The Simultaneity of Monetary Policy Reaction and Stock Market Fluctuations: An Instrumental Variable Approach

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Abstract

The objective of this paper is to address the issue of simultaneity between monetary policy action and contemporaneous stock market returns, to estimate the magnitude of causality. This paper makes inference from a structural vector autoregression (SVAR) model which includes variables for monetary policy and stock returns. External instruments are used for identification; I use the information in the volatility index (VXO) of the Chicago Board Options Exchange, to instrument for stock market returns, in a monetary policy rule. This identifies the response of monetary policy to contemporaneous stock returns. Next, the structural (monetary) shock estimates obtained in the previous equation are used as external instruments for the monetary policy variable, to identify the response of stock prices to monetary policy actions. These two estimates are then imposed in a structural VAR with short run restrictions, to estimate the relationship between the federal funds rate, stock prices, and other macroeconomic variables. I find a significant negative relationship between tightening of policy rate and stock price movement in the short run.

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"The Federal Reserve, consistent with its responsibilities as the Nation's central bank, affirmed today its readiness to serve as a source of liquidity to support the economic and financial system."

- Federal Reserve Board Chairman Alan Greenspan (Oct. 20, 1987)

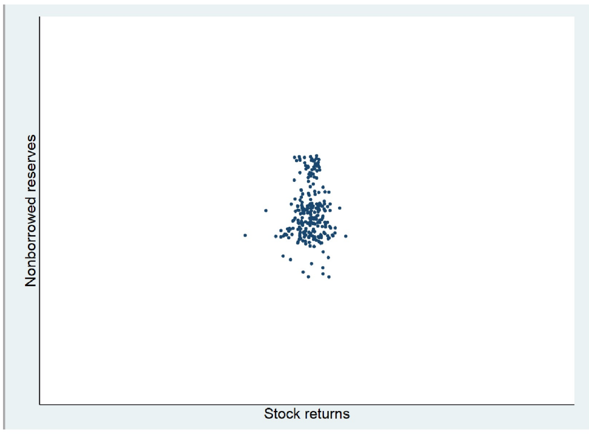
1 Introduction

It is widely believed that the stock market can have a significant impact on the macroeconomy. It comes primarily through two channels. The first, is that movements in stock prices influence aggregate consumption through the wealth channel. For example, stock prices surged 159% between 1989 and 2001, and more than half of US households had stock ownership by 2001. However, in the wake of the subsequent recessions, stock markets crashed and stock ownership rate came down to 47% of households by 2007[1]. Thus, it seems that the fortunes of many families are tied to the vagaries of the stock market. Second, changes in asset prices affect the ability of businesses to raise funds by altering both their capacity to issue new stock and also the value of their collateral. Another reason why the stock market assumes importance, especially from our experience of recent years, is monetary policy makers' concerns about "irrational exuberance" on the part of investors which could potentially lead to asset price bubbles. Thus, although many economists think that a significant fraction of the variation in central bank policy actions reflects policy makers' systematic responses to variations in the state of the economy (formalized by a feedback rule, or reaction function), as a practical matter, it is recognized that not all variations in central bank policy can be accounted for as a reaction to the state of the economy. The unaccounted variation is formalized with the notion of a monetary policy shock. Indeed, the *narrative approach* described in Romer and Romer (1989), citing Friedman and Schwartz, identifies a monetary shock as "an unusual monetary movement that would not have happened in other circumstances given the pattern of real activity". Christiano, Eichenbaum, and Evans (1999) suggests that one of the primary interpretations of these shocks is shifts in the preferences of FOMC members or in the manner in which their views are aggregated.

In this paper I show that one of the sources of the unaccounted variation described above, is the stock market. That is to say that the information content of the stock market matters to the Fed, and hence it could be a significant factor in any feedback rule for monetary policy. Given this background, this paper focuses on the period from 1987-2007. This period almost exactly coincides with the time when Mr. Alan Greenspan was head of the Federal Reserve bank in the United States. This period is particularly remembered because of the usage of the then ubiquitous term 'Greenspan Put'. Those times are remembered as an era when central bank policies, at least to some degree, pushed equities higher. Specifically, it is often suggested that a falling stock market in particular, spurred the central bank to action. Although there is no clear consensus on this topic, even if this were to be true, it is difficult to tease out the response of monetary policy to the stock market. The challenge in estimating the effect of stock market fluctuations on policy decisions, is that, there exists an endogeneity problem: policy actions affect stock prices while at the same time using the information content of the stock market to inform decisions. The simultaneous behavior of policy action and stock fluctuations during the sample period can be inferred from Figure 1. The scattered dots resemble the classic example of equilibrium points, obtained from the intersection of a supply and a demand curve. It can be seen that for a given policy stance (that is, a level of nonborrowed reserves) there can be a lot of variation in stock prices, hinting at the possibility that there could be many more forces that move stock prices.

[1] "Household Wealth Trends in the United States, 1962-2013" (Wolff, 2014)

Figure 1: Joint determination of policy action and stock prices.



