

Monetary Policy and Leverage Shocks*

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Abstract:

The current mainstream approach to monetary policy in the United States is based on the new Keynesian model and is expressed in terms of the federal funds rate. It ignores the role of financial intermediary leverage (or collateral rates). But as the federal funds rate has reached the zero lower bound, the issue is whether there is a useful role of leverage in monetary policy and business cycle analysis. Motivated by these considerations and by recent financial intermediary asset pricing theories, in this paper we investigate the macroeconomic effects of broker-dealer leverage and the interdependence between monetary policy and broker-dealer leverage in the context of a structural vector autoregression model, using quarterly U.S. data over the period from 1967:1 to 2014:3. We address the simultaneity problem of identifying monetary policy and leverage shocks by using a combination of short-run and long-run restrictions. We also use the sign restrictions approach to the identification of shocks to distinguish between leverage supply and leverage demand shocks, as one would expect the macroeconomic effects of these two types of leverage shocks to be quite different. Our results show that monetary policy and broker-dealer leverage demand shocks produce results that capture reasonable macroeconomic dynamics.

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1 Introduction

The mainstream approach to monetary policy is mainly based on the new Keynesian model and is expressed in terms of the interest rate on overnight loans between banks, such as the federal funds rate in the United States. However, in the aftermath of the global financial crisis and Great Recession, short-term nominal interest rates have hardly moved at all, while central bank policies have been the most volatile and extreme in their entire histories. This has discredited the short-term interest rate as an indicator of policy and led central banks to look elsewhere. For example, the Federal Reserve and many central banks around the world have departed from the traditional interest-rate targeting approach to monetary policy and are now focusing on their balance sheet instead, using quantitative measures of monetary policy, such as credit easing and quantitative easing.

One issue with the current approach to monetary policy is that it hardly takes into account the role of the financial intermediary sector. In this approach, financial intermediaries play a passive role that the central bank uses as a channel to implement monetary policy. However, banks and other financial intermediaries have been at the center of the recent global financial crisis. Moreover, a number of market-based financial intermediaries, such as finance companies, security broker-dealers, and asset-backed securities issuers, have become a very important component of the intermediary sector and evolved into the shadow banking system. Unlike traditional banks, shadow banks are not constrained by relationship-based lending and their balance sheets are almost fully marked to market. They have been at the center of the global financial crisis and there is almost universal agreement that the financial crisis originated in this unregulated shadow banking system. See, for example, Fostel and Geanakoplos (2008), Geanakoplos (2010, 2012), and Adrian and Shin (2010, 2011, 2012).

A number of recent theories give financial intermediaries a central role in economics and finance. It has been argued, for example, that the mainstream approach to monetary policy ignores the role of financial intermediary leverage (or collateral rates) in basic monetary theory and monetary policy analysis. Leverage is the ratio of assets to capital and is a measure of how much debt an investor assumes in making an investment. As Geanakoplos (2012, p. 389) puts it, “leverage can be more important to economic activity and prices than interest rates, and more important to manage.” In fact, leverage cycles (fluctuations in collateral rates) can have important effects on the level of economic activity. When leverage is high, economic agents can buy many assets with very little money down, and asset prices increase. When leverage is low, they must have all (or nearly all) of the money in hand to purchase the same assets, and asset prices decline.

Moreover, Adrian *et al.* (2014) show that broker-dealer leverage is a valid representation of the stochastic discount factor in the basic consumption-based asset pricing model. In doing so, they shift attention from measuring the stochastic discount factor of a representative consumer to measuring the stochastic discount factor of a financial intermediary. As they put it, “rather than emphasizing average household behavior, the assumptions of frictionless

markets and intertemporally optimizing behavior suggest to elevate financial intermediaries to the center stage of asset pricing. Indeed, financial intermediaries do fit the assumptions of modern finance theory nicely: They trade in many asset classes following often complex investment strategies. They face low transaction costs, which allows trading at high frequencies. Moreover, intermediaries use sophisticated, continuously updated models and extensive data to form forward-looking expectations of asset returns. Therefore, if we can measure the marginal value of wealth for these active investors, we can expect to price a broader class of assets [an insight due to He and Krishnamurthy, (2013)].”

In a recent paper, Istiak and Serletis (2016) investigate the relationship between leverage and the level of economic activity in the United States, using quarterly data over the 1951 to 2012 period. They address the question for five different measures of leverage — household leverage, nonfinancial firm leverage, commercial bank leverage, broker and dealer leverage, and shadow bank leverage — making a distinction between traditional banks and shadow banks. They investigate whether the relationship between leverage and the level of economic activity is nonlinear and asymmetric using slope-based tests as well as tests of the null hypothesis of symmetric impulse responses, recently introduced by Kilian and Vigfusson (2011). Istiak and Serletis (2016) conclude that the relationship between leverage and the level of economic activity is nonlinear and asymmetric and that negative leverage growth rate shocks have stronger effects on real economic activity than positive ones, suggesting that the deleveraging process that began at the end of 2008 will be long and painful.

In this paper, we investigate the macroeconomic effects of broker-dealer leverage and the interdependence between monetary policy and broker-dealer leverage. We argue that the leverage of financial intermediaries not only helps to price financial assets but also provides an alternative transmission mechanism of monetary policy beyond the traditional interest-rate channel. In doing so, we use a structural vector autoregressive (VAR) model that identifies monetary policy shocks with innovations in the federal funds rate, as in Sims (1992) and Bernanke and Blinder (1992), as well as with innovations in the money supply. The advantage of using a structural VAR model as compared to a forward monetary policy rule is that a structural VAR deals with unanticipated policy shocks while the later deals with anticipated policy shocks. Given that monetary policy in the United States has been extremely volatile, unpredictable, and unique, at least in the aftermath of the global financial crisis, a structural VAR modelling approach is expected to generate more valid and credible monetary policy shocks than a forward monetary policy rule.

In our VAR model, we address the simultaneity problem of identifying monetary policy and leverage shocks by using a combination of short-run and long-run restrictions. We also identify shocks with sign restrictions to ensure robustness across identification schemes. Our results, based on quarterly data over the period 1967:1–2014:3, show that monetary policy and broker-dealer leverage shocks produce responses consistent with a priori expectations about the macroeconomic effects of monetary policy and broker-dealer leverage. They are consistent with those reported by Nelson *et al.* (2015) in the context of a sign-restricted

VAR. Our results also show that broker-dealer leverage shocks can significantly affect stock prices, thus supporting the theoretical model of Adrian *et al.* (2014). Based on our findings, we conclude that the role played by exogenous non-policy shocks, such as broker-dealer leverage shocks seems more important than interest rate policy in explaining the important macroeconomic and financial variables in recent U.S. economic history.

Our paper is characterized by a unique combination of model construction and research objectives. Whereas Istiak and Serletis (2016) use a bivariate model and tests of the null hypothesis of symmetric impulse responses to examine the relationship between leverage and the level of economic activity, this paper takes a more inclusive approach in building the economic model by including more variables. In particular, we use a six-variable structural VAR model to investigate the macroeconomic effects of broker-dealer leverage and the interdependence between monetary policy and broker-dealer leverage. We also address the simultaneity problem of identifying monetary policy and leverage shocks by using a combination of short-run and long-run restrictions, and also use sign restrictions to check the robustness of the results. Nelson *et al.* (2015) also use a VAR model to examine the effects of monetary policy on the asset growth of commercial banks, shadow banks, and securitisation activity. However, they do not apply theory-based short-run and long-run restrictions in their model and they do not investigate the interdependence between monetary policy and broker-dealer leverage, as we do in this paper. Our paper supports the findings of Adrian *et al.* (2014), who theoretically and empirically investigate the explicit link between the balance sheets of financial intermediaries and asset prices. They argue that broker-dealer leverage is a good empirical proxy for the marginal value of wealth of financial intermediaries and that it can thus be used as a representation of the intermediary stochastic discount factor. They also confirm the strong pricing ability of the leverage factor across a variety of equity and bond portfolios. In this paper, we not only investigate the effects of a broker-dealer leverage shock on asset prices, but also on some other interesting macroeconomic variables, in particular the inflation and output growth. We find that positive broker-dealer leverage shocks increase asset prices, inflation, and output in the short run.

The outline of the paper is as follows. Section 2 provides a brief survey of theoretical arguments regarding financial intermediary asset pricing and the macroeconomic effects of broker-dealer leverage. In this section we also make a distinction between leverage supply and leverage demand shocks. Section 3 presents the data and discusses their time series properties. Section 4 presents a simple six-variable structural VAR and the identification schemes used to identify the interdependence between monetary policy and broker-dealer leverage. In section 5 we identify shocks with sign restrictions to distinguish between leverage supply and leverage demand shocks, in section 6 we investigate robustness issues, and in the final section we conclude the paper.

2 Asset Pricing and Broker-Dealer Leverage

To explore the relation between broker-dealer leverage and asset prices, we follow Adrian *et al.* (2014) and use broker-dealer leverage as a proxy for the stochastic discount factor in the Lucas (1978) consumption capital asset pricing model. The agent's problem is

$$\max_{\{c_t, x_{t+1}\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t u(c_t)$$

subject to (for all t)

$$c_t + x_{t+1} = x_t(1 + r_t)$$

where c stands for consumption, x is the asset's random payoff, r indicates the real net rate of return, and β is the subjective discount factor (capturing impatience). The period utility function, $u(c_t)$, is assumed to be increasing (reflecting the desire for more consumption) and concave (reflecting the diminishing marginal utility of consumption). The first order conditions imply that

$$1 = E_t \beta \frac{u'(c_{t+1})}{u'(c_t)} (1 + r_{t+1}).$$

As

$$r_{t+1} = \frac{(p_{t+1} + d_{t+1}) - p_t}{p_t} = \frac{p_{t+1} + d_{t+1}}{p_t} - 1$$

where p denotes the market price of the asset and d the dividend from the asset, the first order conditions yield

$$1 = E_t \beta \frac{u'(c_{t+1})}{u'(c_t)} \left(\frac{p_{t+1} + d_{t+1}}{p_t} \right)$$

or (when solved for p_t)

$$p_t = E_t \beta \frac{u'(c_{t+1})}{u'(c_t)} (p_{t+1} + d_{t+1}).$$

Assuming that $x_{t+1} = (p_{t+1} + d_{t+1})$, the market price of an asset, p_t , is given by

$$p_t = E_t \left[\beta \frac{u'(c_{t+1})}{u'(c_t)} x_{t+1} \right]. \tag{1}$$

The pricing equation (1) can be broken up into

$$p_t = E_t (m_{t+1} x_{t+1}) \tag{2}$$

where

$$m_{t+1} = \beta \frac{u'(c_{t+1})}{u'(c_t)} \tag{3}$$

is the stochastic discount factor (often also called the marginal rate of substitution or the pricing kernel).

