Lawrence J., Eichenbaum, M. and Evans, Charles, L., 1997b, "Sticky Price and Limited Participation Models of Money: A Comparison", *European Economic Review*, 41, 1201-1249.

[9] Clarida, R., Galí, J. and Gertler, M., 1999, "The Science of Monetary Policy: A New Keynesian Perspective" forthcoming *Journal of Economic Literature.*

[10] Cooley, T. and Leroy, S. , 1985, "Atheoretical Macroeconomics: A Critique ", *Journal of Monetary Economics*, 16, 283-308.

[11] Cooley, Thomas F. and Quadrini, V., 1997, "Monetary Policy and Financial Decision of the Firms", UPF manuscript.

[12] Faust, J. , 1998, "The Robustness of identified VAR conclusions about money", forthcoming, *Carnegie Rochester Conference Series.*

[13] Hansen, L. and Sargent, T., 1991, "Two difficulties in Interpreting Vector Autoregressions " in Hansen, L. and Sargent, T. *Rational Expectations Econometrics*, Boulder Press

[14] Friedman, M. and Schwartz, A., 1960, *A Monetary History of United States*, Princeton University Press.

[15] Fuerst, T., 1992, "Liquidity, Loanable Funds and Real Activity", *Journal of Monetary Economics*, 29, 3-24.

[16] Gordon, R. and Leeper, E., 1994, "The Dynamic Impact of Monetary Policy: An Exercise in Tentative Identification", *Journal of Political Economy*, 102, 1228-1247.

[17] King, R. and Watson, M., 1996, "Money, Prices, Interest Rates and the Business Cycle", *Review of Economics and Statistics*, LXXVIII, 35-54

[18] Leeper, E., Sims, C. and Zha, T., 1996, "What Does Monetary Policy Do?",*Brookings Papers on Economic Activity*, 2, 1-78

[19] Lucas, R., 1990, "Liquidity and Interest Rates", *Journal of Economic Theory*, 50, 237-264.

[20] Pina, J. P., 1999 "Essays on Monetary Policy in VARs", Ph.D. dissertation, in progress.

[21] Rudebusch, G., 1998, "Do Measures of Monetary Policy in a VAR make sense?", *International Economic Review*, 39, 907-948 (with discussion and reply).

[22] Sargent, T., 1984, " Autoregression, Expectations, Advice " *American Economic Review*, 74, 408-415.

[23] Sims, C., 1980, " A Comparison of Interwar and Postwar Business Cycles: Monetarism Reconsidered", *American Economic Review*, 70, 250-257.

[24] Sims, C., 1992, "Interpreting the Macroeconomic Time Series Facts: the Effects of Monetary Policy", *European Economic Review*, 36, 975-1000.

[25] Sims, C., 1998, Comment on G. Rudebusch's "Do measures of Monetary Policy in a VAR make sense?", *International Economic Review*, 39, 933-941.

[26] Sims, C. and Zha, T., 1998, " Error Bands for Impulse Responses", Yale University, manuscript, forthcoming, *Econometrica*.

[27] Sims, C. and Zha, T., 1996, " Does Monetary Policy Generate Recessions?", Yale University, manuscript.

[28] Taylor, J., 1993, " Discretion versus Policy Rules in Practice", *Carnegie Rochester Conference Series on Public Policy*, 39, 195-214.

[29] Uhlig, H., 1997, "A Toolkit for Analyzing Nonlinear Dynamic Stochastic Models Easily", Tilburg University, http://center.kub.nl/staff/uhlig.

[30] Uhlig, H., 1999, "What are the Effects of Monetary Policy on Output? Results from an Agnostic Identification Procedure", Tilburg University, CentER working paper 9928.

Table 1 - Equilibrium Policy Functions

A) Partial accommodation economy

$$\begin{bmatrix} \widehat{m}_t \\ \widehat{i}_t \\ \widehat{y}_t \\ \widehat{n}_t \\ \widehat{\omega}_t \\ \widehat{R}_t \\ \widehat{\Pi}_t \end{bmatrix} = \begin{bmatrix} 0.0000 & -0.0000 \\ 0.0000 & 0.0000 \\ 0.0000 & 0.0000 \\ 0.0000 & 0.0000 \\ 0.0000 & 0.0000 \\ 0.0000 & 0.0000 \\ 5.1118 & -4.1118 \end{bmatrix} \begin{bmatrix} \widehat{m}_{t-1} \\ \widehat{i}_{t-1} \end{bmatrix} + \begin{bmatrix} 0.9732 & 0.4428 & -0.4428 & -0.1061 \\ 0.4399 & 0.2123 & -1.3934 & 0.1420 \\ 0.7786 & 0.3543 & -0.3543 & 0.1151 \\ -0.3406 & 0.5450 & -0.5450 & 0.1771 \\ 0.8273 & -0.3236 & -0.6764 & -0.0302 \\ 0.2920 & 0.1328 & 0.8672 & -0.0318 \\ -2.9741 & -1.3532 & -2.7586 & 1.1465 \end{bmatrix} \begin{bmatrix} \widehat{v}_t \\ \widehat{\xi}_t \\ \widehat{\varepsilon}_t \\ \widehat{g}_t \end{bmatrix}$$

B) Feedback economy

$$\begin{bmatrix} \widehat{m}_t \\ \widehat{i}_t \\ \widehat{y}_t \\ \widehat{n}_t \\ \widehat{\omega}_t \\ \widehat{R}_t \\ \widehat{\Pi}_t \end{bmatrix} = \begin{bmatrix} -0.4960 & 0.3990 \\ -1.0039 & 0.8075 \\ -0.3968 & 0.3192 \\ -0.6105 & 0.4910 \\ -0.7576 & 0.6094 \\ 0.9713 & -0.7813 \\ 2.0219 & -1.6264 \end{bmatrix} \begin{bmatrix} \widehat{m}_{t-1} \\ \widehat{i}_{t-1} \end{bmatrix} + \begin{bmatrix} 1.3034 & 0.5930 & -0.1941 & -0.2257 \\ 1.1459 & 0.5621 & -1.4786 & -0.1260 \\ 1.0427 & 0.4744 & -0.1552 & 0.0194 \\ 0.0657 & 0.7299 & -0.2388 & 0.0299 \\ 1.3315 & -0.0942 & -0.2964 & -0.2129 \\ -0.3545 & -0.1613 & 0.3800 & 0.2025 \\ -0.9175 & -0.4175 & -1.2089 & 0.4011 \end{bmatrix} \begin{bmatrix} \widehat{v}_t \\ \widehat{\xi}_t \\ \widehat{\varepsilon}_t \\ \widehat{g}_t \end{bmatrix}$$

Table 2 - Variance Decomposition at the 16-period horizon

A) Partial accommodation economy

	Output	Inflation	Interest rate	Real balances
Technology shocks	69.7	37.1	10.0	70.2
Preference shocks	14.4	7.3	2.1	14.5
Monetary shocks	14.4	50.6	87.8	14.5
Government shocks	1.5	5.0	0.1	0.8

B) Feedback economy

	Output	Inflation	Interest rate	Real balances
Technology shocks	52.4	5.0	1.7	52.2
Preference shocks	11.8	0.7	0.2	11.7
Monetary shocks	35.2	93.6	97.9	35.1
Government shocks	0.6	0.7	0.2	1.0

Table 3 - Estimated short run coefficients

A) CEE identification scheme

$$\widehat{y}_t = e_{1t}$$
$$\widehat{\Pi}_t = a_{21} * \widehat{y}_t + e_{2t}$$
$$\widehat{R}_t = a_{31} * \widehat{y}_t + a_{32} * \widehat{\Pi}_t + e_{3t}$$
$$\widehat{m}_t = a_{41} * \widehat{y}_t + a_{42} * \widehat{\Pi}_t + a_{43} * \widehat{R}_t + e_{4t}$$

	PA Economy	FB Economy
a_{21}	-1.72122 (0.31876)	-0.64691 (0.09436)
a_{31}	-0.55743 (0.00453)	-0.55501 (0.00362)
a_{32}	-0.24120 (0.00106)	-0.24129 (0.00275)
a_{41}	1.03882 (0.01797)	1.06010 (0.01729)
a_{42}	-0.09160 (0.00775)	-0.08307 (0.00757)
a_{43}	-0.37558 (0.03209)	-0.34297 (0.03106)