Holding all else equal, lower policy rates (or higher liquidity, indicated by an increase in nonborrowed reserves) imply a lower discount rate for expected future cashflows. Since higher future cashflows translate to higher stock prices, low interest rates are associated with higher equity prices. A number of studies analyze the response of stock prices to policy decisions, but empirical evidence with regards to the Fed's reaction to the stock market is relatively sparse. Studies that estimate only one of the parameters—-the stock market reaction to the Fed—-have consistently reported that an unexpected tightening in policy rates causes a significant decline in stock prices (e.g.Rigobon and Sack 2004; Bernanke and Kuttner 2005). There is a small literature that has sought to identify both reponses. Rigobon and Sack (2003) uses heteroskedasticity of stock market returns (essentially, observing shifts in the variance of stock market shocks relative to policy shocks which depend on responsiveness of interest rates to equity prices). This methodology might be inappropriate for two reasons. First, the coefficient of interest may be biased because it is left heavily contingent upon the liquidity of the three-month t-bill market. Second, since they use the three month t-bill as proxy for monetary policy reaction, it seems a bit far-fetched to imagine that the change in *daily* stock prices might have an influence on the Federal Reserve's policy decisions. D'Amico and Farka (2011) uses an instrumental variable for stock market returns: they use high frequency futures market data to estimate the response of stock market futures to changes in federal funds futures on the days of FOMC meetings.They then impose this estimate in a monthly VAR to estimate the response of monetary policy to stock prices.This methodology is based on certain strong assumptions: they assume that the same relationship between reduced form and structural form errors exists between intraday and monthly frequencies. This argument seems untenable because the structural shocks of a daily VAR and a monthly VAR might have very different interpretations. Also, this assumption ignores the idiosyncratic forces of the stock market that might influence the prices of index futures. Crowder (2006) reported that policy shocks lead to an immediate and opposite movement in stock prices, whereas the stock market has no contemporaneous impact on policy rates. As is evident, in a structural VAR setup, the determination of policy response to stock market fluctuations requires identifying assumptions that do not allow for contemporaneous reactions between these variables. At best, exclusion restrictions allow identification of one of them (Goto and Volkanov (2002)). This paper tries to circumvent such exclusion restrictions and estimate the simultaneous effects of our interest: impact of monetary policy shocks on the stock market and the impact of stock market fluctuations on open market operations. I impose these estimates in a structural VAR with short-run restrictions to estimate the impact of liquidity shocks on macroeconomic variables, and also the impact of a federal funds rate shock on stock prices.

To the best of my knowledge, there is no study that has used an external instrumental variable for stock market fluctuations, without imposing strong assumptions about how policy rules and stock prices behave contemporaneously. In this paper I use least squares estimation on two single equations pulled out from a monthly semi-structural VAR.The two equations from a structural VAR are shown below:[2]

$$Monetary\,Policy_t = \beta Stock\,Returns_t + \theta X_t + \epsilon_t \tag{1}$$

$$Stock\,Returns_t = \alpha Monetary\,Policy_t + \phi X_t + \eta_t \tag{2}$$

Equation (1) can be considered a modified version of Taylor rule for monetary policy reaction function at monthly frequency; X_t is a vector of macroeconomic control variables, and ϵ_t are structural liquidity shocks.[3] It is important to note here that the proposed specification of a monetary rule, which considers the stock market, suggests that the decisions of the monetary authorities are shaped by the information that is available to stock market investors. Moreover, to the extent that a broad stock market index is used in this specification, it is assumed that the information of relevance is public information. Equation (2) captures influences over monthly stock prices, and η_t are structural stock market shocks. Equation (2) essentially conveys the well-established notion from financial theory that stock returns are driven by future series of dividends and I follow Rigobon and Sack (2003) in assuming that the expectations of future dividends and short term interest rates are shaped linearly by current and lagged values of macroeconomic variables. I introduce a novel instrumental variable for the stock market, one that is synthesized with the help of the *economic policy uncertainty index*,*EPU*, created by Baker, Bloom and Davis (2016)[4]. The data from 1986:1 to 2007:12 indicate that stock prices decline on average by 1.10% in response to a 25 basis points increase in federal funds rate (within the same month).In addition, the results show that the Fed responds to the stock market contemporaneously as in Rigobon and Sack (2003) and D'Amico and Farka (2011) and that this response is also statistically significant. These results are robust to different sample periods, different measures of liquidity, and market interest rates.[5]
The rest of the paper is structured as follows: Section 2 introduces the identification strategy, Section 3 describes the data used, Section 4 presents empirical results and Section 5 concludes.

2 Identification Strategy

Suppose the economy is described by the structural form VAR:

$$B_0 X_t = B(L) X_t + \epsilon_t \tag{3}$$

and its reduced form is given by $X_t = A(L)X_t + u_t$ where ϵ_t is an (n x 1) vector of structural shocks with variance-covariance matrix $\mathbf{D}$ which is an identity matrix, $\mathbf{u_t} = \mathbf{R}\epsilon_\mathbf{t}$ is a vector of reduced form errors,the diagonal elements of B_0 are equal to one, and $\mathbf{R} = \mathbf{B_0}^{\mathbf{-1}}$. X_t is given by

[2] The equations have a lag structure which I ignore for ease of exposition.

[3] One can argue for a vector of unobservable explanatory variables like Z_t and Z'_t, one for each equation. I follow Keating (1992) and assume that shocks have temporary effects so Z_t=ϵ_t and Z'_t=η_t.

[4] The EPU index is explained in detail under section 3

[5] In deriving these results time fixed effects were used. Extreme market movements in the tails were excluded.