Because much of modern finance theory focuses on expected returns, a simple manipulation of the pricing equation (2) yields [see Cochrane (2001) for more details]

$$E[R] - R_f = -\frac{\text{cov}[R_{t+1}, u'(c_{t+1})]}{Eu'(c_{t+1})} \quad (4)$$

according to which the expected return on a risky asset, $E[R]$, equals the risk-free rate, R_f , plus a risk premium. The risk premium depends on the covariance between the asset's return and aggregate consumption. An asset whose return covaries positively with consumption (pays off big when times are good), is not as attractive, and so must offer a higher expected return to induce investors to hold it. Conversely, an asset whose return covaries negatively with consumption (pays off big when times are bad and you really need the money), is attractive (in the sense of making consumption less volatile), and so can offer a lower expected return than the risk-free rate (or even a negative net expected return).

As mentioned in the introduction, Adrian *et al.* (2014) shift attention from measuring the stochastic discount factor of a representative consumer or investor to measuring the stochastic discount factor of security broker-dealers. They argue that broker-dealers are market makers across various asset classes and the key economic agents whose arbitrage ensures that risk is priced consistently across assets. That is, instead of trying to explain risk premia in terms of the marginal value of a dollar to a representative investor, they suggest that we should look at the marginal value of a dollar to broker-dealers as a group. Security broker-dealers are unregulated nonbank financial intermediaries without access to central bank liquidity, and whose balance sheets are almost fully marked to market and potentially hold more information regarding underlying financial conditions than traditional bank balance sheets.

Table 1 shows the aggregate balance sheet of broker-dealers and the breakdown of assets and liabilities as of 2014:3. They are funded mostly by security credit, security repos, and corporate and foreign bonds; together, they account for 83% of the balance sheet. Their risk asset portfolio is made up of credit market instruments, security credit, and corporate equities; together they account for 29% of assets. The low-risk assets are largely checkable deposits and currency (3.4%). Figure 1 shows that broker-dealers credit market assets (which accounted for only 11.5% of assets in 2014:3) increased from less than \$3 billion in 1967 to \$385.7 billion in 2014. Although broker-dealers are small compared to other financial intermediaries, their balance sheet is marked to market and facilitates the trades of active investors such as hedge funds and asset managers.

To provide some perspective on the leverage of security broker-dealers, we calculate the following measure of leverage [following Adrian *et al.* (2014)]

$$l = \frac{A}{A - L} \quad (5)$$

where A denotes total financial assets and L total financial liabilities. If we think of assets minus liabilities as the net equity (capital) of broker-dealers, this measure of broker-dealer leverage is the ratio of assets to capital and reflects the risk-taking activities of security broker-dealers. Figure 2 plots the level and growth rate of broker-dealer leverage, using quarterly data over the period from 1967:1 to 2014:3; shaded areas represent NBER recessions. The plot shows that broker-dealer leverage increased during the 1970 and 1982 recessions as well as at the start of the 2001 and 2007-2009 recessions. However, broker-dealer leverage declined sharply after specific financial events such as the October 1987 stock market crash, the December 1994 peso crisis, the collapse of Long Term Capital Management in the fall of 1998, the September 2001 terrorist attacks of the World Trade Center, and the September 2008 failure of Lehman Brothers, (at the time) the fourth-largest investment bank in the United States.

Clearly, the leverage of security broker-dealers varies substantially over time, reflecting the tightness of risk constraints (such as those on funding) that broker-dealers face and therefore their marginal value of wealth. If we think of leverage (and not wealth) as the key measure of the marginal value of wealth, as in the theories by Gromb and Vayanos (2002), Brunnermeier and Pedersen (2009), Geanakoplos (2010), Shleifer and Vishny (1997, 2010), He and Krishnamurthy (2013), and Rytchkov (2014), then times of high leverage are characterized by low marginal utility of wealth (and low risk aversion). Following Adrian *et al.* (2014, p. 2562), we assume that this negative relation between leverage and the marginal utility of wealth can be represented by the following relation

$$u'(w_{t+1}) \simeq a - b(l_{t+1})$$

where $u'(w_{t+1})$ is the marginal value of an extra dollar of borrowed money to broker-dealers and l stands for broker-dealer leverage. Then, from equation (4), assuming that the financial market is represented by broker-dealers as a group and replacing $u'(c_{t+1})$ by $u'(w_{t+1})$, we get

$$\begin{aligned} E[R] - R_f &= -\frac{\text{cov}[R_{t+1}, u'(w_{t+1})]}{Eu'(w_{t+1})} \\ &= -\frac{\text{cov}[R_{t+1}, a - b(l_{t+1})]}{Eu'(w_{t+1})} \\ &= \gamma \text{cov}(R_{t+1}, l_{t+1}), \quad \text{when } \gamma > 0. \end{aligned}$$

Hence, assets whose returns covary positively with leverage will earn higher average returns and are more risky. In particular, when leverage is high, it is easy for broker-dealers to use their assets to meet margin requirements. Hence, an asset that pays off big in high leverage states is less useful to broker-dealers (and so must offer a higher expected return in compensation) compared to an asset that provides a hedge against low leverage states (hard times).

From equation (5) we see that if economic agents are passive and do not adjust their balance sheets to changes in capital, then there would be a negative relationship between changes in leverage and changes in total assets, since leverage would fall when total assets rise and it would rise when total assets fall. However, as shown in Figure 3, there is a positive relationship between changes in broker-dealer leverage and changes in their assets, meaning that broker-dealers manage their balance sheets actively in response to developments in the economy and in such a way that broker-dealer leverage is procyclical (high during good times and low during hard times). This is also consistent with the evidence provided by Adrian and Shin (2010) using their shorter sample, suggesting that security broker-dealers react to changes in assets prices by changing their stance on leverage. In fact, Adrian *et al.* (2014) also show that broker-dealer leverage contains strong predictive power for stock and bond returns (and thus for the evolution of risk premia over time). A broker-dealer leverage shock facilitates the trades of active investors (such as hedge funds and asset managers), mainly through the borrowing and lending of securities, and affects asset prices and ultimately economic activity by changing real consumption and productive investment.

We follow Adrian *et al.* (2014) and use the aggregate leverage of security broker-dealers as a proxy for the stochastic discount factor. In fact, we identify shocks to security broker-dealers leverage as a proxy for shocks to the stochastic discount factor and investigate their effects on general macroeconomic variations and in particular on inflation and output growth. According to equation (3), the stochastic discount factor can be represented as $\beta u'(w_{t+1})/u'(w_t)$, where β is the discount factor and $u'(w_t)$ represents the marginal value of an extra dollar of borrowed money to broker-dealer institutions at time t . Factors (other than the variables in our VAR model) affecting the components of the stochastic discount factor, β and $u'(w_{t+1})/u'(w_t)$, can produce a shock to broker-dealer leverage. Consider, for example, a preference shock (an increase in β) that changes the attitude of broker-dealer intermediaries towards risk. This can be thought of as positive leverage demand shock, and if broker-dealer intermediaries play an important role in the macroeconomy then we should see aggregate demand to pick up and, consequently, inflation to increase. Monetary authorities would respond in this case according to the Taylor principle by increasing interest rates to bring inflation back to the target. On the other hand, an expansionary monetary policy makes it easier to obtain loans and thus reduces $u'(w_t)$. This leads to a rise in the ratio $u'(w_{t+1})/u'(w_t)$ and thus the stochastic discount factor, m_{t+1} . This can be thought of as a positive supply of leverage shock. In this paper we also use the sign restrictions approach to the identification of shocks to distinguish between leverage supply and leverage demand shocks, as one would expect the macroeconomic effects of these two types of leverage shocks to be quite different.

3 The Data

In choosing the variables in our VAR model, we follow the model of Bjørnland and Leitemo (2009) and consider a set of quarterly variables for the United States collected in an 6×1 vector $\mathbf{z}_t = (y_t, \pi_t, \lambda_t, l_t, s_t, i_t)'$, where y_t is the quarterly linearly detrended logged real GDP (output gap), π_t the quarterly change in the logged GDP deflator, and λ_t the quarterly change in the logged CRB BLS spot market price index. The CRB BLS spot index is a measure of price movements of 22 sensitive basic commodities whose markets are greatly influenced by changes in economic fluctuations. It serves as one early indication of impending changes in business activity and we use it as a proxy for the commodity price index, following the standard practice of including a price index in the VAR model to eliminate the price puzzle. Finally, l_t is the quarterly change in the logged security broker-dealer leverage, s_t is the quarterly change in the logarithm of the real S&P 500 index (we divide the S&P 500 index by the GDP deflator to get the real S&P 500 index, which is widely used as a measure of the general level of real stock prices), and i_t is the level of the federal funds rate. We refrain from adding more variables in the model, because as Kilian (2013) argues, with typical sample sizes, standard VAR models cannot handle more than six variables. In particular, he argues that adding more variables creates overfitting problems and undermines the credibility of the VAR model.

We use quarterly data over the period from 1967:1 to 2014:3. The real GDP, GDP deflator, S&P 500 index, and federal funds rate series are obtained from the Federal Reserve Economic Database (FRED) maintained by the Federal Reserve Bank of St. Louis. The federal funds rate is observed daily, but averaged quarterly to reflect the same information as the other quarterly variables. The aggregate broker-dealer leverage series is from the Board of Governors of the Federal Reserve System and the CRB BLS spot market price index series is from the Commodity Index Report published by the Commodity Research Bureau (CRB). We transform all data to reflect the data-generating process found in Svensson (1997) and Bjørnland and Leitemo (2009). We use stationary variables, so that the moving average representation of the VAR is convergent. We follow Bjørnland and Leitemo (2009) and use the output gap instead of the output growth rate, because the former is a better measure in some specific situations. For example, after a recession an increase in output does not necessarily imply a strong economy until the level of output increases above its trend. However, in the robustness section we replace the output gap with the quarterly output growth rate and get similar results.

Formal lag selection procedures, such as the Hannan and Quinn information criterion (HQIC) and the Bayesian information criterion (BIC), suggest one lag in our VAR model. However, the Lagrange multiplier test for autocorrelation shows that a model with one lag has serial correlation in the residuals. Therefore the VAR is specified with five lags. Using five lags, the VAR satisfies the stability condition and basic diagnostic tests, such as no autocorrelation and normality of residuals. We also used other lag structures in the model

and got similar findings as with five lags, suggesting that our results are robust to different lag structures. These issues are also discussed at the end of section 4.