B) SZ identification scheme

$$\widehat{y}_t = e_{1t}$$
$$\widehat{\Pi}_t = a_{21} * \widehat{y}_t + e_{2t}$$
$$\widehat{R}_t = a_{34} * \widehat{m}_t + e_{3t}$$
$$\widehat{m}_t = a_{41} * \widehat{y}_t + a_{42} * \widehat{\Pi}_t + a_{43} * \widehat{R}_t + e_{4t}$$

	PA economy	FB economy
a_{21}	-1.72122 (0.31876)	-0.64691 (0.09436)
a_{34}	0.12066 (0.07065)	-0.30293 (0.01855)
a_{41}	1.02895 (0.01884)	1.08689 (0.01767)
a_{42}	-0.09587 (0.00813)	-0.07142 (0.00773)
a_{43}	-0.39329 (0.03365)	-0.29470 (0.03174)

Table 4 - Estimated Variance Decomposition at the 16-period horizon

1) CEE identification scheme

A) Partial accommodation economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in $\widehat{y}_t$	$[69.5, 93.7]$	$[8.7, 17.1]$	$[1.5, 17.1]$	$[70.4, 94.1]$
Innovations in $\widehat{\Pi}_t$	$[0.9, 15.0]$	$[81.8, 90.3]$	$[74.7, 95.8]$	$[0.9, 14.6]$
Innovations in $\widehat{R}_t$	$[0.6, 9.5]$	$[0.1, 0.9]$	$[0.3, 5.2]$	$[0.6, 9.2]$
Innovations in $\widehat{m}_t$	$[0.7, 10.0]$	$[0.1, 1.1]$	$[0.2, 6.5]$	$[0.7, 9.5]$

B) Feedback economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in $\widehat{y}_t$	$[32.4, 59.7]$	$[2.9, 7.5]$	$[1.6, 7.5]$	$[31.8, 59.2]$
Innovations in $\widehat{\Pi}_t$	$[15.7, 38.0]$	$[73.9, 91.3]$	$[68.3, 91.2]$	$[15.7, 37.8]$
Innovations in $\widehat{R}_t$	$[0.7, 12.2]$	$[1.5, 13.3]$	$[1.6, 17.9]$	$[0.7, 12.6]$
Innovations in $\widehat{m}_t$	$[7.2, 35.5]$	$[0.5, 9.2]$	$[0.5, 11.3]$	$[0.8, 36.2]$

2) SZ identification scheme

A) Partial accommodation economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in AS	$[3.4, 54.1]$	$[3.4, 12.9]$	$[1.7, 12.9]$	$[3.4, 50.2]$
Innovations in AD	$[24.1, 50.1]$	$[42.9, 79.8]$	$[39.0, 67.6]$	$[24.9, 50.0]$
Innovations in MP	$[17.0, 51.8]$	$[9.2, 51.0]$	$[24.9, 53.9]$	$[18.7, 51.8]$
Innovations in MD	$[0.1, 0.2]$	$[0.1, 0.1]$	$[0.1, 0.2]$	$[0.1, 0.2]$

B) Feedback economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in AS	$[1.0, 36.0]$	$[0.4, 4.2]$	$[0.3, 4.4]$	$[1.0, 35.7]$
Innovations in AD	$[12.7, 50.5]$	$[45.6, 73.3]$	$[46.4, 77.2]$	$[12.3, 50.5]$
Innovations in MP	$[22.0, 55.0]$	$[21.1, 51.3]$	$[15.9, 50.9]$	$[22.2, 55.1]$
Innovations in MD	$[0.4, 22.1]$	$[0.2, 3.3]$	$[0.2, 4.3]$	$[0.4, 22.4]$

Note: AS stands for aggregate supply, AD for aggregate demand, MP for monetary policy and MD for money demand.

Table 5 - True/Estimated Covariance-Correlation Matrix

A) Partial accommodation economy

	True				Estimated			
	$\widehat{y}_t$	$\widehat{\Pi}_t$	$\widehat{R}_t$	$\widehat{m}_t$	$\widehat{y}_t$	$\widehat{\Pi}_t$	$\widehat{R}_t$	$\widehat{m}_t$
$\widehat{y}_t$	0.4322	−0.4587	−0.0385	0.9997	0.4249	−0.4045	−0.1497	0.9998
$\widehat{\Pi}_t$		9.2238	−0.8700	−0.4591		7.6919	−0.8424	−0.4073
$\widehat{R}_t$			0.4309	−0.0384			0.3840	−0.1473
$\widehat{m}_t$				0.6753				0.6642

B) Feedback economy

	True				Estimated			
	$\widehat{y}_t$	$\widehat{\Pi}_t$	$\widehat{R}_t$	$\widehat{m}_t$	$\widehat{y}_t$	$\widehat{\Pi}_t$	$\widehat{R}_t$	$\widehat{m}_t$
$\widehat{y}_t$	0.6737	−0.5313	−0.8024	0.9998	0.6161	−0.4910	−0.8189	0.9999
$\widehat{\Pi}_t$		1.2497	−0.0771	−0.5316		1.0697	−0.0933	−0.4911
$\widehat{R}_t$			0.1494	−0.8030			0.1462	−0.8194
$\widehat{m}_t$				1.0528				0.9640

Note: In the upper part are correlations and on the main diagonal are the variances.

Table 6 - Dynamic Cross Correlations

1) Theoretical Model

A) Partial accommodation economy

Lags	−4	−3	−2	−1	0	1	2	3	4
Inflation-Interest rate	−24.1	27.5	29.6	31.0	−33.5	17.7	16.5	15.2	13.1
Real balances-Interest rate	−27.3	44.2	62.7	81.1	−100.0	−81.9	−62.8	−44.5	−27.4

B) Feedback economy

Lags	−4	−3	−2	−1	0	1	2	3	4
Inflation-Interest Rate	−26.3	−24.7	−17.9	8.6	86.6	33.7	15.8	7.8	2.5
Real balances-Interest Rate	5.7	−4.4	−17.5	−41.4	−100.0	−41.3	−17.6	−4.7	5.9

2) VAR Models

A) Partial accommodation economy

Lags	−4	−3	−2	−1	0	1	2	3	4
Inflation-Interest Rate	−17.2	−19.0	−20.9	−23.2	−26.1	33.2	25.2	20.3	15.9
Real balances-Interest Rate	−13.1	−29.6	−48.5	−69.7	−93.6	−90.6	−72.1	−54.8	−38.1

B) Feedback economy

					Interest rate				
Lags	−4	−3	−2	−1	0	1	2	3	4
Inflation-Interest Rate	−25.9	−11.5	9.2	36.5	80.9	61.9	50.1	34.7	19.8
Real balances-Interest Rate	−21.1	−42.6	−64.1	−83.2	−98.8	−78.4	−52.8	−29.5	−7.8

Table 7 - Variance Decomposition: Alternative Identification

A) Partial accommodation economy

	Output	Inflation	Interest rate	Real balances
Theoretical MP shocks	14.4	50.6	87.8	14.5
Identified MP shocks	$[16.1, 32.0]$	$[61.5, 64.2]$	$[91.2, 96.3]$	$[15.8, 31.6]$

B) Feedback economy

	Output	Inflation	Interest rate	Real balances
Theoretical MP shocks	35.2	93.6	97.9	35.1
Identified MP shocks	$[37.0, 53.1]$	$[74.1, 86.2]$	$[76.6, 87.8]$	$[36.8, 52.8]$

Appendix

This appendix contains the results of the experiments we mentioned in the text.