$(\mathbf{Y_t}, NBR_t, SR_t)'$ where $\mathbf{Y_t}$ is a vector of $n-2$ macroeconomic variables representing industrial production, inflation, unemployment, federal funds rate and NBR_t and SR_t denote nonborrowed reserves and stock returns respectively. The recursive ordering followed here is adopted from Christiano and Eichenbaum (1992a), and Goto (2001); It is known that monetary policy variables work with a lag, so it seems reasonable to place them lower in the ordering, below macroeconomic state variables. Stock prices are the quickest to change so they are placed at the bottom – stock prices are affected by all kind of shocks. Strongin (1995) and Eichenbaum (1992) suggests that an appropriate measure of policy-induced liquidity effect is nonborrowed reserves, and hence I use that as proxy for the Federal Reserve's stance on liquidity, in the model. The equation for monetary policy, equation (1), can be considered a modified version of 'Taylor rule' where the Federal Reserve considers past and current values of real inflation, unemployment, output, interest rates, and asset prices, to target nonborrowed reserves appropriately. The model (3) describes the economy at monthly frequency and imposes the following short-run identifying assumptions resulting in a structural model of the form:[6]

$$\mathbf{u_t} \equiv \begin{pmatrix} u_t^{real\ activity} \\ u_t^{inflation} \\ u_t^{unemployment} \\ u_t^{federal\ funds\ rate} \\ u_t^{nonborrowed\ reserves} \\ u_t^{stock\ returns} \end{pmatrix} = \begin{bmatrix} r_{11} & 0 & 0 & 0 & 0 & 0 \\ r_{21} & r_{22} & 0 & 0 & 0 & 0 \\ r_{31} & r_{32} & r_{33} & 0 & 0 & 0 \\ r_{41} & r_{42} & r_{43} & r_{44} & 0 & 0 \\ r_{51} & r_{52} & r_{53} & r_{54} & r_{55} & r_{56} \\ r_{61} & r_{62} & r_{63} & r_{64} & r_{65} & r_{66} \end{bmatrix} \begin{pmatrix} \epsilon_t^{aggregate\ demand\ shock} \\ \epsilon_t^{aggregate\ supply\ shock} \\ \epsilon_t^{business\ cycle\ shock} \\ \epsilon_t^{preference\ shock} \\ \epsilon_t^{money\ supply\ shock} \\ \epsilon_t^{stock\ market\ shock} \end{pmatrix}$$

where the first matrix on the right hand side is ${B_0}^{-1}$. I refer to the vector $\mathbf{Y_t}$ as the *macroeconomy block* and the variables NBR_t and SR_t collectively as the *financial block*. The ordering suggests that the macroeconomy block does not react to the financial block shocks within a month. This is reasonable since a liquidity shock is known to have impact in a lagged fashion. I do not impose the restriction that $r_{56} = 0$,necessarily, which allows for a contemporaneous feedback into monetary policy from the stock market. It follows from the above equation that the matrix $\mathbf{B_0}$ is of the form:

$$\mathbf{B_0} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ b_{21} & 1 & 0 & 0 & 0 & 0 \\ b_{31} & b_{32} & 1 & 0 & 0 & 0 \\ b_{41} & b_{42} & b_{43} & 1 & 0 & 0 \\ b_{51} & b_{52} & b_{53} & b_{54} & 1 & -\beta \\ b_{61} & b_{62} & b_{63} & b_{64} & -\alpha & 1 \end{bmatrix}$$

Since I am interested in identification of only the financial shocks, a convenient way to write $\mathbf{B_0}$ is:

$$\mathbf{B_0} = \begin{bmatrix} \mathbf{B^m_{0M(4x4)}} & \mathbf{0_{4x2}} \\ \mathbf{B^f_{0M(2x4)}} & \mathbf{B^f_{0F(2x2)}} \end{bmatrix}$$

where $\mathbf{B^m_{0M}}$ is a (4x4) lower triangular matrix, while the $\mathbf{B^f_{0M}}$ and $\mathbf{B^f_{0F}}$ matrices are the contemporaneous responses of financial variables(f) to macroeconomic(M) and financial(F) shocks. The equations for the financial variables (NBR) and (SR) are given by

[6]The structural shock pertaining to federal funds rate is called a preference shock in accordance with Christiano, Eichenbaum, Evans (1999), who suggest that monetary surprises are considered to arise from shifting preferences of FOMC members.

$$\mathbf{B^f_{0F}}\begin{pmatrix} NBR_t \\ SR_t \end{pmatrix} = \mathbf{B^f_{0M}Y_t} + \mathbf{B^f(L)X_t} + \begin{pmatrix} \epsilon_t^{NBR} \\ \epsilon_t^{SR} \end{pmatrix}, \tag{4}$$

where $\mathbf{B^f(L)}$ denotes the last two rows of $\mathbf{B(L)}$. The matrix $\mathbf{B^f_{0F}}$ is $(\begin{smallmatrix} 1 & -\beta \\ -\alpha & 1 \end{smallmatrix})$. Since the matrix $\mathbf{R}$ is the inverse of matrix $\mathbf{B_0}$, $\mathbf{R}$ will also be of similar block-diagonal form with the southeast block of $\mathbf{R}$ given by $\mathbf{R^f_F} = (\mathbf{B^f_{0F}})^{-1}$.

$$\mathbf{R^f_F} = \frac{1}{1-\alpha\beta}\begin{pmatrix} 1 & \beta \\ \alpha & 1 \end{pmatrix}$$

so that $\frac{\alpha}{1-\alpha\beta}$ denotes the response of stock market to policy shocks. From model (3) we see that the covariance matrix($\sum_u$) of the reduced form innovations u_t is given by

$$\sum_u = \mathbb{E}(u_t u_t^{'}) = B_0^{-1}\mathbb{E}(\epsilon_t\epsilon_t^{'})B_0^{-1'} = B_0^{-1}\mathbf{D}B_0^{-1'} = B_0^{-1}B_0^{-1'}$$

The above equation represents a system of equations in the unknown parameters of B_0^{-1}[7]. In a typical structural VAR the variance covariance matrix of the reduced form model, by construction, contains n(n + 1)/2 distinct elements. Thus n(n + 1)/2 is the maximum number of parameters that can be uniquely identified in the matrix B_0^{-1}. In the given model, there are n(n + 1)/2+1 unknowns, since I allow for contemporaneous interactions between NBR_t and SR_t. However, because I am able to identify two unknown parameters outside the VAR using external instruments, I am essentially left with n(n + 1)/2-1 unknown parameters to be solved by n(n + 1)/2 equations. The effect of introducing two additional restrictions is created by using instrumental variables in equations (1) and (2).