4 The Structural VAR

We use the Wold (1938) representation of the structural VAR, describing the dynamic interrelations among the variables in \mathbf{z}_t as follows

$$\mathbf{z}_t = \mathbf{C}(L)\mathbf{S}\boldsymbol{\varepsilon}_t \quad (6)$$

where \mathbf{S} is the inverse of the contemporaneous coefficients matrix, $\boldsymbol{\varepsilon}_t$ is an 6×1 vector of mean zero serially uncorrelated innovations (or shocks), and $\mathbf{C}(L)$ is a matrix lag polynomial of infinite order, $\mathbf{C}(L) = \mathbf{C}_0 + \mathbf{C}_1L + \mathbf{C}_2L^2 + \dots$, with \mathbf{C}_k being an $n \times n$ matrix with typical element c_{ij}^k . Viewed as a function of k , c_{ij}^k is the impulse response function (also called dynamic multiplier) of z_{it} with respect to ε_{jt} ; it shows how $z_{i,t+k}$ changes in response to a one unit impulse in ε_{jt} . Equation (6) can be written more fully as

$$\begin{pmatrix} y_t \\ \pi_t \\ \lambda_t \\ l_t \\ s_t \\ i_t \end{pmatrix} = \mathbf{C}(L) \begin{pmatrix} s_{11} & s_{12} & s_{13} & s_{14} & s_{15} & s_{16} \\ s_{21} & s_{22} & s_{23} & s_{24} & s_{25} & s_{26} \\ s_{31} & s_{32} & s_{33} & s_{34} & s_{35} & s_{36} \\ s_{41} & s_{42} & s_{43} & s_{44} & s_{45} & s_{46} \\ s_{51} & s_{52} & s_{53} & s_{54} & s_{55} & s_{56} \\ s_{61} & s_{62} & s_{63} & s_{64} & s_{65} & s_{66} \end{pmatrix} \begin{pmatrix} \varepsilon_t^y \\ \varepsilon_t^\pi \\ \varepsilon_t^\lambda \\ \varepsilon_t^l \\ \varepsilon_t^s \\ \varepsilon_t^i \end{pmatrix}. \quad (7)$$

For the structural identification of (7), we assume that the conditional covariance matrix Σ_ε is diagonal (meaning that the structural shocks are contemporaneously uncorrelated). Moreover, we assume that the diagonal elements of \mathbf{S} are equal to 1. Additionally, we impose fourteen zero restrictions and one long run restriction on the elements of \mathbf{S} . With all these restrictions on the \mathbf{S} matrix, the model (7) can be represented as

$$\begin{pmatrix} y_t \\ \pi_t \\ \lambda_t \\ l_t \\ s_t \\ i_t \end{pmatrix} = \mathbf{C}(L) \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ s_{21} & 1 & 0 & 0 & 0 & 0 \\ s_{31} & s_{32} & 1 & 0 & 0 & 0 \\ s_{41} & s_{42} & s_{43} & 1 & s_{45} & s_{46} \\ s_{51} & s_{52} & s_{53} & 0 & 1 & s_{56} \\ s_{61} & s_{62} & s_{63} & 0 & s_{65} & 1 \end{pmatrix} \begin{pmatrix} \varepsilon_t^y \\ \varepsilon_t^\pi \\ \varepsilon_t^\lambda \\ \varepsilon_t^l \\ \varepsilon_t^s \\ \varepsilon_t^i \end{pmatrix}. \quad (8)$$

In doing so, we follow the standard monetary VAR literature according to which macroeconomic variables do not simultaneously react to policy variables while policy variables simultaneously react to the macroeconomic environment — see, for example, Christiano *et al.* (1999, 2005) and Bjørnland and Leitemo (2009). For example, the restrictions

$s_{12} = s_{13} = s_{14} = s_{15} = s_{16} = 0$ on the \mathbf{S} matrix in (8) imply that inflation, commodity prices, broker-dealer leverage, stock prices, and the federal funds rate do not have a contemporaneous effects on real output, but only affect it with a lag. This assumption is consistent with the notion that only technology shocks affect real output. The restrictions $s_{23} = s_{24} = s_{25} = s_{26} = 0$ imply that inflation simultaneously reacts to output only. The restrictions $s_{34} = s_{35} = s_{36} = 0$ imply that commodity prices simultaneously react to output and inflation only. All the nonzero elements of the fourth row of the \mathbf{S} matrix imply that all the variables have a contemporaneous effect on broker-dealer leverage. However, we assume that broker-dealer leverage has no contemporaneous effects on stock prices (so that $s_{54} = 0$) and the interest rate (so that $s_{64} = 0$), but affects these two variables with a lag. This is based on the idea that when broker-dealer leverage is high, economic agents can buy many assets with very little money down. This creates excess demand for assets and the increase in asset prices leads to an increase in aggregate demand and inflation. To stabilize inflation, the monetary policymaker follows the Taylor principle and increases the nominal interest rate. Thus, stock prices and the interest rate respond with a lag to a shock in leverage.

Finally, following Bjørnland and Leitemo (2009), we impose a long-run identifying restriction that a monetary policy shock can have no long-run effects on the level of real stock prices. This assumption is based on monetary neutrality, that once and for all changes in the money stock have no effect on real variables in the long run. This restriction can be imposed by setting the infinite number of relevant lag coefficients in equation (7) equal to zero. Writing the long run expression of $\mathbf{C}(L)$ as $\mathbf{C}(1)$, this condition implies

$$c_{51}(1)s_{16} + c_{52}(1)s_{26} + c_{53}(1)s_{36} + c_{54}(1)s_{46} + c_{55}(1)s_{56} + c_{56}(1)s_{66} = 0$$

which, given that $s_{16} = s_{26} = s_{36} = 0$ and $s_{66} = 1$ in equation (8), reduces to

$$c_{54}(1)s_{46} + c_{55}(1)s_{56} + c_{56}(1)s = 0. \tag{9}$$

With the imposition of the long-run identifying restriction (9), we have exact identification — fourteen zero restrictions and one long-run restriction.

Turning to the empirical results, Figure 4 shows the impulse responses of the output (real GDP) gap, broker-dealer leverage, inflation, S&P 500 index, commodity price index, and federal funds rate to a monetary policy shock. Figure 5 shows the impulse responses of the same variables to a broker-dealer leverage shock. The shocks are normalized in the first quarter and the responses are graphed with probability bands represented as 0.16 and 0.84 fractiles (equivalent to 90% confidence interval), computed according to the Monte Carlo method described in Doan (2004) with 10,000 draws from the posterior distribution of the VAR coefficients and the covariance matrix of the innovations.

According to Figure 4, the monetary policy shock temporarily increases the federal funds rate. As expected, output declines by close to 0.6% after two years. In fact, the negative effect on output is significantly different from zero, but it dies out after three and half years.

The negative effect on inflation, following a monetary policy shock, is significantly different from zero after two years, suggesting that inflation declines by about 0.1% in the long-run following a contractionary monetary policy shock. Turning to commodity prices, they start to decline significantly after three years, suggesting that commodity prices decline by about 2% in the long-run following a contractionary monetary policy shock. Our results show that the contractionary monetary policy shock has no significant impact on broker-dealer leverage and stock prices.

Figure 5 shows that a positive broker-dealer leverage shock increases inflation, commodity prices, output, and stock prices significantly. This supports the theory that positive leverage shocks increase real economic activity via changing asset prices, as we discussed in Section 2. The positive effect on stock prices is significantly different from zero up to one year, with stock prices increasing by about 0.1% following an expansionary broker-dealer leverage shock. This is consistent with the view in Geanakoplos (2010) who shows that housing prices and those of AAA securities rise as leverage increases and fall as leverage declines. The rise in asset prices increases consumer expenditure (spending by consumers on durable and nondurable goods and services) through a wealth effect and investment spending (the purchase of new investment goods) through a Tobin q effect, both of which in turn lead to an increase in aggregate demand. Our results show that output increases by close to 0.02% by the end of the first year in response to a positive broker-dealer leverage shock and that the positive effect on output continues in the long run. We can also see that inflation increases by close to 0.02% by the second quarter, but the effect dies out after that. The increase in inflation leads to a rise in commodity prices, which increase by 0.05% by the second quarter, but the effect becomes insignificant after the third quarter. The fed funds rate does not respond significantly to a positive broker-dealer leverage shock.

In Figures 4 and 5 we show the impulse responses to positive interest rate and broker-dealer leverage shocks from the structural VAR with five lags. In this regard, Faust and Leeper (1997) argue that under long run restrictions there is a chance that impulse responses will be badly biased in all sample sizes and the long run expression of $\mathbf{C}(L)$ will have no meaningful confidence intervals. To solve the problem they suggest the use of long lag lengths which increases the confidence intervals for both the estimates of $\mathbf{C}(L)$ and the impulse responses under the long-run scheme. More recently, De Graeve and Westermarck (2013) also argue in favour of long lag lengths in structural VAR models as this reduces misspecification, bias, and variance. Though long lag lengths increase the number of estimated parameters, the reduction in variance will work against the imprecision resulting from increased parametrization. In order to check the robustness of our results, we use a lag order of 10 determined by the “general to specific approach.” The results (not shown here but available on request) are very close to those we achieve under the previous lag structure.

5 Identification with Sign Restrictions

An important issue is the economic interpretation of our broker-dealer leverage shock. The question is whether this is a supply of leverage or a demand to leverage shock, as one would expect the macroeconomic effects of a leverage supply and a leverage demand shock to be quite different. To distinguish between these two types of leverage shocks, we use the sign restrictions approach to the identification of shocks pioneered in Canova and De Nicolò (2002) and Uhlig (2005).

We assume that the error term of the reduced form of model (6) is e_t . In order to impose sign restrictions on the \mathbf{S} matrix, let us start from the composition of the reduced form error e_t

$$e_t = \mathbf{S}\varepsilon_t$$

$$E(e_t e_t') = E[\mathbf{S}\varepsilon_t (\mathbf{S}\varepsilon_t)']$$

$$\Sigma_e = \mathbf{S} E(\varepsilon_t \varepsilon_t') \mathbf{S}'$$

$$\Sigma_e = \mathbf{S} \Sigma_\varepsilon \mathbf{S}'.$$

Assuming that Σ_ε is an identity matrix yields

$$\Sigma_e = \mathbf{S} \mathbf{S}'.$$

Now assume \mathbf{Q} be the lower triangular Cholesky decomposition that satisfies

$$\Sigma_e = \mathbf{Q} \mathbf{Q}' \tag{10}$$

and let \mathbf{R} be any orthogonal $N \times N$ matrix [thus $\mathbf{R}'_{(N \times N)} = \mathbf{R}_{(N \times N)}^{-1}$] such that

$$\mathbf{S} = \mathbf{Q} \mathbf{R}. \tag{11}$$

Note that condition (11) satisfies condition (10). We can now draw random values from \mathbf{R} and only accept the solutions for \mathbf{S} that satisfy a set of a priori sign restrictions on the implied impulse response functions. We continue until we have 1,000 favorable draws and then take their mean to get the impulse response functions.