Basic Setup, 600 data points

Table A.1 - Estimated Short run coefficients

A) CEE identification scheme

$$\widehat{\Pi}_t = a_{21} * \widehat{y}_t$$
$$\widehat{R}_t = a_{31} * \widehat{y}_t + a_{32} * \widehat{\Pi}_t$$
$$\widehat{m}_t = a_{41} * \widehat{y}_t + a_{42} * \widehat{\Pi}_t + a_{43} * \widehat{R}_t$$

	Partial accommodation	Feedback
a_{21}	−2.02702 (0.17246)	−0.71221 (0.04466)
a_{31}	−0.54857 (0.00214)	−0.55257 (0.00189)
a_{32}	−0.24219 (0.00046)	−0.24069 (0.00145)
a_{41}	1.06551 (0.01002)	1.07606 (0.00863)
a_{42}	−0.08138 (0.00441)	−0.07649 (0.00379)
a_{43}	−0.33456 (0.01818)	−0.31176 (0.01556)

B) SZ identification scheme

$$\widehat{\Pi}_t = a_{21} * \widehat{y}_t$$
$$\widehat{R}_t = a_{34} * \widehat{m}_t$$
$$\widehat{m}_t = a_{41} * \widehat{y}_t + a_{42} * \widehat{\Pi}_t + a_{43} * \widehat{R}_t$$

	Partial accommodation	Feedback
a_{21}	−2.02702 (0.17246)	−0.71221 (0.04466)
a_{34}	0.20888 (0.03910)	−0.29198 (0.00877)
a_{41}	1.04429 (0.01076)	1.10177 (0.00880)
a_{42}	−0.09075 (0.00473)	−0.06529 (0.00386)
a_{43}	−0.37323 (0.01953)	−0.26525 (0.01587)

Table A.2 - Estimated Variance Decomposition at the 4-year horizon

1) CEE identification

A) Partial accommodation economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in $\widehat{y}_t$	$[93.4, 99.0]$	$[11.7, 16.0]$	$[0.3, 3.4]$	$[94.0, 99.1]$
Innovations in $\widehat{\Pi}_t$	$[0.2, 2.6]$	$[83.9, 88.1]$	$[95.1, 99.1]$	$[0.3, 2.6]$
Innovations in $\widehat{R}_t$	$[0.0, 1.6]$	$[0.0, 0.1]$	$[0.1, 0.7]$	$[0.0, 1.4]$
Innovations in $\widehat{m}_t$	$[0.1, 3.0]$	$[0.0, 0.2]$	$[0.0, 1.4]$	$[0.1, 2.6]$

B) Feedback economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in $\widehat{y}_t$	$[68.0, 83.8]$	$[4.0, 7.6]$	$[1.7, 8.0]$	$[68.3, 84.1]$
Innovations in $\widehat{\Pi}_t$	$[13.2, 28.5]$	$[90.2, 94.7]$	$[89.9, 96.8]$	$[13.1, 28.4]$
Innovations in $\widehat{R}_t$	$[0.2, 3.8]$	$[0.2, 1.4]$	$[0.1, 1.6]$	$[0.2, 3.6]$
Innovations in $\widehat{m}_t$	$[0.1, 2.3]$	$[0.2, 1.4]$	$[0.2, 1.6]$	$[0.1, 2.1]$

2) SZ identification

A) Partial accommodation economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in AS	$[6.4, 81.9]$	$[7.1, 15.4]$	$[1.8, 6.2]$	$[6.8, 80.4]$
Innovations in AD	$[9.4, 45.3]$	$[47.7, 84.0]$	$[8.6, 66.4]$	$[9.7, 44.9]$
Innovations in MP	$[8.2, 48.9]$	$[2.1, 46.2]$	$[30.2, 85.6]$	$[9.1, 48.5]$
Innovations in MD	$[0.0, 0.1]$	$[0.0, 0.1]$	$[0.0, 0.2]$	$[0.0, 0.1]$

B) Feedback economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in AS	$[5.9, 67.4]$	$[2.9, 8.6]$	$[1.2, 7.7]$	$[6.6, 70.0]$
Innovations in AD	$[25.9, 55.0]$	$[29.6, 80.2]$	$[36.0, 87.3]$	$[23.8, 54.8]$
Innovations in MP	$[4.3, 40.8]$	$[13.3, 65.5]$	$[7.6, 58.4]$	$[4.0, 40.2]$
Innovations in MD	$[0.1, 1.6]$	$[0.2, 1.2]$	$[0.1, 1.5]$	$[0.1, 1.5]$

Basic Setup, True VCV

Table A.3 - Short run coefficients

A) CEE identification scheme

$$\widehat{\Pi}_t = a_{21} * \widehat{y}_t$$
$$\widehat{R}_t = a_{31} * \widehat{y}_t + a_{32} * \widehat{\Pi}_t$$
$$\widehat{m}_t = a_{41} * \widehat{y}_t + a_{42} * \widehat{\Pi}_t + a_{43} * \widehat{R}_t$$

	Partial accommodation	Feedback
a_{21}	−2.11893 (0.33630)	−0.72351 (0.09484)
a_{31}	−0.55323 (0.00251)	−0.55330 (0.00252)
a_{32}	−0.24296 (0.00054)	−0.24248 (0.00185)
a_{41}	0.70947 (0.01746)	0.72046 (0.01436)
a_{42}	−0.23725 (0.00766)	−0.23238 (0.00631)
a_{43}	−0.97565 (0.03151)	−0.95589 (0.02591)

B) SZ identification scheme

$$\widehat{\Pi}_t = a_{21} * \widehat{y}_t$$
$$\widehat{R}_t = a_{34} * \widehat{m}_t$$
$$\widehat{m}_t = a_{41} * \widehat{y}_t + a_{42} * \widehat{\Pi}_t + a_{43} * \widehat{R}_t$$

	Partial accommodation	Feedback
a_{21}	−2.11893 (0.33630)	−0.72351 (0.09484)
a_{34}	0.65007 (0.11514)	−0.23775 (0.02015)
a_{41}	0.67691 (0.01821)	0.73738 (0.01461)
a_{42}	−0.25155 (0.00799)	−0.22497 (0.00642)
a_{43}	−1.03449 (0.03287)	−0.92531 (0.02637)

Table A.4 - Variance Decomposition at the 4-year horizon

1) CEE identification

A) Partial accommodation economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in $\widehat{y}_t$	$[68.3, 93.3]$	$[11.6, 21.3]$	$[0.7, 11.6]$	$[69.2, 93.7]$
Innovations in $\widehat{\Pi}_t$	$[0.9, 15.2]$	$[77.5, 87.4]$	$[78.5, 97.0]$	$[0.9, 14.9]$
Innovations in $\widehat{R}_t$	$[1.4, 18.5]$	$[0.1, 1.7]$	$[0.4, 11.1]$	$[1.3, 17.7]$
Innovations in $\widehat{m}_t$	$[0.2, 2.8]$	$[0.0, 0.3]$	$[0.1, 1.8]$	$[0.2, 2.6]$

B) Feedback economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in $\widehat{y}_t$	$[23.0, 52.8]$	$[3.1, 8.0]$	$[1.5, 7.2]$	$[22.3, 52.4]$
Innovations in $\widehat{\Pi}_t$	$[12.4, 36.3]$	$[80.1, 93.5]$	$[78.4, 95.0]$	$[12.3, 36.0]$
Innovations in $\widehat{R}_t$	$[14.3, 50.5]$	$[1.0, 10.6]$	$[1.1, 12.5]$	$[14.8, 51.2]$
Innovations in $\widehat{m}_t$	$[2.1, 9.3]$	$[0.2, 3.5]$	$[0.2, 4.4]$	$[2.2, 9.5]$

2) SZ identification

A) Partial accommodation economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in AS	$[17.0, 43.3]$	$[14.5, 26.8]$	$[12.8, 27.8]$	$[16.9, 40.5]$
Innovations in AD	$[19.5, 35.6]$	$[23.9, 48.5]$	$[22.9, 49.0]$	$[20.0, 35.6]$
Innovations in MP	$[31.7, 52.1]$	$[33.4, 51.9]$	$[32.0, 52.6]$	$[34.2, 52.2]$
Innovations in MD	$[0.0, 0.0]$	$[0.0, 0.0]$	$[0.0, 0.0]$	$[0.0, 0.0]$

B) Feedback economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in AS	$[1.3, 8.1]$	$[1.4, 8.2]$	$[1.2, 8.1]$	$[1.3, 8.1]$
Innovations in AD	$[40.3, 50.0]$	$[40.7, 50.3]$	$[41.1, 51.6]$	$[40.2, 50.0]$
Innovations in MP	$[45.8, 54.5]$	$[44.8, 53.3]$	$[44.5, 53.2]$	$[45.9, 54.7]$
Innovations in MD	$[0.0, 0.1]$	$[0.0, 0.2]$	$[0.0, 0.2]$	$[0.0, 0.1]$

$$\hat{R}_t = 0.1 * \hat{m}_t + \hat{\varepsilon}_t$$

Table A5 - Estimated Short run coefficients

A) CEE identification scheme

$$\widehat{\Pi}_t = a_{21} * \widehat{y}_t$$
$$\widehat{R}_t = a_{31} * \widehat{y}_t + a_{32} * \widehat{\Pi}_t$$
$$\widehat{m}_t = a_{41} * \widehat{y}_t + a_{42} * \widehat{\Pi}_t + a_{43} * \widehat{R}_t$$