2.1 Why volatility index as instrument:

A reasonable model for why stock prices fluctuate, asserts that prices are essentially expectations of future real dividends discounted by a real rate of interest, and that any fluctuation is brought about by "new information" about future dividends. Shiller (1981) calls this model an "efficient markets model". Stock price indexes have often been described in popular discussions as too "volatile", which is to say that the movements in stock price indexes could not realistically be attributed to any objective new information, since movements in the price indexes seem "too big" relative to subsequent events. Shiller finds that measures of stock price volatility (over a century's worth of data) appear far too high to be attributed to new information about future real dividends, and concludes by saying that both, the possibility of time-varying real interest rates, or the insufficiency of our measure of the uncertainty regarding future dividends – sample standard deviation – are not able to explain satisfactorily, the volatility of stock prices. He suggests, what is called in econometricians' parlance, "unobservables" as a reason for why stock prices are so volatile.

Understandably, there has been considerable curiosity about the relationship between stock prices and expectations about the future - Christie (1982), French, Schwert, and Stambaugh (1987) and Schwert (1989) are just some of the studies that found evidence of a strong relationship between stock returns and expected volatility.[8] One popular measure of future stock market volatility is the VXO (or VIX) which is created from index options.[9] Fleming, Ostdiek, Whaley

[7] To keep this explanation generic, I ignore for the moment, the assumption that the diagonal elements of B_0 are equal to one.

[8] also Ang,Hodrick,Yuhang,Zhang (2006)

[9] VXO is implied volatility computed from the S&P 100 index options prices and VIX is computed from the

(1995) provides a comprehensive description of VIX. They find, from the time series history of VIX that it is "well-behaved with little evidence of seasonality", that there is a strong negative correlation with contemporaneous stock market returns, and that it exhibits a strong relationship to future stock market volatility. It concludes by saying that VIX embeds market expectations and can be a useful instrument for forecasting volatility. Whaley (2000) calls VXO/VIX the "investor fear gauge" and suggests that it is considered a harbinger of future macroeconomic uncertainty. Bailey, Zheng, and Zhou (2012) attempts to find out "What makes the VIX tick". They affirm that VIX is not just a popular empirical indicator that "works" but it may as well proxy as a source of more fundamental information. They propose as explanatory factors, elements of the trading process such as volume and direction, noise trading, market making and even a psychological aspect to VIX – investor sentiment. Finally, De Long et al. (1990) provide evidence on the abundance of *noise traders* in the stock market, whose unsophisticated opinions and actions make arbitrage opportunities less attractive to more rational investors, thereby driving a wedge between market prices and fundamental values. They claim that a defining characteristic of these noise traders is their unpredictability which stems from the traders' belief in their *pseudosignals*. These pseudosignals include price patterns, various stock indexes, and the forecasts of Wall Street gurus. As they suggest in their paper that, while it is not always necessary to specify the content of unpredictable investor behavior, it is important to acknowledge its effects. To that extent, a volatility index such as VXO assumes importance in the context of this study. However, it is also true that VXO (VIX) has an *implied* connotation and is not a *real* economic variable. Therefore, it is not unreasonable to assume that any structural policy rule will not depend directly on the VXO, which is simply a statistical concept. It seems logical, though, to use VXO as an instrument for (real) stock returns, which in turn, may potentially have implications for a monetary policy rule. Further, in light of the claim made by Bailey, Zheng, and Zhou (2012), it is possible that VXO may be imbued with some information about monetary policy uncertainty (and uncertainty about the economy in general). To *strip* VXO of the influences of any prevalent macroeconomic uncertainty, I regress VXO on the indices of economic policy uncertainty, and monetary policy uncertainty (Equation 5).[10] This exercise, hopefully, renders a component of VXO that is influenced by forces other than uncertainty about economic fundamentals (and hence monetary policy). This component is embodied in the residual, it is meaningful to at least some investors in the stock market, and it spurs them to act upon this information. Hence, I choose these residuals as instruments for stock returns.[11]

$$VXO_t = \gamma Economic\ uncertainty_t + \theta Monetary\ policy\ uncertainty_t + \tau_t \tag{5}$$

The residuals τ_t are instrumented in regression (1). Table 1 shows correlations between monthly values of the uncertainty indexes, stock returns, and the residuals. We can see that the correlation between stock returns and the uncertainty indexes is negative, which conveys the notion that the stock market declines with rising volatility and uncertainty about the future. More importantly, monthly stock returns show a substantial correlation of -0.34 with its instrument (*Residuals*). Thus, I estimate how nonborrowed reserves respond contemporaneously to stock returns.

In the second step, I use the residuals from regression (1) as instrumental variables for monetary

S&P 500 index options prices. They are strongly correlated.

[10]The economic uncertainties being referred to here are only about the United States; The assumption being that the VXO can be influenced by many other factors but this regression exercise will cleanse the VXO of uncertainty stemming from contemporaneous-period monetary policy decisions of the Federal Reserve.

[11]Data on the uncertainty indices are freely available at www.policyuncertainty.com and introduced in the paper "Measuring Economic Policy Uncertainty," *The Quarterly Journal of Economics* (2016) by Bloom, Nicholas, Baker, Scott R., and Davis, Steven J.