In order to economically interpret our broker-dealer leverage shock and address the question of whether this is a supply of leverage or a demand to leverage shock, we use the sign restricted VAR model and postulate that an unexpected increase in the interest rate is associated with an increase in the federal funds rate and the absence of increases in output, inflation, and commodity prices for half a year following the policy shock. We impose no restrictions regarding the response of stock prices and leverage to an interest rate shock. As

can be seen in Figure 6, a contractionary interest rate shock has no significant impact on broker-dealer leverage and stock prices, evidence against a supply of leverage shock. This finding is consistent with Nelson *et al.* (2015) who find that the contribution of monetary policy shocks on asset growth in the financial sector as a whole has been small.

In our effort to distinguish between a supply of leverage and a demand to leverage shock, we also postulate that an unexpected expansion in demand to broker-dealer leverage is associated with an increase in leverage, the absence of decline in output (as leverage is procyclical), inflation (as output or aggregate demand rises), and stock prices [following the findings of Geanakoplos (2010)] for half a year following the shock. No restrictions are imposed on the response of commodity prices and the interest rate. With this sign restriction scheme, we expect that a leverage demand shock would not be associated with a decrease in the federal funds rate, but with some other factor such as, for example, an increase in the risk taking behavior of broker-dealers. As can be seen in Figure 7, this sign restriction structure has a positive (but insignificant) impact on commodity prices and increases the federal funds rate significantly. The response of the federal funds rate is consistent with that of an inflation-targeting central bank seeking to keep commodity prices and thus inflation stable.

6 Robustness

We investigate the robustness of our results to alternative sample periods and alternative measures of the stance of monetary policy. In particular, because our sample period includes the global financial crisis, during which one would expect much larger effects of broker-dealer leverage shocks, we estimate the model for a subsample that does not include the period from 2007:1 to 2014:3. Figures 8 and 9 show the impulse responses from an interest rate shock and a broker-dealer leverage shock, respectively, in a sign restricted VAR, for this shorter sample period from 1967:1 to 2006:4. Figure 8 indicates that the responses are qualitatively similar to those in Figure 6, with small differences in magnitude. In particular, in Figure 8 output decreases a bit less than in Figure 6, because the shorter sample in Figure 8 excludes the Great Recession. Also, in Figure 8, inflation decreases a bit less compared to the decrease in Figure 6, because the longer sample in Figure 6 includes the 2007:1 to 2014:3 period when inflation was relatively low. We also find that commodity prices decrease more in the longer sample, as commodity prices increased by close to 90% from 2003:1 to their peak in 2008:2. The impulse responses in Figure 9 are also qualitatively very similar to those in Figure 7.

We follow Adrian *et al.* (2014) and use broker-dealer leverage data after the mid 1960s. As Adrian *et al.* (2014, pp. 2565) argue, “while the *Flow of Funds* data begin in 1952Q1, the data from the broker-dealer sector prior to 1968 raise suspicions: broker-dealer equity is *negative* over the period 1952Q1 to 1960Q4 and extremely low for most of the 1960s, resulting in unreasonably high leverage ratios.” As a result, we begin our sample in 1967Q1,

since we have reasonable leverage data since then. But, the fact that our sample period is long enough to span several monetary policy regimes, raises the question of whether the federal funds rate is the appropriate measure of the stance of monetary policy. For example, in the 1960s, monetary policy was procyclical with the Fed targeting on money market conditions using interest rates as the primary operating instrument. In the 1970s, monetary policy continued to be procyclical because the Fed was using the federal funds rate as its operating instrument and monetary aggregates as intermediate targets. From October 1979 to October 1982, the Fed de-emphasized the federal funds rate as an operating instrument and used nonborrowed reserves as the primary operating instrument. Between October 1982 and the early 1990s, the Fed targeted on borrowed reserves and abandoned monetary aggregates as a guide for monetary policy. Finally, since the early 1990s the Fed has been using the federal funds rate as the primary operating instrument, but in the aftermath of the global financial crisis the federal funds rate has reached the zero lower bound and the Fed has resorted to unconventional monetary policy (quantitative easing, long-term bond purchases, and managing expectations) in order to lower long-term interest rates and stimulate the economy.

To address the issue of different approaches to monetary policy over the sample period, and the fact that the zero lower bound constraint on the policy rate has been binding in 2003-2004 and in the aftermath of the global financial crisis, we estimate the model with the Center for Financial Stability (CFS) Divisia M4 monetary aggregate as the monetary policy variable. The CFS Divisia M4 is the broadest and most important measure of money — see Barnett and Chauvet (2010), Barnett *et al.* (2013), and Serletis and Gogas (2014) for more details regarding the advantages of the CFS Divisia monetary aggregates. Figures 10 and 11 show the impulse responses from an unexpected increase in the CFS Divisia M4 monetary aggregate and broker-dealer leverage, respectively. According to Figure 10, the money supply shock has the expected effects on output, inflation, and commodity prices, but has no significant impact on broker-dealer leverage and stock prices. Figure 11 indicates that a positive broker-dealer leverage shock also has the expected effects on inflation, commodity prices, output, and stock prices. We also run our model with the CFS Divisia M4- monetary aggregate as the monetary policy variable and get results (not shown here but available upon request) very similar to those in Figures 10 and 11.

7 Conclusion

A consequence of financial innovation and deregulation in the financial services industry over the past 20 years was the development of a number of market-based financial intermediaries, such as finance companies, security broker-dealers, and asset-backed securities issuers. These financial institutions have become a very important component of the intermediary sector and evolved into the shadow banking system. They have been at the center of the global

financial crisis and there is almost universal agreement that the financial crisis of 2007-2008 originated in this unregulated shadow banking system. In fact, in a recent paper Adrian *et al.* (2014) suggest that we should look at security broker-dealers to measure the stochastic discount factor underlying modern finance theory. They argue that broker-dealers are the key economic agents, being rational, forward looking, and continuously well informed. They also identify shocks to broker-dealer leverage with shocks to the pricing kernel of the consumption-based asset pricing model.

In this paper, we integrate the broker-dealer leverage shocks into an empirical macroeconomic model to bring new insights about the interaction between the real economy and financial intermediaries. In particular, we investigate the macroeconomic effects of broker-dealer leverage and the interdependence between monetary policy and broker-dealer leverage in the context of a structural VAR. We address the simultaneity problem of identifying monetary policy and leverage shocks by using a combination of short-run and long-run restrictions. We also show responses to shocks identified with sign restrictions to investigate robustness across identification schemes and distinguish between the macroeconomic effects of leverage supply and leverage demand shocks. Our results show that broker-dealer leverage shocks are associated with demand for leverage, not supply of leverage, and that interest rate and broker-dealer leverage shocks produce results that capture reasonable macroeconomic dynamics. In particular, we show that positive broker-dealer leverage shocks increase both inflation and output in the short run, consistent with the view in Geanakoplos (2010) who shows that asset prices rise as leverage increases and fall as leverage declines — the rise in asset prices leads to an increase in aggregate demand by increasing consumer expenditure through a wealth effect and investment spending through a Tobin q effect.

We conclude that in the aftermath of the global financial crisis and with the federal funds rate at the zero lower bound, broker-dealer leverage has become an important variable capturing reasonable macroeconomic dynamics. We argue that the leverage of financial intermediaries not only helps to price financial assets but is an important macroeconomic variable with a potential to affect macroeconomic conditions. Moreover, there are significant leverage spillover and interaction effects across different sectors of the economy. As Gai and Kapadia (2010, pp. 2401) put it, “in modern financial systems, an intricate web of claims and obligations links the balance sheets of a wide variety of intermediaries, such as banks and hedge funds, into a network structure. The advent of sophisticated financial products, such as credit default swaps and collateralised debt obligations, has heightened the complexity of these balance sheet connections still further.” Given the procyclical and interconnected nature of the balance sheets of financial institutions, an increase in leverage in one institution amplifies the business cycle and ultimately leads to contagion and amplification effects in other institutions — see also Gai *et al.* (2011) and Glasserman and Young (2015). This suggests that monetary policymakers should be considering the procyclical nature of leverage in order to have an accurate assessment of the effect of their policies on the macroeconomy. In particular, they should be monitoring the balance sheets of broker-dealers and other

financial intermediaries and avoid contractionary monetary policy in times of low leverage and expansionary monetary policy in times of high leverage.

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TABLE 1

ASSETS AND LIABILITIES OF BROKERS-DEALERS
(IN BILLIONS OF USD AS OF THE END OF 2014Q3)

Total financial assets	3335.7
Checkable deposits and currency	116.7
Security repos	1220.4
Credit market instruments	385.7
Open market paper	20.9
Treasury securities	56.0
Agency- and GSE-backed securities	106.7
Municipal securities	16.2
Corporate and foreign bonds	139.1
Syndicated loans	46.8
Corporate equities	176.9
Security credit	390.3
U.S. direct investment abroad	234.9
Miscellaneous assets	810.8
Total liabilities	3250.1
Security repos	1606.3
Corporate and foreign bonds	123.9
Trade payables	19.9
Security credit	982.4
Taxes payable	5.4
Foreign direct investment	121.8
Miscellaneous liabilities	390.4

Source: U.S. Flow of Funds Release, December 11, 2014, Table L.128.