	Partial accommodation
a_{21}	−0.88012 (0.29018)
a_{31}	−0.55862 (0.00389)
a_{32}	−0.24125 (0.00106)
a_{41}	1.03956 (0.1797)
a_{42}	−0.09147 (0.00775)
a_{43}	−0.37513 (0.03206)

B) SZ identification scheme

$$\widehat{\Pi}_t = a_{21} * \widehat{y}_t$$
$$\widehat{R}_t = a_{34} * \widehat{m}_t$$
$$\widehat{m}_t = a_{41} * \widehat{y}_t + a_{42} * \widehat{\Pi}_t + a_{43} * \widehat{R}_t$$

	Partial accommodation
a_{21}	−0.88012 (0.29018)
a_{34}	−0.08723 (0.06344)
a_{41}	1.04728 (0.01891)
a_{42}	−0.08814 (0.00815)
a_{43}	−0.36132 (0.03374)

Table A6 - Variance Decomposition at the 4-year horizon

1) Theoretical Model
Partial accommodation economy

	Output	Inflation	Interest rate	Real balances
Technology shocks	69.9	24.2	1.2	70.1
Preference shocks	14.5	4.9	0.3	14.5
Monetary shocks	14.5	66.1	98.5	14.5
Government shocks	1.1	4.8	0.0	0.9

2) VAR Models

A) CEE identification
Partial accommodation economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in $\widehat{y}_t$	$[69.2, 93.5]$	$[4.7, 9.5]$	$[7.3, 32.2]$	$[70.1, 93.4]$
Innovations in $\widehat{\Pi}_t$	$[1.0, 14.9]$	$[88.2, 94.2]$	$[59.0, 87.4]$	$[0.9, 14.8]$
Innovations in $\widehat{R}_t$	$[0.6, 9.7]$	$[0.1, 1.5]$	$[0.3, 6.9]$	$[0.6, 9.4]$
Innovations in $\widehat{m}_t$	$[0.8, 10.2]$	$[0.2, 1.7]$	$[0.3, 8.2]$	$[0.7, 9.8]$

B) SZ identification
Partial accommodation economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in AS	$[2.7, 52.4]$	$[2.4, 9.2]$	$[2.0, 16.6]$	$[2.7, 48.8]$
Innovations in AD	$[25.4, 50.9]$	$[43.3, 83.1]$	$[40.3, 65.2]$	$[26.5, 50.8]$
Innovations in MP	$[16.9, 51.8]$	$[10.0, 51.1]$	$[22.5, 52.3]$	$[18.8, 51.8]$
Innovations in MD	$[0.1, 0.2]$	$[0.1, 0.2]$	$[0.1, 0.2]$	$[0.1, 0.2]$

$$\hat{R}_t = 0.8 * \hat{m}_t + \hat{\varepsilon}_t$$

Table A7 - Estimated Short run coefficients

A) CEE identification scheme

$$\widehat{\Pi}_t = a_{21} * \widehat{y}_t$$
$$\widehat{R}_t = a_{31} * \widehat{y}_t + a_{32} * \widehat{\Pi}_t$$
$$\widehat{m}_t = a_{41} * \widehat{y}_t + a_{42} * \widehat{\Pi}_t + a_{43} * \widehat{R}_t$$

	Partial accommodation
a_{21}	-3.82306 (0.39018)
a_{31}	-0.55406 (0.00649)
a_{32}	-0.24110 (0.00106)
a_{41}	1.03717 (0.01800)
a_{42}	-0.09175 (0.00777)
a_{43}	-0.37602 (0.03217)

B) SZ identification scheme

$$\widehat{\Pi}_t = a_{21} * \widehat{y}_t$$
$$\widehat{R}_t = a_{34} * \widehat{m}_t$$
$$\widehat{m}_t = a_{41} * \widehat{y}_t + a_{42} * \widehat{\Pi}_t + a_{43} * \widehat{R}_t$$

	Partial accommodation
a_{21}	-3.82306 (0.39018)
a_{34}	0.63549 (0.08846)
a_{41}	0.99335 (0.01936)
a_{42}	-0.11081 (0.00836)
a_{43}	-0.45511 (0.03463)

Table A8 - Variance Decomposition at the 4-year horizon

1) Theoretical Model
Partial accommodation economy

	Output	Inflation	Interest rate	Real balances
Technology shocks	68.7	58.2	40.7	70.1
Preference shocks	14.2	11.4	8.4	14.5
Monetary shocks	14.2	25.7	50.4	14.5
Government shocks	2.9	4.7	0.5	0.9

2) VAR Models

A) CEE identification
Partial accommodation economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in $\widehat{y}_t$	$[69.9, 94.0]$	$[27.3, 39.5]$	$[4.5, 17.9]$	$[71.1, 94.5]$
Innovations in $\widehat{\Pi}_t$	$[0.9, 15.5]$	$[59.8, 72.3]$	$[76.9, 93.5]$	$[0.9, 15.0]$
Innovations in $\widehat{R}_t$	$[0.5, 9.0]$	$[0.0, 0.4]$	$[0.2, 3.1]$	$[0.4, 8.5]$
Innovations in $\widehat{m}_t$	$[0.6, 9.6]$	$[0.1, 0.5]$	$[0.1, 3.6]$	$[0.6, 9.1]$

B) SZ identification
Partial accommodation economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in AS	$[4.8, 58.7]$	$[5.6, 28.7]$	$[4.2, 25.0]$	$[4.9, 55.8]$
Innovations in AD	$[21.5, 48.6]$	$[41.0, 63.7]$	$[19.8, 61.2]$	$[22.6, 48.5]$
Innovations in MP	$[15.7, 51.8]$	$[7.1, 50.7]$	$[25.8, 56.7]$	$[17.4, 51.6]$
Innovations in MD	$[0.0, 0.1]$	$[0.0, 0.1]$	$[0.0, 0.1]$	$[0.0, 0.1]$

$$\hat{R}_t = 0.55 * \hat{y}_t + 1.2 * \hat{\Pi}_t + \hat{\varepsilon}_t$$

Table A9 - Estimated Short run coefficients

A) CEE identification scheme

$$\widehat{\Pi}_t = a_{21} * \widehat{y}_t$$
$$\widehat{R}_t = a_{31} * \widehat{y}_t + a_{32} * \widehat{\Pi}_t$$
$$\widehat{m}_t = a_{41} * \widehat{y}_t + a_{42} * \widehat{\Pi}_t + a_{43} * \widehat{R}_t$$

	Feedback
a_{21}	-0.65777 (0.05216)
a_{31}	-0.53933 (0.01073)
a_{32}	-0.22409 (0.01174)
a_{41}	1.20448 (0.01107)
a_{42}	-0.02282 (0.00530)
a_{43}	-0.07936 (0.01996)

B) SZ identification scheme

$$\widehat{\Pi}_t = a_{21} * \widehat{y}_t$$
$$\widehat{R}_t = a_{34} * \widehat{m}_t$$
$$\widehat{m}_t = a_{41} * \widehat{y}_t + a_{42} * \widehat{\Pi}_t + a_{43} * \widehat{R}_t$$

	Feedback
a_{21}	-0.65777 (0.05216)
a_{34}	-0.31229 (0.01108)
a_{41}	1.21466 (0.01115)
a_{42}	-0.01859 (0.00533)
a_{43}	-0.06049 (0.02009)

Table A10 - Variance Decomposition at the 4-year horizon

1) Theoretical Model
Feedback economy

	Output	Inflation	Interest rate	Real balances
Technology shocks	14.2	21.5	21.3	14.2
Preference shocks	1.4	2.4	2.4	1.4
Monetary shocks	84.1	75.8	75.9	83.8
Government shocks	0.2	0.3	0.4	0.6