Table 1: Cross-correlation table

Variables	**Stock returns**	**Residuals**	**VXO**	**EPU**	**MPU**
Stock returns	1.00				
Residuals	-0.34	1.00			
VXO	-0.40	0.83	1.00		
EPU	-0.20	0	0.32	1.00	
MPU	-0.17	0	0.23	0.75	1.00

policy (nonborrowed reserves) in equation (2). The instrumented residuals are essentially estimates of $\epsilon_t^{liquidty\ shock}$ — a structural shock, which by definition, is uncorrelated with other shocks. These can affect stock prices only indirectly, through their effect on policy decisions. Thus, in this step I estimate how the stock market responds contemporaneously to nonborrowed reserves. Once I have estimated the responses, $\widehat{\alpha}$ and $\widehat{\beta}$, I impose these estimates in a short run structural VAR (Equation 3) to obtain the impact of a federal funds rate move on stock prices.

3 Data description

3.1 Financial variables and Instrumental Variable data

Value-weighted real monthly returns, adjusted for dividends, on the S&P 500 index are obtained from CRSP database (Center for Research in Security Prices)[12]. I follow Bernanke and Kuttner (2005) and omit data points pertaining to September 2001 which leads to unusual outliers due to the 9/11 terrorist attacks.

Volatility Index: The VXO (or VIX) is a real-time index like any other stock market index, computed throughout the day and published by the Chicago Board Options Exchange (CBOE). The VXO is a forward-looking expectation of 30-day volatility. The original index, introduced in 1993 was based on the S&P 100 index but in 2003 CBOE announced a switch to using the S&P 500 index for computing implied volatility. After the switch, CBOE continued to publish implied volatilities based on the original S&P 100 index under the name "VXO". To maintain consistency, I use VXO instead of VIX. Also, data on VIX is unavailable for periods before 1990. This does not bias the results very much since the VXO and VIX are strongly correlated with each other, and exhibit the same level of correlation with stock returns.[13] I use the average closing VXO values for a month, from CBOE website.

Economic Policy Uncertainty Index: The EPU is a new index of economic policy uncertainty based on newspaper coverage frequency of articles from 10 leading U.S. newspapers that contain the following trio of terms: "economic or "economy"; "uncertain" or "uncertainty"; and one or more of "Congress", "deficit", "Federal Reserve", "legislation", "regulation", or "White House". The creators of this index have extended this generic index into specific policy categories also, where they look for a different clique of words, in addition to the words above. The authors also have subjected this index to various robustness checks and found a strong correlation between their EPU index and the VIX, and also the frequency with which the Federal Reserve System's Beige Books mention policy uncertainty. The authors' EPU data are available at monthly and daily frequencies at their website and are carried by Bloomberg, Haver, FRED, and Reuters.

[12]The database can be accessed at https://wrds-web.wharton.upenn.edu/wrds/index.cfm?
[13]For the sample in this study correlation between VXO and VIX is 0.98

3.2 VAR data

In the second step, I estimate a traditional VAR augmented with stock returns. The specification includes several benchmark variables: industrial production (*IP*), the consumer price index (*CPI*), nonfarm payrolls (*NFP*), the federal funds rate (*FF*), nonborrowed reserves (*NBR*), and S&P 500 stock returns (*SR*). I follow Christiano, Eichenbaum, Evans (1999) and express the variables IP, CPI, NFP, and NBR in logarithmic form. All macroeconomic data series are obtained from FRED. The ordering of the variables in the VAR is (IP, CPI, NFP, FFR, NBR, SR). VAR estimates are carried out in monthly frequency and in the baseline sample from January 1986 to December 2007, they include three lags of each variable . The number of lags is chosen by the Akaike information selection criterion (AIC).

4 Empirical Results

In the macroeconomic literature, identification of VAR often takes the form of exclusion restrictions - that either α or β is zero. Neither of these restrictions is appropriate in the current context. However, if we assume, inappropriately, that the stock market does not react to monetary policy, then we ignore endogeneity. In that case, the policy reaction function (equation 1) can be estimated directly. The results from that estimation are shown in Table 2. Only the relationship with contemporaneous variables is shown here.We can see that the coefficient for stock returns is almost equal to zero (and insignificant), suggesting that within the same month, policy decisions are not guided by stock prices.

To identify the true β (response to stock returns), I synthesize an instrumental variable for stock returns, to use in equation (1). These are the residuals (henceforth referred to as RI_t) of regression (5). This regression is required to extract that component of VXO that is truly exogenous to monetary policy. I regress the monthly change in VXO on the monthly change in the index values of EPU and MPU. I collect the orthogonalized residuals of this regression and use them as instrumental variables. Results of this *cleansing* regression (Equation (5)) are shown in Table 3.[14] We see that the coefficients for EPU (and its lags) are significantly positive, even after including four lags of VXO. The significantly positive coefficient implies that on average, monthly growth in economic policy uncertainty is a significant predictor of growth in stock market volatility over the same month. Moreover, the significance of lagged coefficients implies that the monthly change in EPU index is significant in predicting volatility growth not only for the current month but also up to three months into the future. The way the EPU is constructed (from newspaper/media coverage of certain particular terms), it is possible for some uncertainty about monetary policy to be encapsulated in a given month's EPU index value. We just saw from Table 3 that this uncertainty is important in predicting that same month's stock market volatility (VXO). Thus, in order to be able to use VXO as a valid instrument for stock returns, we need to strip away from VXO, the predictability that stems from policy uncertainty, leaving us with only that component of VXO which is random. This information is embodied in the residual, τ_t. We know that τ_t is significantly correlated with stock returns (Table 1), yet removed from policy expectations. There are many ways to interpret this residual. One interpretation of this residual could be that it embodies expectations or information about economic fundamentals from other countries. This is plausible since the global financial markets might be interconnected, and also, the assumption here is that the Federal Reserve, when making decisions, would not concern itself with the economic or political fortunes of other countries. Another interpretation could be that these residuals represent