Figure 1 Total credit market assets of broker-dealers (in billions of US dollars), 1967:1-2014:3

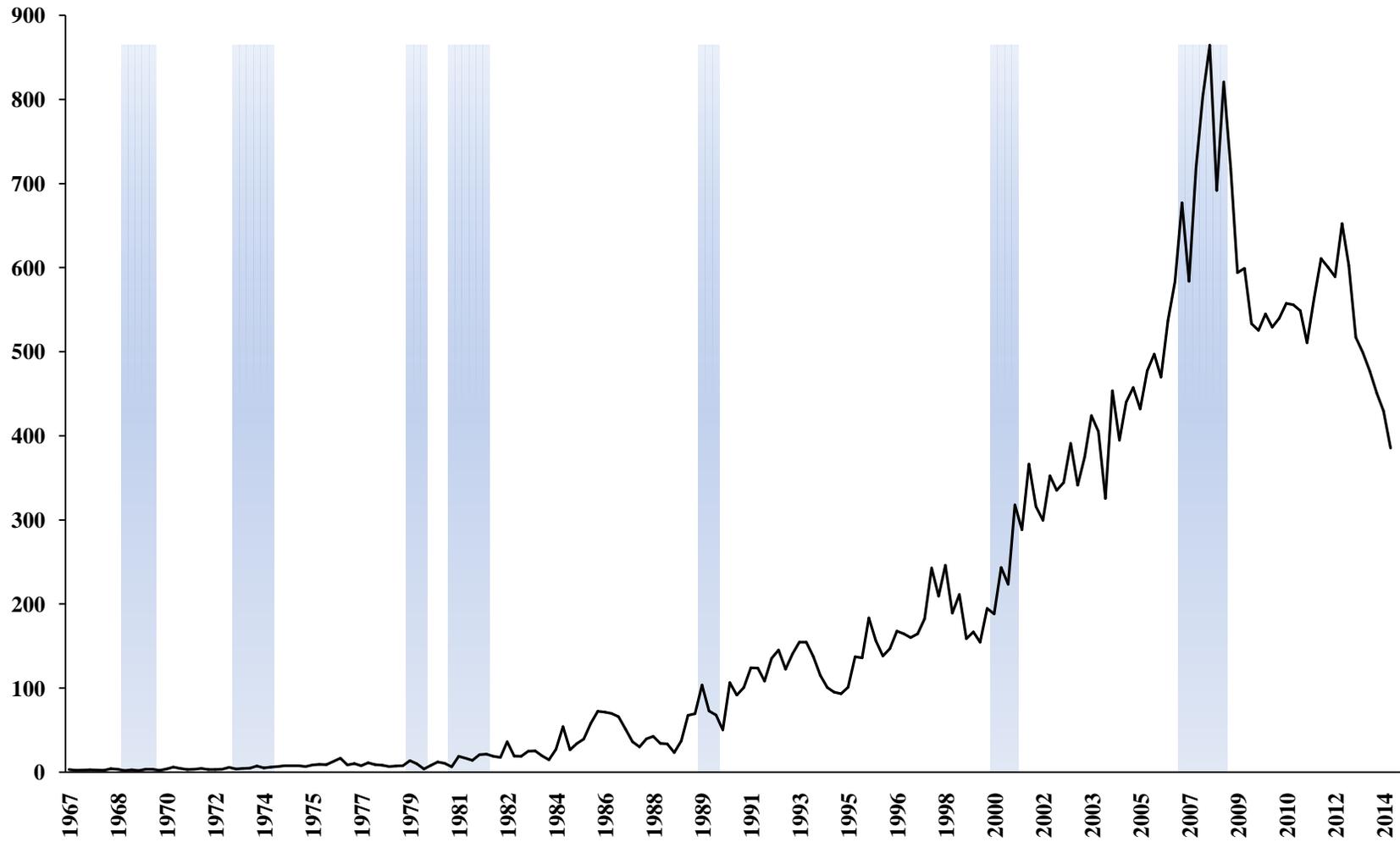


Figure 2 Broker-dealer leverage and its growth rate, 1967:1-2014:3

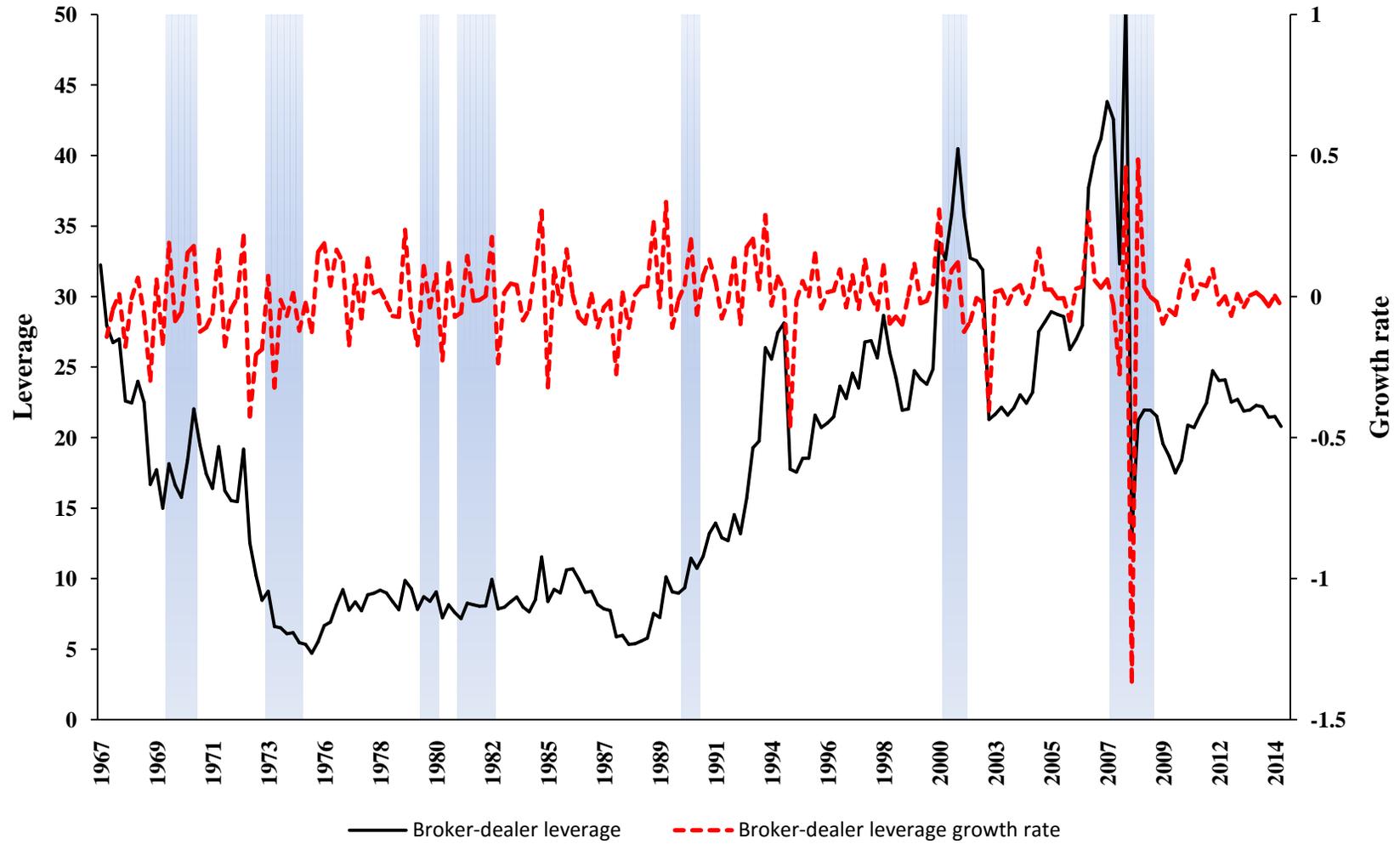


Figure 4 Responses to an interest rate shock in a structurally identified VAR, 1967:1-2014:3

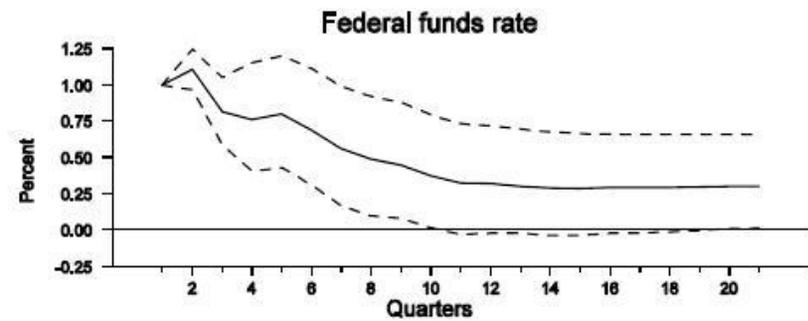
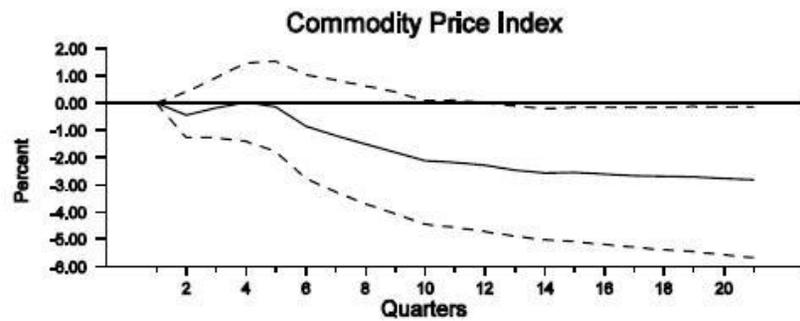
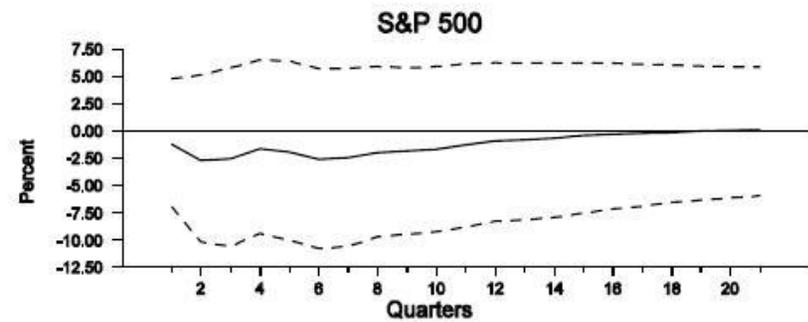
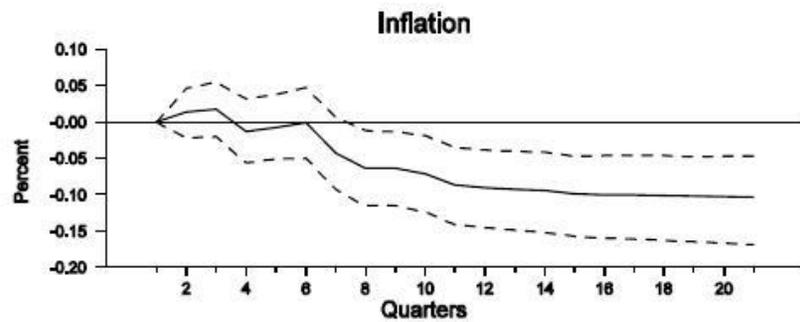
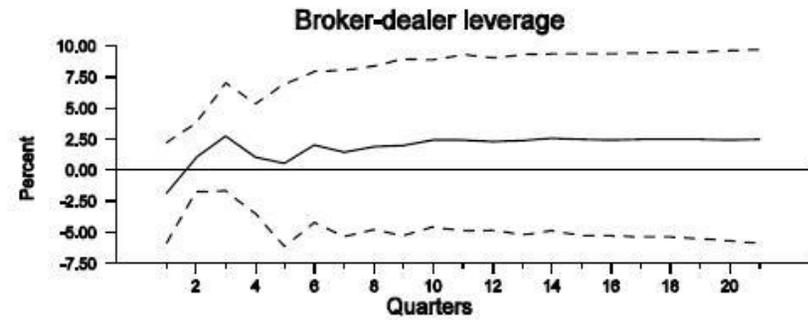
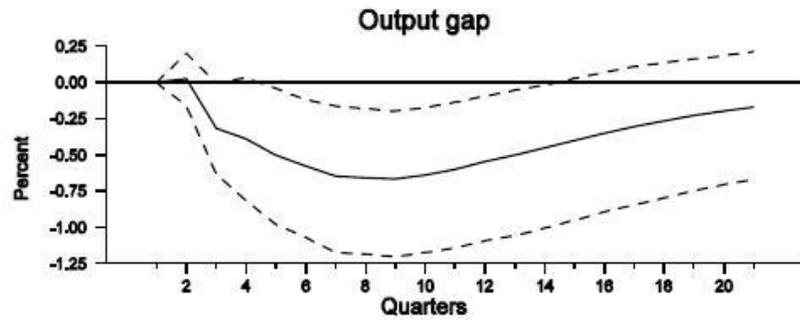