2) VAR Models

A) CEE identification
Feedback economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in $\widehat{y}_t$	$[1.9, 11.6]$	$[1.4, 14.3]$	$[1.3, 14.3]$	$[1.9, 11.7]$
Innovations in $\widehat{\Pi}_t$	$[76.8, 93.8]$	$[77.1, 94.8]$	$[77.0, 94.9]$	$[76.7, 93.8]$
Innovations in $\widehat{R}_t$	$[0.8, 6.1]$	$[0.6, 5.2]$	$[0.5, 5.2]$	$[0.8, 6.1]$
Innovations in $\widehat{m}_t$	$[0.6, 9.8]$	$[0.2, 7.1]$	$[0.3, 7.4]$	$[0.6, 9.7]$

B) SZ identification
Feedback economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in AS	$[2.4, 13.3]$	$[2.1, 16.7]$	$[1.9, 16.4]$	$[2.4, 13.2]$
Innovations in AD	$[52.5, 87.9]$	$[59.8, 90.3]$	$[60.3, 90.6]$	$[52.1, 87.8]$
Innovations in MP	$[3.5, 30.0]$	$[2.3, 23.5]$	$[2.0, 23.4]$	$[3.6, 30.2]$
Innovations in MD	$[0.8, 10.2]$	$[0.3, 7.2]$	$[0.3, 7.5]$	$[0.8, 10.1]$

$$\sigma_\eta^2 = 0.5 * \sigma_\vartheta^2$$

Table A11 - Estimated Short run coefficients

A) CEE identification scheme

$$\widehat{\Pi}_t = a_{21} * \widehat{y}_t$$
$$\widehat{R}_t = a_{31} * \widehat{y}_t + a_{32} * \widehat{\Pi}_t$$
$$\widehat{m}_t = a_{41} * \widehat{y}_t + a_{42} * \widehat{\Pi}_t + a_{43} * \widehat{R}_t$$

	Partial accommodation	Feedback
a_{21}	-2.57367 (0.24969)	-0.73170 (0.06850)
a_{31}	-0.55450 (0.00569)	-0.56125 (0.01124)
a_{32}	-0.24041 (0.00143)	-0.21983 (0.01011)
a_{41}	1.03827 (0.01801)	1.21469 (0.01011)
a_{42}	-0.09170 (0.00777)	-0.01701 (0.00437)
a_{43}	-0.37519 (0.03222)	-0.05890 (0.01732)

B) SZ identification scheme

$$\widehat{\Pi}_t = a_{21} * \widehat{y}_t$$
$$\widehat{R}_t = a_{34} * \widehat{m}_t$$
$$\widehat{m}_t = a_{41} * \widehat{y}_t + a_{42} * \widehat{\Pi}_t + a_{43} * \widehat{R}_t$$

	Partial accommodation	Feedback
a_{21}	-2.57367 (0.24969)	-0.73170 (0.06850)
a_{34}	0.18879 (0.05187)	-0.31874 (0.01383)
a_{41}	1.02314 (0.01851)	1.22285 (0.01006)
a_{42}	-0.09826 (0.00798)	-0.01382 (0.00439)
a_{43}	-0.40247 (0.03313)	-0.04437 (0.01742)

Table A12 - Estimated Variance Decomposition at the 4-year horizon

1) CEE identification

A) Partial accommodation economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in $\widehat{y}_t$	$[69.9, 93.7]$	$[28.0, 39.9]$	$[0.9, 9.3]$	$[70.9, 94.2]$
Innovations in $\widehat{\Pi}_t$	$[1.1, 16.4]$	$[59.2, 71.3]$	$[83.3, 97.1]$	$[1.0, 15.9]$
Innovations in $\widehat{R}_t$	$[0.5, 8.6]$	$[0.0, 0.6]$	$[0.4, 4.1]$	$[0.4, 8.3]$
Innovations in $\widehat{m}_t$	$[0.6, 9.4]$	$[0.1, 0.8]$	$[0.2, 5.4]$	$[0.6, 8.8]$

B) Feedback economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in $\widehat{y}_t$	$[36.4, 60.4]$	$[6.2, 13.2]$	$[2.8, 9.3]$	$[36.8, 60.9]$
Innovations in $\widehat{\Pi}_t$	$[11.6, 36.8]$	$[71.0, 86.3]$	$[71.2, 90.7]$	$[11.4, 36.4]$
Innovations in $\widehat{R}_t$	$[0.8, 8.3]$	$[1.2, 5.4]$	$[0.6, 6.4]$	$[0.8, 8.6]$
Innovations in $\widehat{m}_t$	$[12.4, 34.3]$	$[2.2, 13.3]$	$[1.8, 16.5]$	$[12.1, 33.8]$

2) SZ identification

A) Partial accommodation economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in AS	$[2.1, 59.2]$	$[3.1, 30.4]$	$[1.4, 11.3]$	$[2.2, 59.5]$
Innovations in AD	$[23.0, 51.9]$	$[44.7, 65.9]$	$[32.5, 68.2]$	$[22.9, 51.6]$
Innovations in MP	$[13.5, 51.6]$	$[5.9, 50.0]$	$[25.9, 59.4]$	$[14.0, 51.5]$
Innovations in MD	$[0.1, 0.3]$	$[0.1, 0.2]$	$[0.2, 0.3]$	$[0.1, 0.3]$

B) Feedback economy

	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in AS	$[3.3, 44.6]$	$[2.6, 11.6]$	$[1.6, 8.3]$	$[3.2, 44.2]$
Innovations in AD	$[7.2, 45.2]$	$[21.2, 57.9]$	$[17.4, 70.2]$	$[7.5, 44.9]$
Innovations in MP	$[18.7, 56.2]$	$[26.3, 65.8]$	$[16.3, 70.0]$	$[19.7, 56.2]$
Innovations in MD	$[0.9, 23.4]$	$[0.8, 10.7]$	$[0.9, 15.0]$	$[0.8, 22.3]$

Sims (1992) identification scheme

Table A13 - Estimated Short run coefficients

$$\widehat{m}_t = a_{21} * \widehat{R}_t$$
$$\widehat{\Pi}_t = a_{31} * \widehat{R}_t + a_{32} * \widehat{m}_t$$
$$\widehat{y}_t = a_{41} * \widehat{R}_t + a_{42} * \widehat{m}_t + a_{43} * \widehat{\Pi}_t$$

	Partial accommodation	Feedback
a_{21}	-0.19377 (0.10657)	-2.10391 (0.12057)
a_{31}	-4.12852 (0.01548)	-4.08128 (0.04001)
a_{32}	-1.84863 (0.01177)	-1.81991 (0.01558)
a_{41}	0.27025 (0.03554)	0.24341 (0.03315)
a_{42}	0.92152 (0.01594)	0.90756 (0.01476)
a_{43}	0.06607 (0.00860)	0.05893 (0.00806)

Table A14 - Estimated Variance Decomposition at the 4-year horizon

	A) Partial accommodation economy			
	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in $\widehat{y}_t$	$[1.5, 14.7]$	$[0.2, 1.4]$	$[0.4, 8.5]$	$[1.3, 14.3]$
Innovations in $\widehat{\Pi}_t$	$[0.6, 6.2]$	$[0.2, 0.7]$	$[0.1, 3.5]$	$[0.5, 6.0]$
Innovations in $\widehat{R}_t$	$[3.2, 25.6]$	$[73.5, 80.2]$	$[79.7, 97.3]$	$[3.1, 25.2]$
Innovations in $\widehat{m}_t$	$[60.4, 88.3]$	$[18.6, 24.9]$	$[0.4, 10.3]$	$[61.4, 88.8]$
	B) Feedback economy			
	$Var(\widehat{y}_t)$	$Var(\widehat{\Pi}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{m}_t)$
Innovations in $\widehat{y}_t$	$[8.6, 36.3]$	$[0.4, 7.4]$	$[0.5, 8.9]$	$[9.0, 37.0]$
Innovations in $\widehat{\Pi}_t$	$[0.4, 7.3]$	$[2.6, 20.6]$	$[3.7, 26.5]$	$[0.4, 7.4]$
Innovations in $\widehat{R}_t$	$[50.7, 79.0]$	$[21.8, 41.7]$	$[24.2, 47.1]$	$[49.9, 78.6]$
Innovations in $\widehat{m}_t$	$[5.0, 12.6]$	$[40.6, 64.6]$	$[31.4, 57.4]$	$[5.0, 12.6]$