[14] Various other specifications for this regression were tested. Results obtained were similar.

actual shocks, such as, a natural disaster, a political calamity, or any such event (outside the US) which has a *shock* value that can potentially contribute to uncertainty. This uncertainty, because of interconnectedness of global financial markets, might not remain 'local' and spills over into the US stock market, thereby affecting US stock prices directly, or through ripple effects.[15]

Instrumenting for stock returns

First Stage: I run a regression on equation (1) again, this time using instrumental variables. In section 2, stock returns were shown to be reasonably correlated with their instrument. A test of endogeneity was run on equation (1). I failed to reject the null hypothesis that stock returns (SR) is an exogenous variable. The first stage regression results are shown in Table 4.The coefficient on the instrument is highly significant and the F-statistic is fairly high. This shows that on average, holding constant the economic fundamentals of the US, there are significant outside forces (which are represented by the instrument RI_t) that influence stock prices in the US. It is important to note here that these forces which influence stock prices, by construction, are removed from any effect of domestic monetary policy.

Second Stage: Table 5 shows the results of the second stage of TSLS applied over Equation (1). In contrast with Table 2, the coefficient for stock returns is significantly different from zero and is negative which indicates that a monetary policy rule which considers the stock market, would dictate expanding liquidity as stock prices fall. In particular, the coefficient implies that on average, a drop in the stock market index of 5% within a month, predicts an increase in nonborrowed reserves by approximately 38 basis points, within the same month. The coefficient for stock returns thus obtained, estimates the contemporaneous response of liquidity stance to stock market movement,that is,β. Next, I use the residuals (henceforth referred to as PI_t) of equation (1) as instrument for monetary policy in equation (2), to estimate the contemporaneous response of stock prices to changes in liquidity position,that is, α. It is useful to note that the residuals obtained in the previous regression are essentially estimates of the structural shock, $\epsilon_t^{liquidity\ shock}$. They can influence stock returns only through their direct effect on policy stance. Thus, I perform a TSLS again, this time on equation (2).[16] The results of this regression are shown in table 6.

Within the same month, the effect of an increase in nonborrowed reserves on the stock market is significantly positive, and huge. This suggests that an expansionary monetary policy stance will cause stock prices to rise. In particular, even a 10 basis points increase in nonborrowed reserves is accompanied by a stock market increase of approximately 11%, within the same month. This suggests that stock prices can be very sensitive to the Federal Reserve's liquidity position.

One reason why the *lagged* value of industrial production (IP) assumes significance could be that investors likely perceive the industrial production index to be *excessively forward looking*. If that is true, then current stock prices should be explained more by forwarded values of IP and some lagged values of IP that correspond to the present time.[17]

Once I obtain estimates of the two responses, $\widehat{\alpha}$ and $\widehat{\beta}$, I directly impose these two estimates in the monthly VAR model (3) to identify the structural matrix of contemporaneous responses ($\mathbf{B_0}$) using the AB model of structural VAR estimation. From model (3), we see that period t disturbance in stock market returns is given by the following linear equation:

[15] for example, Japan earthquake of 2011:http://money.cnn.com/2011/03/11/markets/world_markets/index.htm Libyan Civil war http://www.masslive.com/news/index.ssf/2011/03/stocks_dip_as_concerns_about_c.html

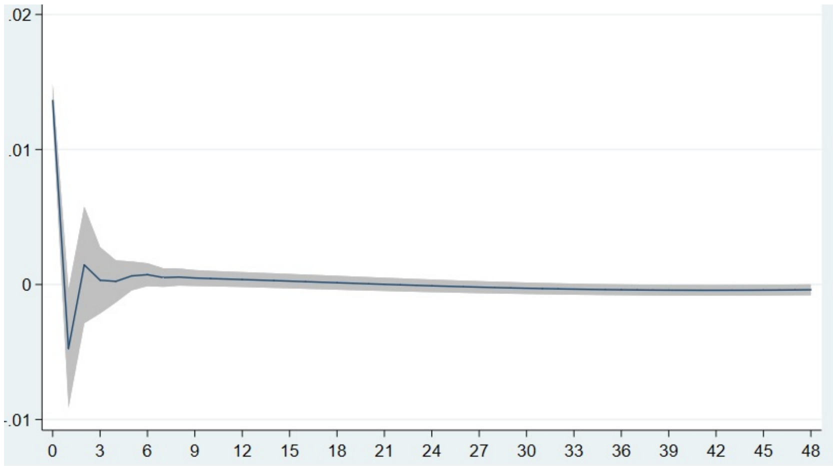
[16] Results of first stage regression and F-test are shown in Table 10.

[17] This was found to be the case when I added forwarded values of IP in my regression. The three-period-lagged IP along with three-period-forwarded IP were estimated with significance. Contemporaneous nonborrowed reserves retained the same level of significance.