Figure 5 Responses to a broker-dealer leverage shock in a structurally identified VAR, 1967:1-2014:3

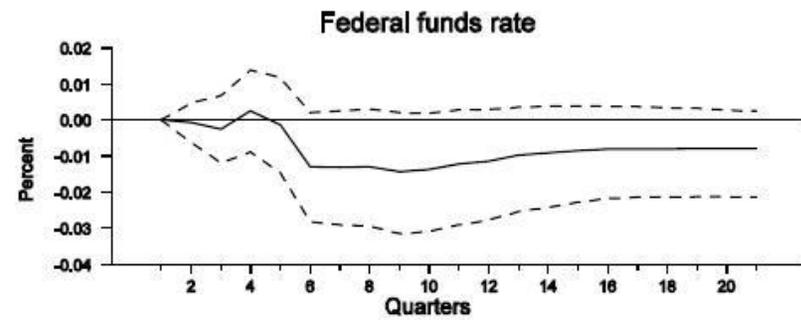
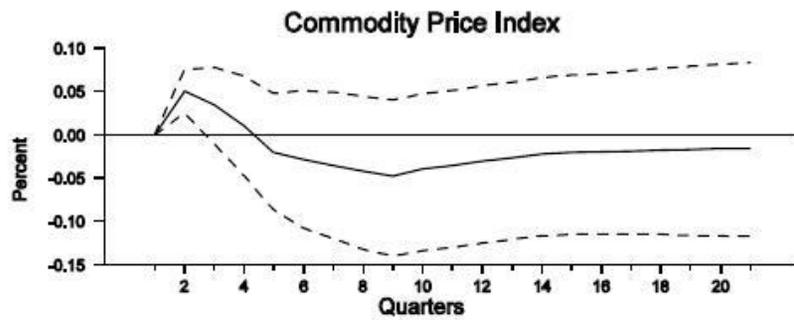
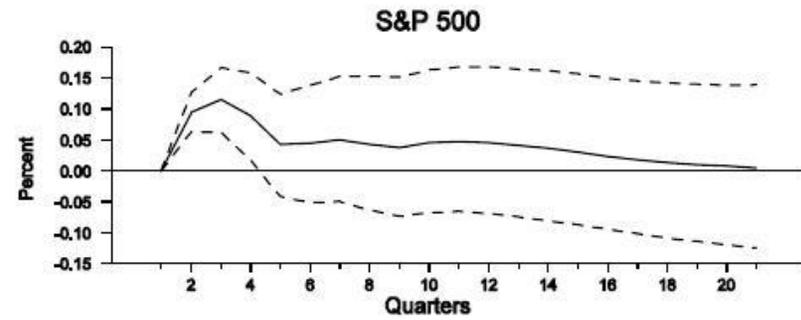
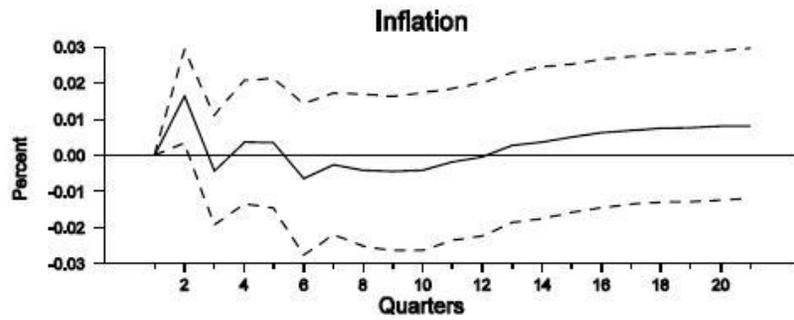
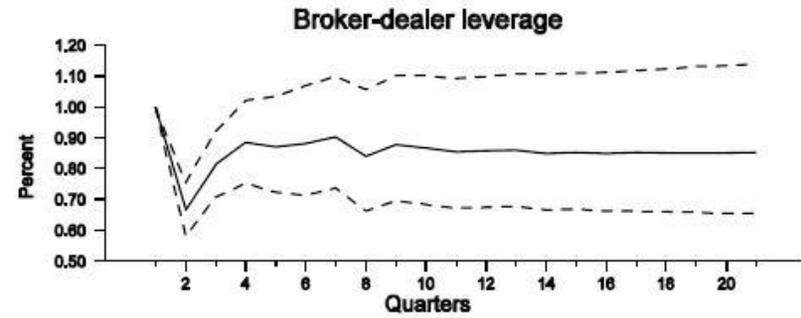
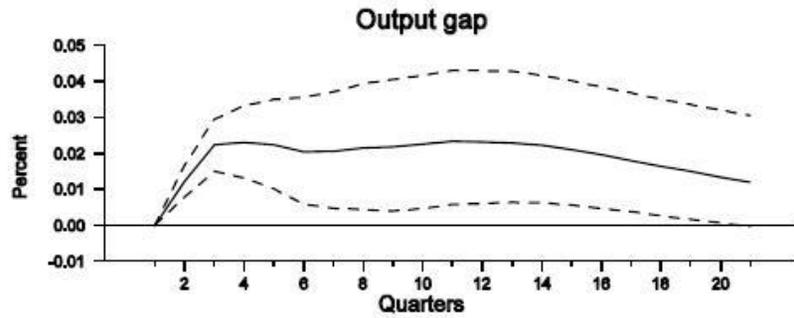


Figure 6 Responses to an interest rate shock in a sign restricted VAR, 1967:1-2014:3

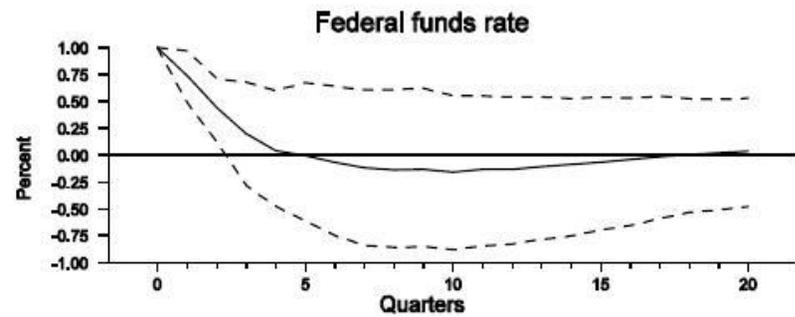
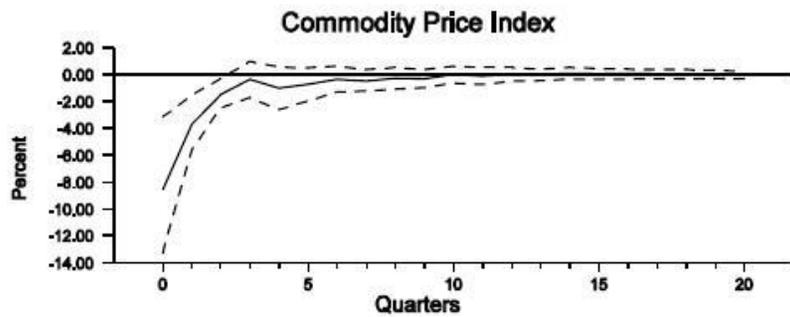
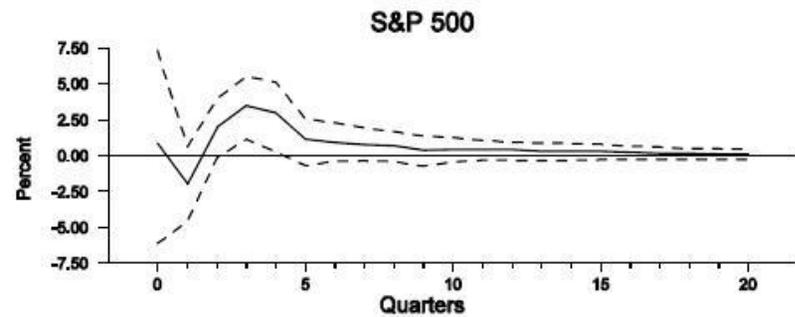
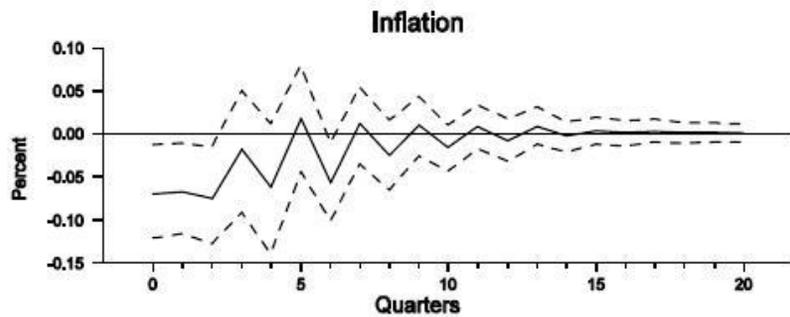
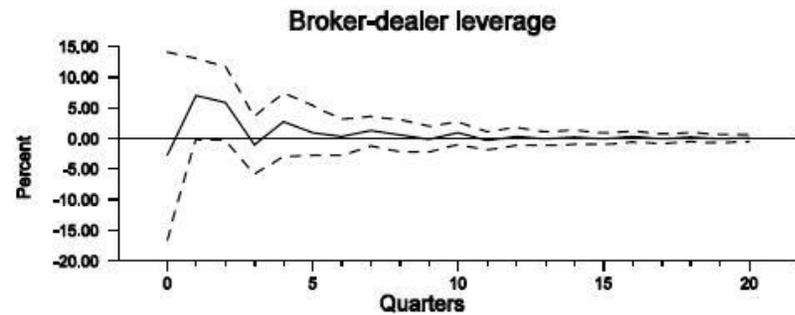
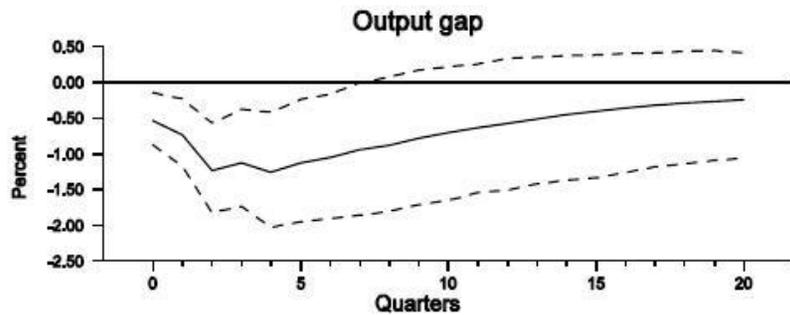