VAR with $\hat{y}_t, \hat{P}_t, \hat{R}_t, \hat{M}_t$

Table A15 - Estimated short run coefficients

A) CEE identification scheme

$$\widehat{P}_t = a_{21} * \widehat{y}_t$$
$$\widehat{R}_t = a_{31} * \widehat{y}_t + a_{32} * \widehat{P}_t$$
$$\widehat{M}_t = a_{41} * \widehat{y}_t + a_{42} * \widehat{P}_t + a_{43} * \widehat{R}_t$$

	Partial accommodation	Feedback
a_{21}	−1.65882	−0.73343
	(0.33003)	(0.09143)
a_{31}	−0.55504	−0.72316
	(0.00458)	(0.06819)
a_{32}	−0.24134	−0.10482
	(0.00105)	(0.05106)
a_{41}	1.02560	1.24752
	(0.01708)	(0.00230)
a_{42}	0.90183	0.99830
	(0.00740)	(0.00132)
a_{43}	−0.40238	−0.00308
	(0.03062)	(0.00209)

B) SZ identification scheme

$$\widehat{P}_t = a_{21} * \widehat{y}_t$$
$$\widehat{R}_t = a_{34} * \widehat{M}_t$$
$$\widehat{M}_t = a_{41} * \widehat{y}_t + a_{42} * \widehat{P}_t + a_{43} * \widehat{R}_t$$

	Partial accommodation	Feedback
a_{21}	−1.65882	−0.73343
	(0.33003)	(0.09143)
a_{34}	−0.23372	−0.30726
	(0.00520)	(0.05856)
a_{41}	1.04560	1.24766
	(0.01724)	(0.00230)
a_{42}	0.91053	0.99832
	(0.00747)	(0.00132)
a_{43}	−0.36635	−0.00288
	(0.03091)	(0.00209)

Table A16 - Theoretical Variance Decomposition at the 4-year horizon

A) Partial accommodation economy

	Output	Prices	Interest rate	Money
Technology shocks	69.7	12.7	10.0	7.0
Preference shocks	14.4	3.8	2.1	1.7
Monetary shocks	14.4	78.3	87.9	86.1
Government shocks	1.5	5.2	0.0	5.2

B) Feedback economy

	Output	Prices	Interest rate	Money
Technology shocks	52.4	0.7	1.7	1.4
Preference shocks	11.8	0.2	0.2	0.0
Monetary shocks	35.2	98.8	97.9	98.4
Government shocks	0.6	0.3	0.2	0.2

Table A17 - Estimated Variance Decomposition at the 4-year horizon

1) CEE identification

A) Partial accommodation economy

	$Var(\widehat{y}_t)$	$Var(\widehat{P}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{M}_t)$
Innovations in $\widehat{y}_t$	$[69.1, 92.5]$	$[8.3, 21.0]$	$[1.2, 12.8]$	$[4.2, 15.7]$
Innovations in $\widehat{P}_t$	$[5.2, 27.1]$	$[75.9, 89.7]$	$[80.6, 96.9]$	$[81.5, 94.0]$
Innovations in $\widehat{R}_t$	$[0.2, 3.5]$	$[0.3, 2.2]$	$[0.2, 4.5]$	$[0.3, 2.0]$
Innovations in $\widehat{M}_t$	$[0.1, 3.1]$	$[0.1, 2.7]$	$[0.1, 4.9]$	$[0.1, 2.5]$

B) Feedback economy

	$Var(\widehat{y}_t)$	$Var(\widehat{P}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{M}_t)$
Innovations in $\widehat{y}_t$	$[41.5, 65.7]$	$[0.8, 5.3]$	$[2.0, 11.0]$	$[0.4, 4.5]$
Innovations in $\widehat{P}_t$	$[21.6, 45.2]$	$[90.0, 97.2]$	$[75.9, 93.2]$	$[90.0, 97.8]$
Innovations in $\widehat{R}_t$	$[1.0, 6.2]$	$[0.2, 1.1]$	$[0.5, 2.8]$	$[0.1, 0.9]$
Innovations in $\widehat{M}_t$	$[1.9, 15.8]$	$[0.3, 5.3]$	$[1.3, 13.3]$	$[0.4, 6.2]$

2) SZ identification

A) Partial accommodation economy

	$Var(\widehat{y}_t)$	$Var(\widehat{P}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{M}_t)$
Innovations in AS	$[50.7, 85.1]$	$[4.6, 30.8]$	$[4.1, 43.5]$	$[3.2, 32.0]$
Innovations in AD	$[1.9, 21.0]$	$[33.8, 86.0]$	$[13.5, 88.2]$	$[28.8, 86.6]$
Innovations in MP	$[2.7, 40.1]$	$[6.6, 37.6]$	$[4.8, 40.8]$	$[7.1, 41.7]$
Innovations in MD	$[0.1, 1.7]$	$[0.2, 1.6]$	$[0.2, 1.9]$	$[0.1, 1.5]$

B) Feedback economy

	$Var(\widehat{y}_t)$	$Var(\widehat{P}_t)$	$Var(\widehat{R}_t)$	$Var(\widehat{M}_t)$
Innovations in AS	$[20.7, 41.9]$	$[0.8, 13.9]$	$[2.4, 20.1]$	$[0.8, 13.3]$
Innovations in AD	$[25.8, 52.7]$	$[71.6, 93.2]$	$[51.4, 87.0]$	$[73.8, 93.8]$
Innovations in MP	$[12.2, 34.3]$	$[2.6, 12.9]$	$[5.4, 22.1]$	$[1.8, 11.1]$
Innovations in MD	$[2.1, 9.4]$	$[0.2, 5.6]$	$[1.0, 10.3]$	$[0.3, 6.4]$