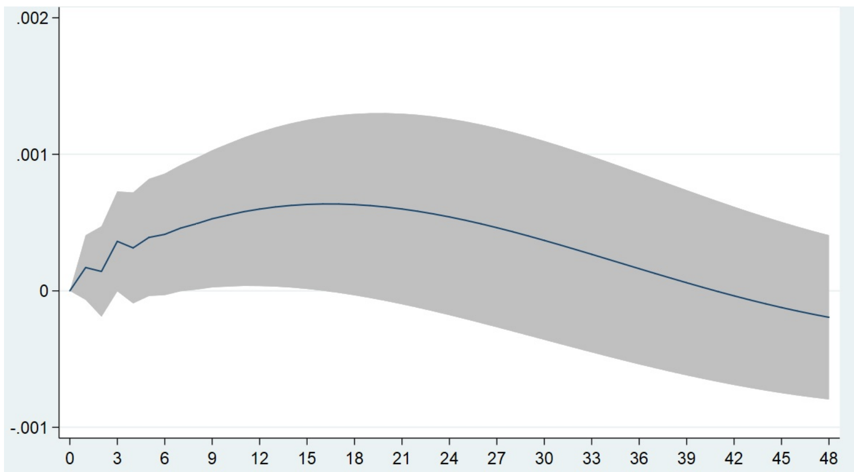
$$
\left[u_t^{stock\ returns} =\right] = \begin{bmatrix} -b_{61} \\ -b_{62} \\ -b_{63} \\ -b_{64} \\ \alpha \\ 1 \end{bmatrix}' \begin{bmatrix} u_t^{IP} \\ u_t^{CPI} \\ u_t^{NFP} \\ u_t^{FFR} \\ u_t^{NBR} \\ \epsilon_t^{stock\ market\ shock} \end{bmatrix}
$$

The first matrix on the right hand side is obtained from the fifth row of the estimated $\mathbf{B_0}$ matrix. These contemporaneous estimates are shown in Table 7. We see that within a month only Federal Reserve actions are significant for explaining stock market movements.The contemporaneous relationship between liquidity position (nonborrowed reserves) and stock returns was established in Table 5. Another interesting relationship to be noticed is that between the federal funds rate and contemporaneous stock market returns. The coefficient is significantly negative which supports the anecdotal evidence that tightening interest rates have a negative ripple effect on stock markets. On average, a 25 basis points increase in federal funds rate is accompanied by a stock market drop of approximately 107 basis points, in the same month. From the estimated structural VAR I construct impulse responses. Figure 2 shows the structural impulse response functions of various variables to a positive nonborrowed reserves shock (monetary expansion), and the response of the stock market to a positive federal funds rate shock. We see that immediately after a positive liquidity shock, the stock market index shoots up. This suggests that excess liquidity in the economy might possibly find an outlet in asset markets, leading to an increase in stock prices. This also hints at one popular notion of that time – the "Greenspan Put"– which was understood as the Federal Reserve backstopping falling stock prices by loosening its liquidity stance. The stock market's immediate reaction to a positive federal funds rate shock also is consistent with actual experience – the stock price index declines immediately following a hike in the federal funds rate, sustaining the decline for about a month but stabilizing within the next six months in the absence of other shocks. Employment level shows a positive response to a positive liquidity shock and keeps rising, reaching a peak in about two years after which it starts to decline. A positive liquidity shock leads to an increase in real activity which reaches a peak in about a year and half after which it starts to descend. It is difficult to talk about the effect on inflation of a liquidity shock since there is no clear positive or negative impact. However, in the long term a positive money supply shock seemingly puts inflation on an upward trajectory. Figure 3 indicates that a positive federal funds rate hike precipitates a stock market plunge which is sustained for about 2 months, and then stock prices stabilize over the next 6-7 months.

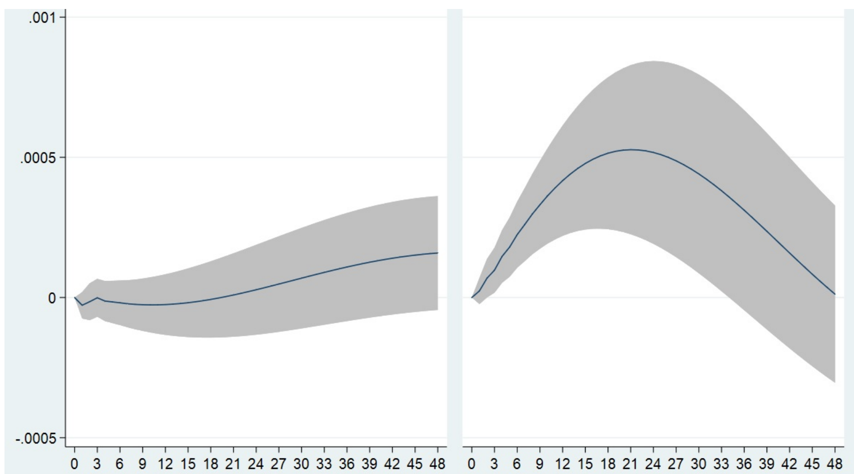
Figure 2: Impulse response to a liquidity shock