Figure 7 Responses to a broker-dealer leverage shock in a sign restricted VAR, 1967:1-2014:3

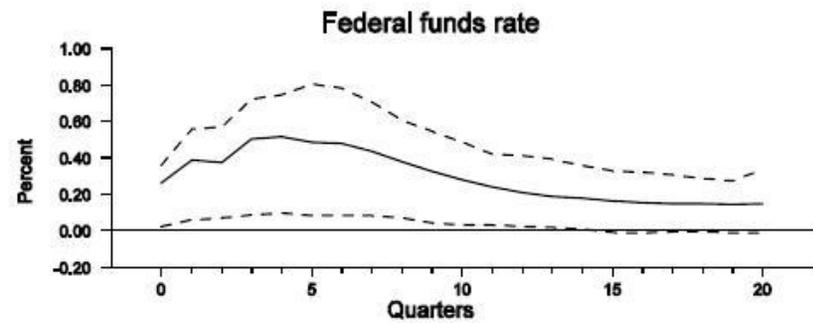
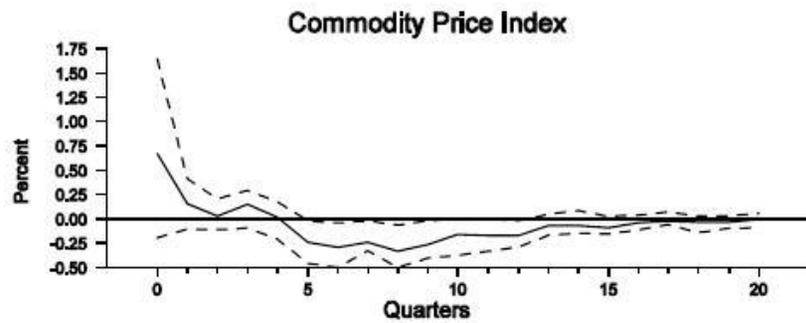
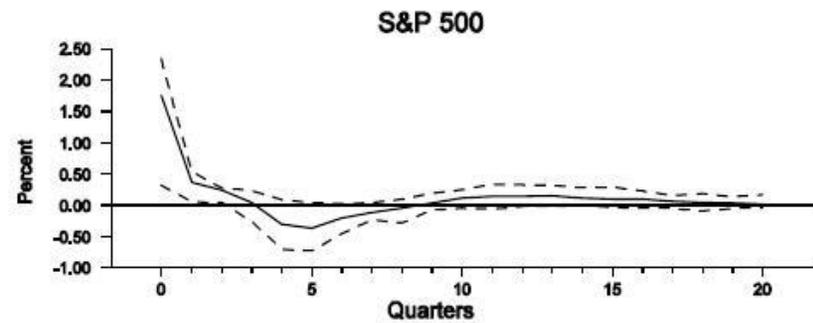
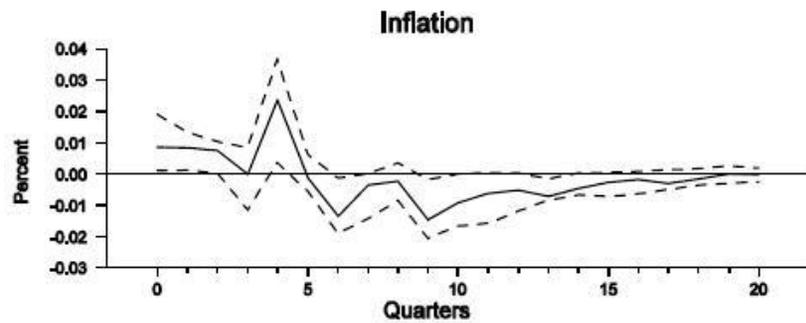
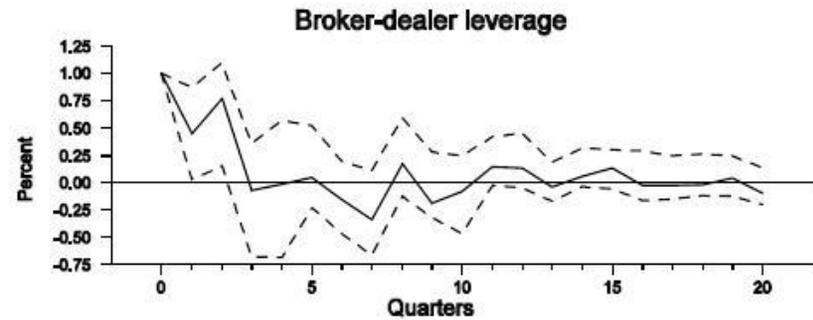
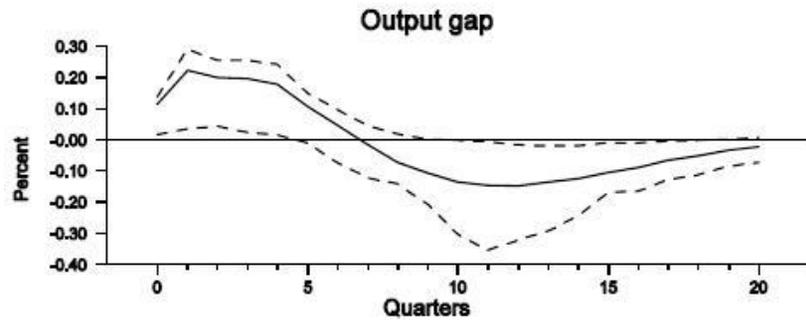


Figure 8 Responses to an interest rate shock in a sign restricted VAR, 1967:1-2006:4

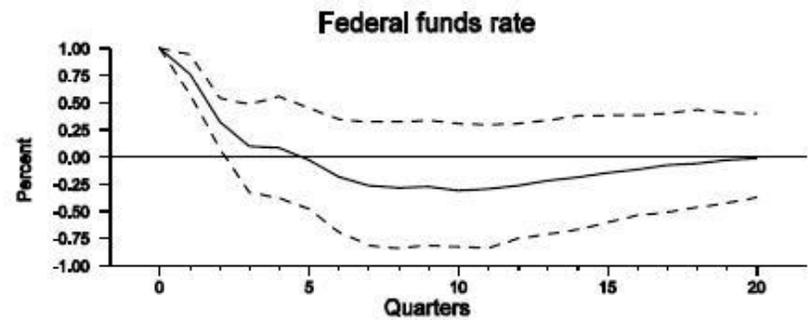
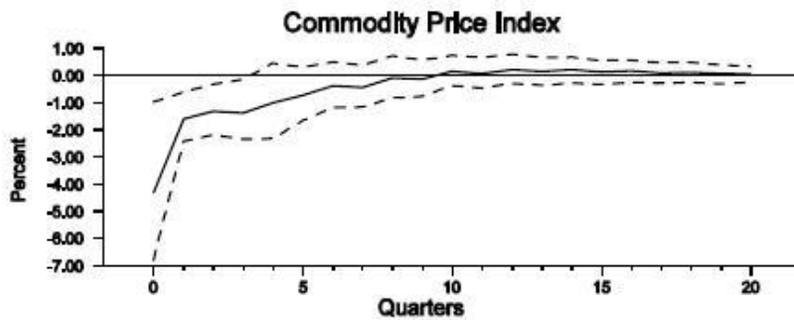
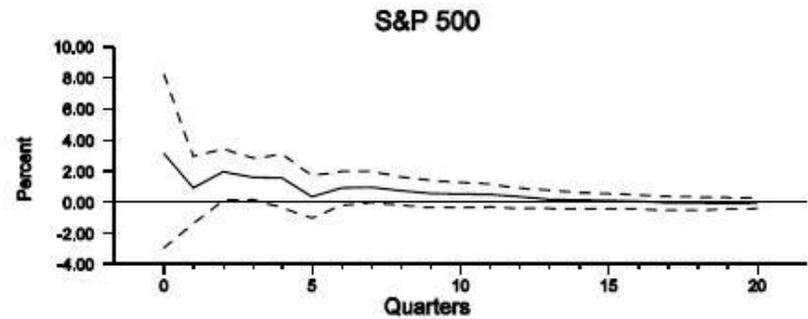
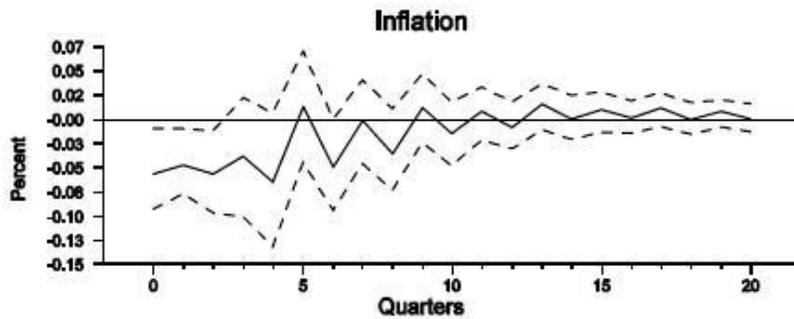
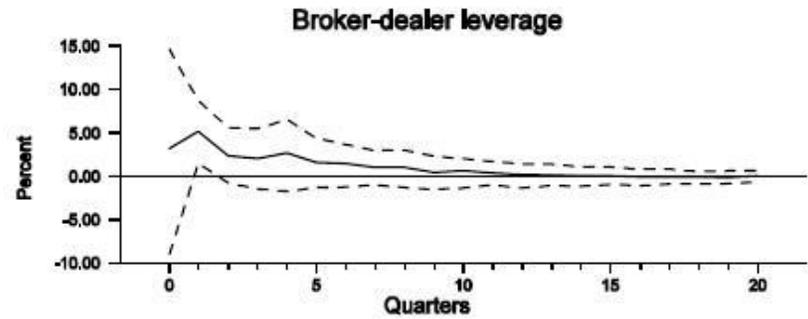
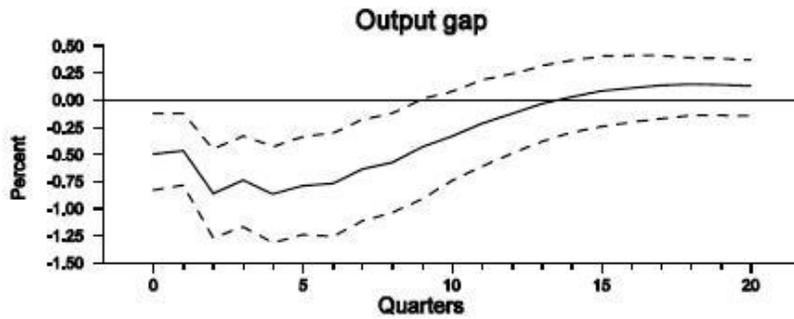