Figure 1

Theoretical Responses, Partial Accommodation Economy

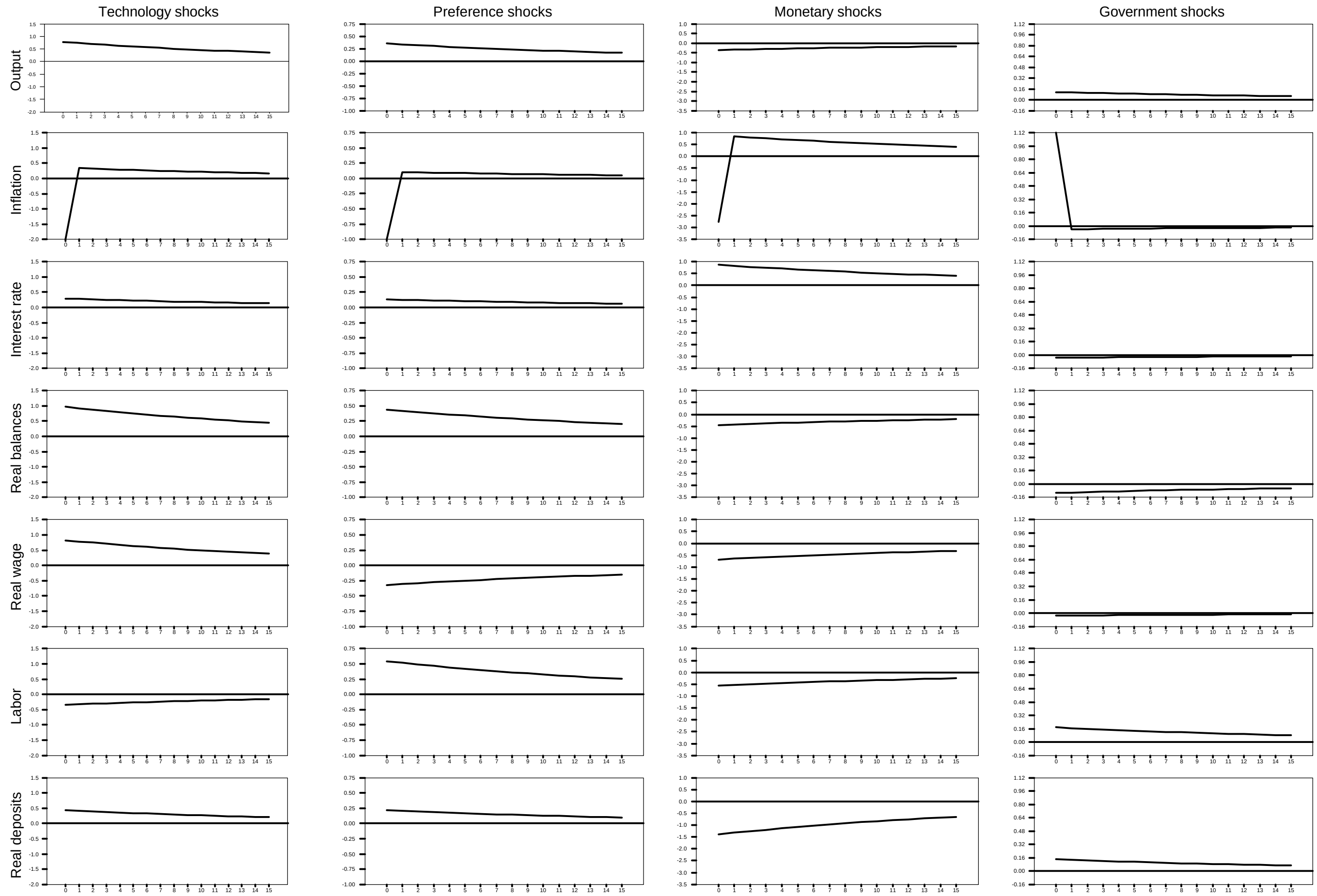


Figure 2

Responses to a Monetary Shock

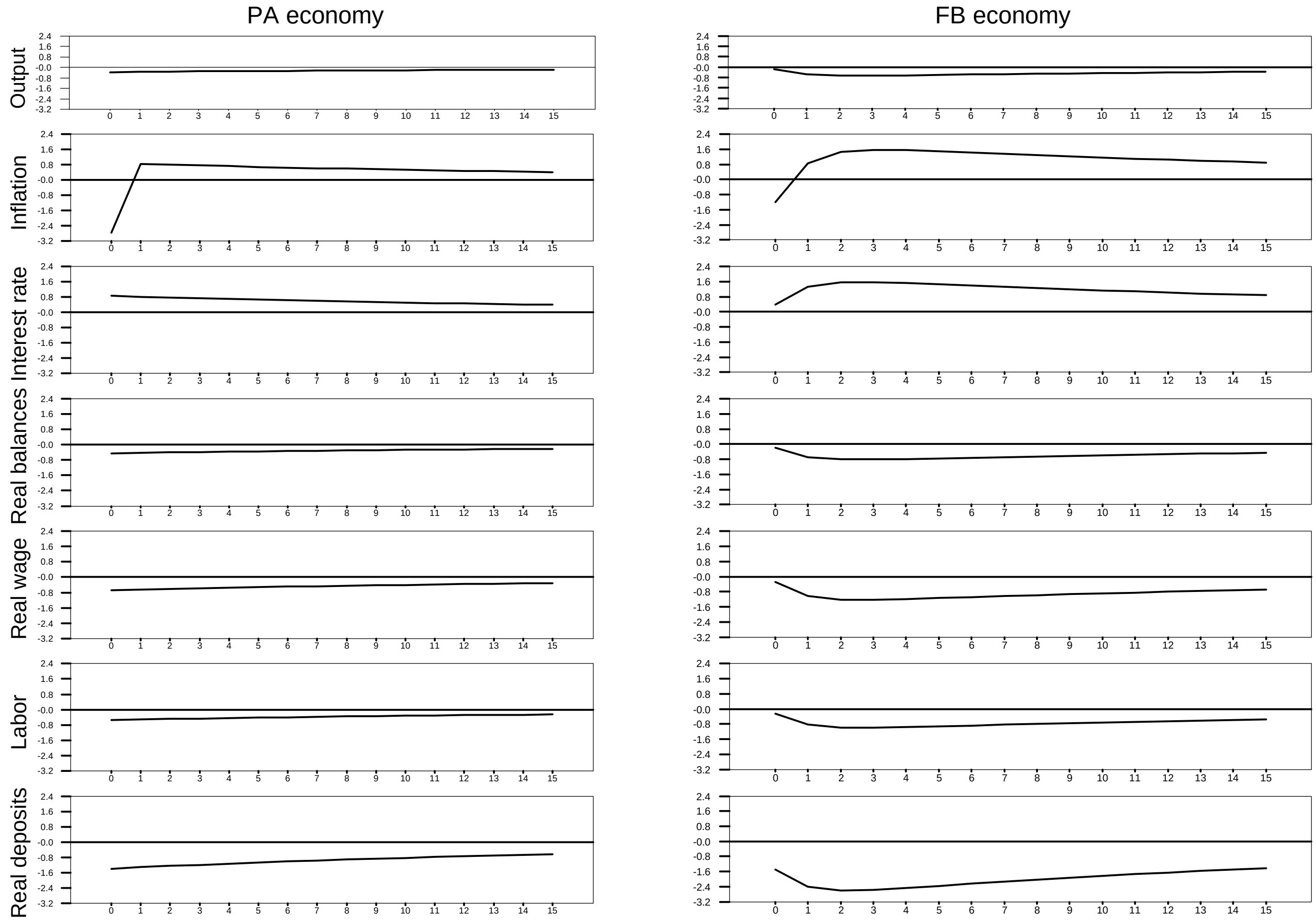


Figure 3

Estimated Impulse Response Bands

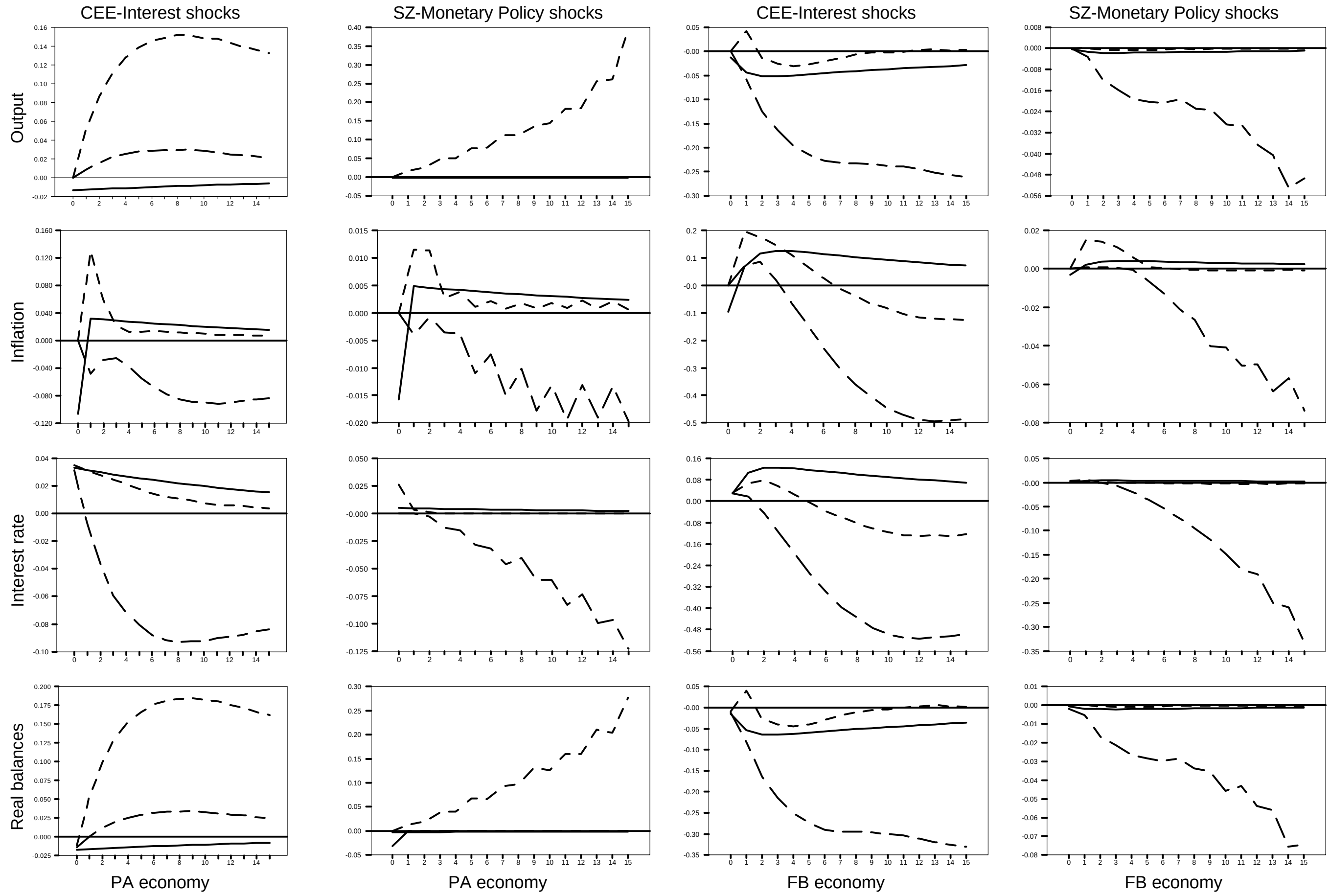