Figure 9 Responses to a broker-dealer leverage shock in a sign restricted VAR, 1967:1-2006:4

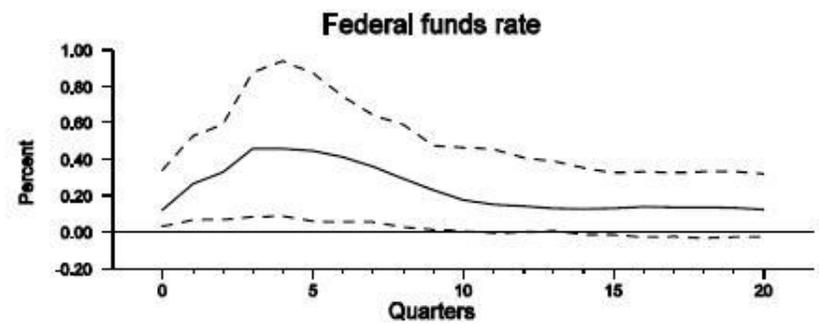
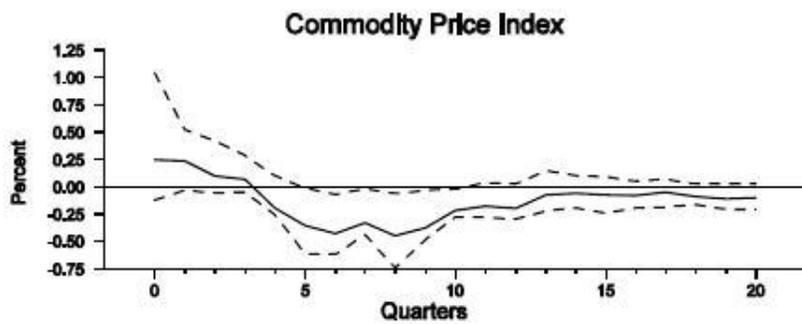
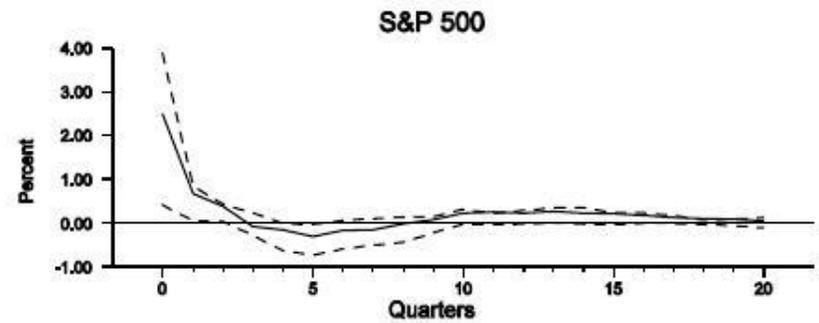
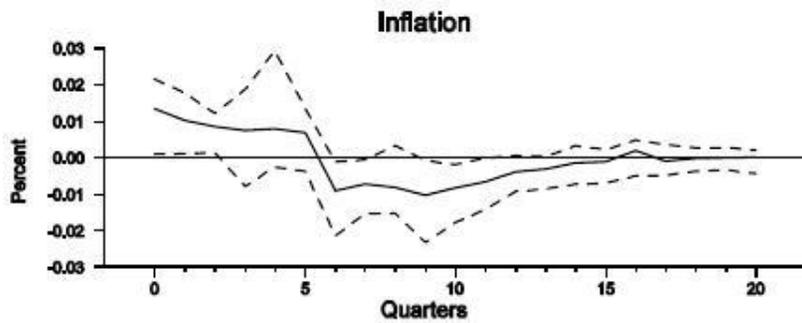
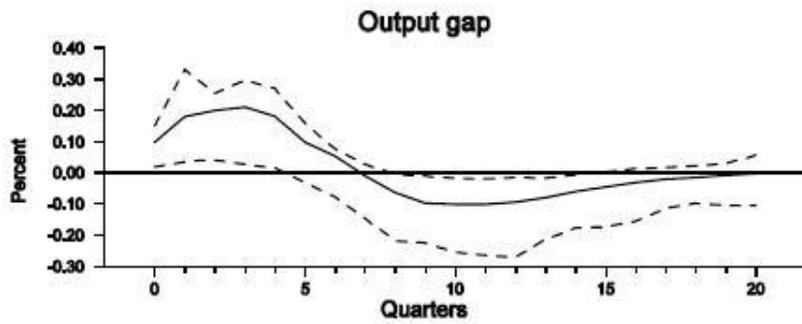


Figure 10 Responses to a money supply shock in a sign restricted VAR, 1967:1-2014:3

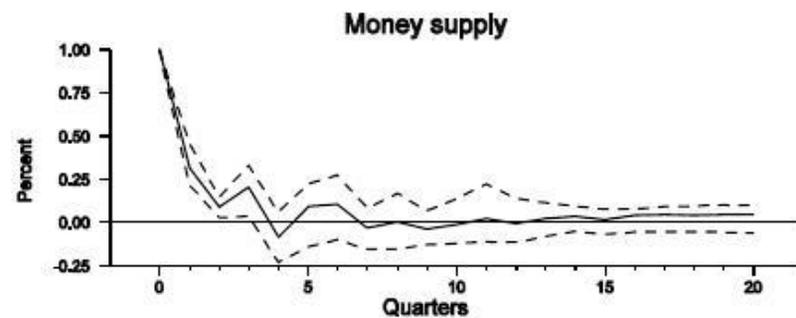
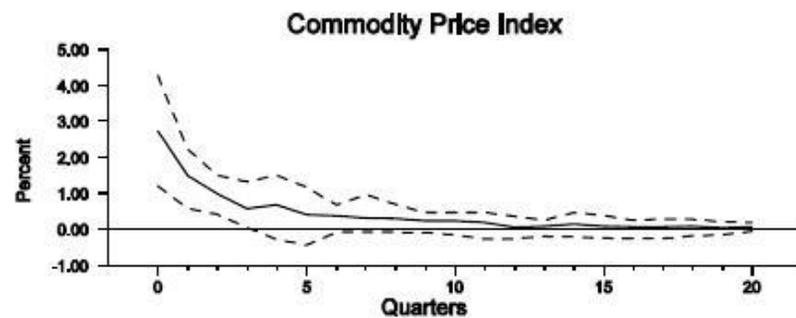
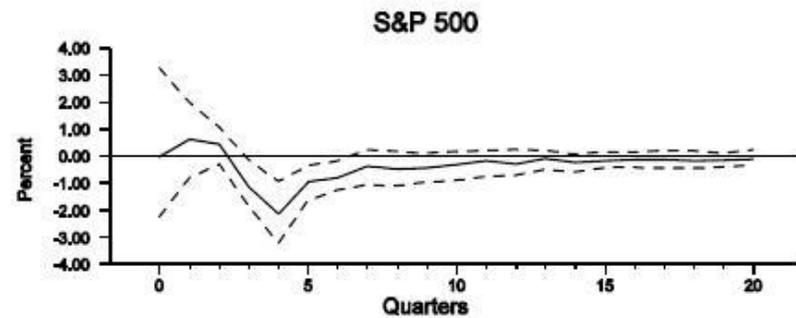
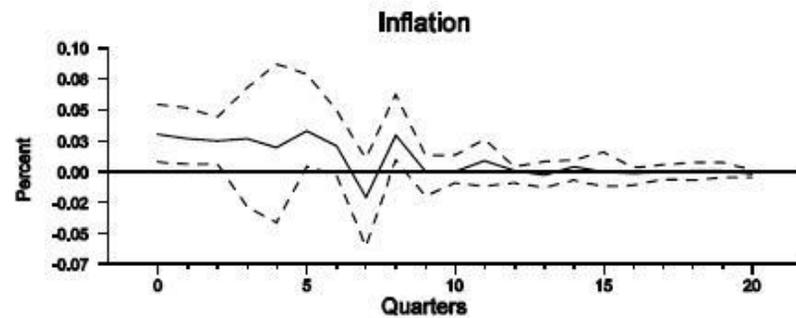
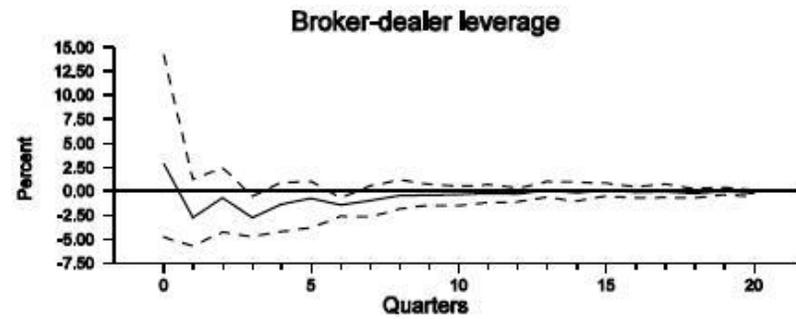
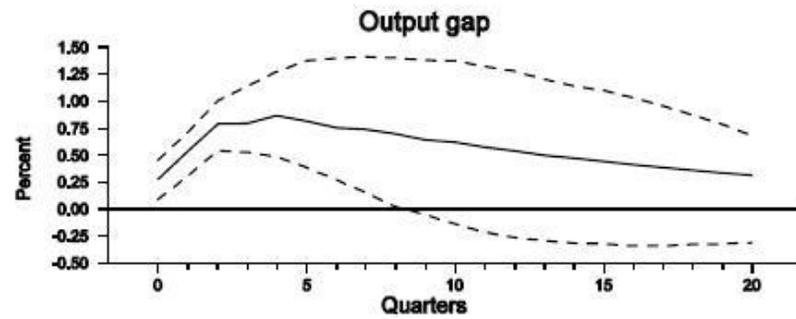


Figure 11 Responses to a broker-dealer leverage shock in a sign restricted VAR including money supply, 1967:1-2014:3