Figure 4

Estimated Impulse Response Bands with Alternative Identification, Policy shock

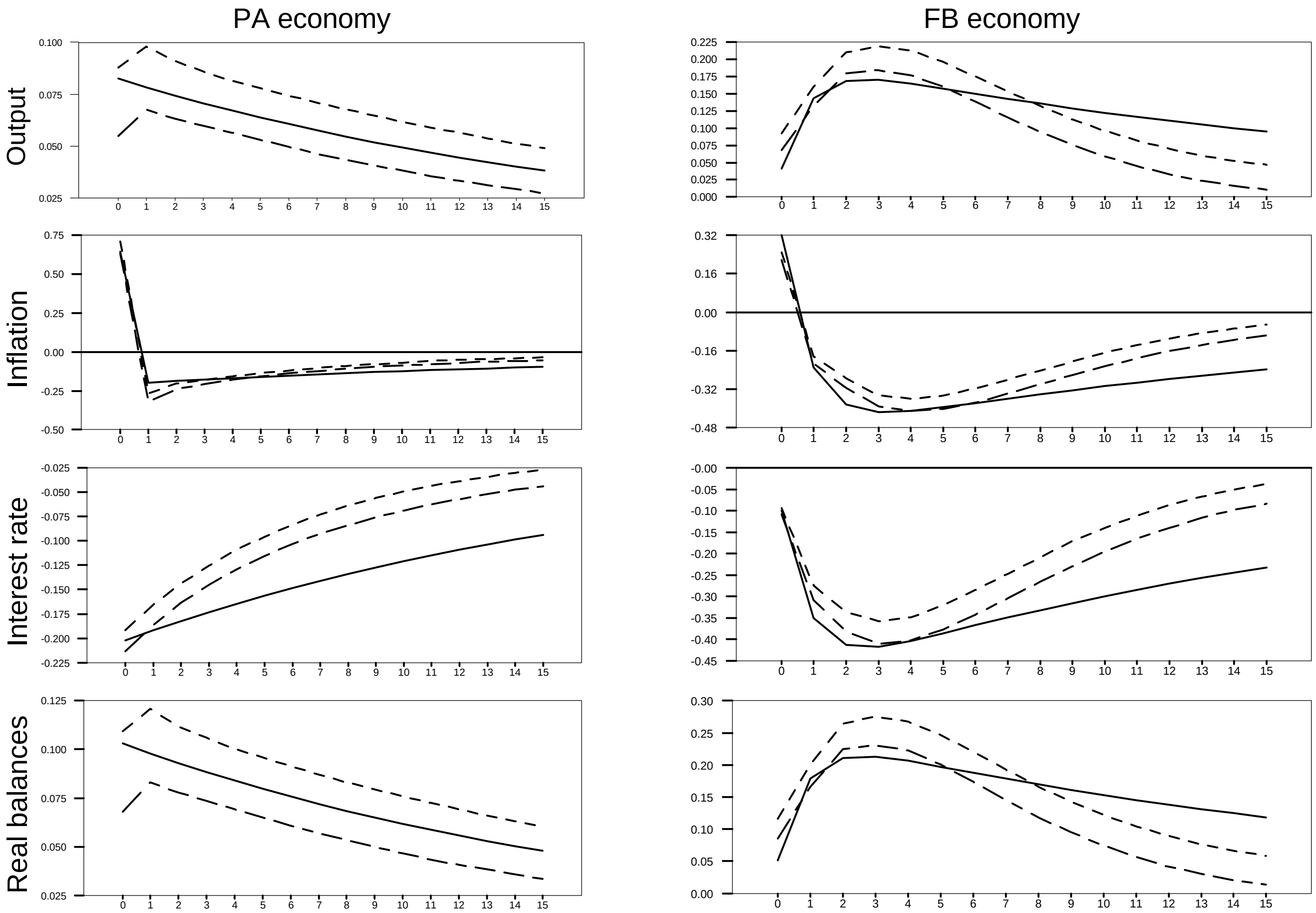
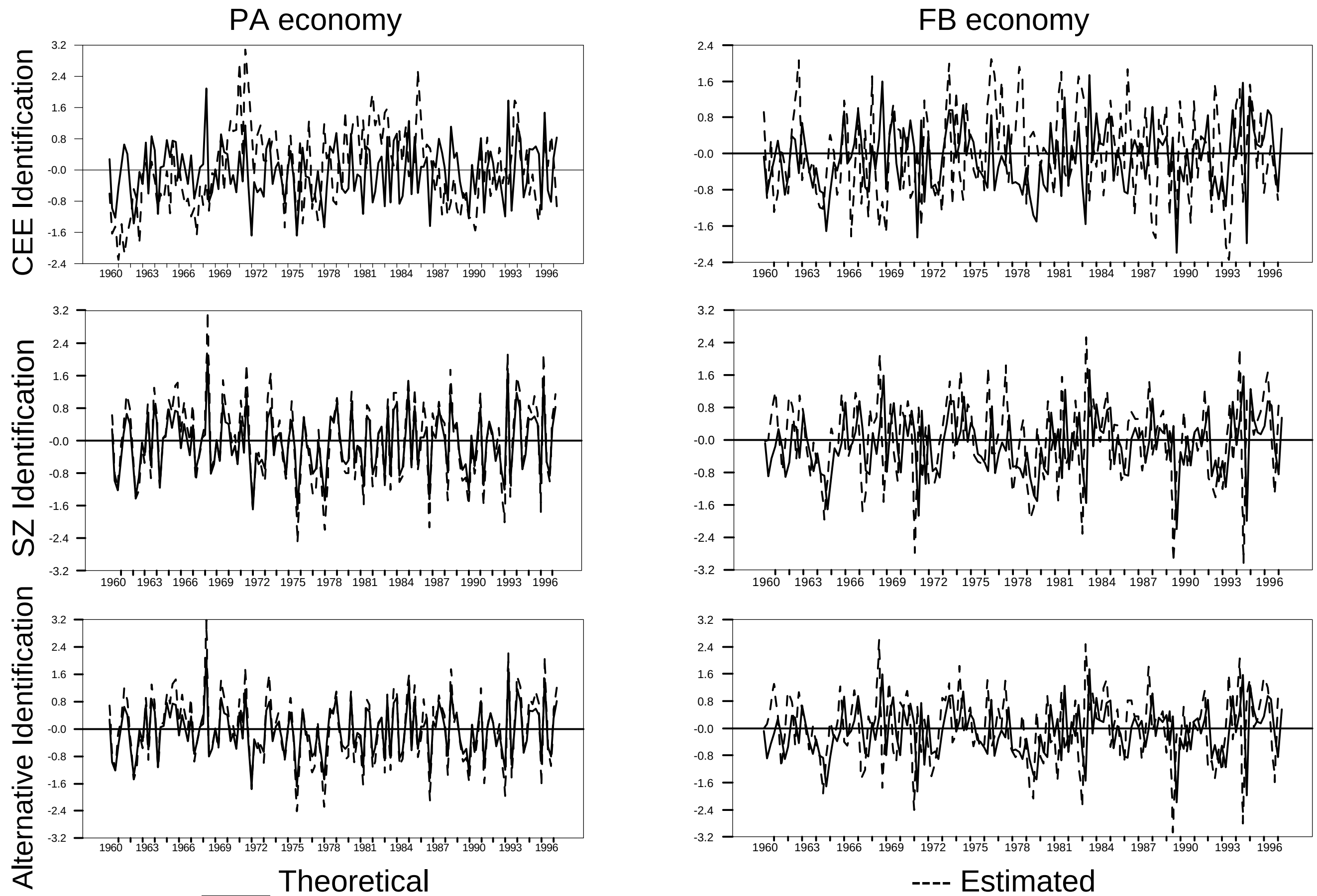


Figure 5

Theoretical and Estimated Monetary Policy Shocks



____ Theoretical ---- Estimated