(a) Stock returns



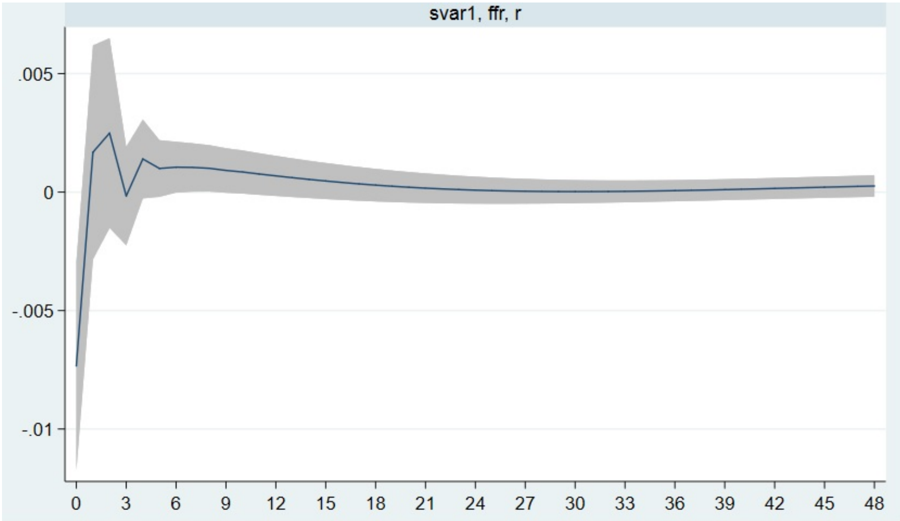
(b) Industrial Production



(c) Inflation and Employment

Note: Impulse response is shown with 95% confidence intervals estimated using bootstrapped standard errors based on 2000 draws. A recursive ordering is followed, allowing for contemporaneous responses between stock returns and nonborrowed reserves.

Figure 3: Response of stock returns to a positive federal funds rate shock



Note: Impulse response is shown with 95% confidence intervals estimated using bootstrapped standard errors based on 2000 draws. A recursive ordering is followed, allowing for contemporaneous responses between stock returns and nonborrowed reserves.

Robustness Checks

The Federal Reserve has at its disposal various different tools to execute its policy plan. While the Fed has a broader mandate that it has to fulfill at all times, its precise focus has been changing over the course of its history, depending on the *operating instruments* that it chooses to use. There is not a broad consensus about whether there were switches in monetary policy regimes[18]. However, I carried out the analysis for a particular subsample, the period from 1987-2000. Although the FOMC had stopped setting a growth target rate for the narrow M1 money stock after 1986, the Committee was still formulating policy in terms of a targeted growth rate for the broader M2 aggregate. After 1993, the Committee continued to set a range for M2 growth in order to "communicate its expectations of the growth of M2 that would result under specified assumed conditions". Beginning in 2001, the Committee stopped setting such ranges altogether (Friedman, 2006). I expected stock prices and monetary aggregates to show a stronger relationship during this period. Indeed, this was found to be the case. The results are shown in Table 8. We see that in the subsample, stock returns are extremely sensitive to contemporaneous values of both nonborrowed reserves and federal funds rate. On average, even a 10 basis points monthly increase in nonborrowed reserves is accompanied by a contemporaneous increase of approximately 21% in the same month. The effect of a federal funds rate loosening is more modest. A 25 basis points decrease in the federal funds rate is accompanied by a contemporaneous increase of approximately 1.5 %. This suggests that choosing federal funds rate as a policy tool, instead of bank reserves, might have more controlled ripple effects on the stock market.

The regression exercise was carried out with different measures of monetary aggregates.I sampled the times series with *M2*. I also tested the model by replacing the federal funds rate with three month t-bill rates. I found that same relationships existed between our variables of interest, stock returns and Federal Reserve policies. The results of robustness checks are shown in Table 9. It is worth mentioning here that stock returns are more sensitive to loosening of M2 than nonborrowed

[18] see Sargent, Williams, Zha (2004)

reserves – the coefficient of M2 in Table 9 is 11.15, which is almost four times the coefficient of nonborrowed reserves from Table 6. The sensitivity of stock prices to federal funds rate remains almost the same regardless of the change in our liquidity measure. However, we see that on using t-bill rates instead of federal funds rate, the significance of contemporaneous effect of interest rate on stock prices vanishes.

The structural VAR model used in this study is over-identified. There are n(n-1)/2 equations and n(n-1)/2 + 1 unknown parameters. However, there are two unknowns that are identified outside the VAR. Thus, there are effectively n(n-1)/2 - 1 unknowns to be identified in the VAR by n(n-1)/2 equations. As an additional robustness check, instead of imposing both the external estimates, I impose just one of the parameters, and compare the SVAR estimate of the other parameter with its analogous OLS estimate. I find that the two coefficients – one from OLS and the other from SVAR are very similar. The results of this comparison are shown in Table 11.

5 Summary and Conclusion

This study develops a new identification appoach to estimate the contemporaneous responses between stock returns and nonborrowed reserves in a monthly VAR with short run restrictions. This sample used in this study covers the period from 1987-2006 when Mr. Alan Greenspan was the head of the Federal Reserve in the US. This era is popularly known as the era of the "Greenspan Put" since it was believed that the Fed's implicit tendency to support falling asset prices, by infusing liquidity was akin to owning a 'Put Option' that provided protection against downside risks. While this period received much public attention, there is little empirical evidence that documents the Federal Reserve supporting the market. Thus, the objective of this paper is to determine whether there was a contemporaneous feedback from the stock market to the Federal Reserve's stance on liquidity position. The identification strategy makes use of external instruments in a VAR model. I use as instrument, a component of the volatility index, VXO, that is published by the Chicago Board Options Exchange (CBOE) throughout the day. VXO has exhibited a strong correlation with stock returns over long time periods and hence makes a relevant instrument for stock returns, which can be used in a monetary policy rule. Thus, I am able to estimate the response of the Fed to stock prices. I also instrument for money supply to estimate the response of stock prices to market liquidity. I find a strong positive relationship between stock prices and liquidity for the sample, in support of the popular notion that as liquidity increased, so did stock prices. Moreover, the coefficient for contemporaneous stock returns in the monthly policy rule (Equation (1)), was estimated to be negative which indicates that on average, declining stock returns coincided with an increase in liquidity; a 10% drop in stock returns led to a loosening of liquidity conditions by approximately 150 basis points. I impose these estimates in a structural VAR model with short-run restrictions to estimate how stock prices react contemporaneously to a federal funds rate hike. I found a significantly negative relationship between federal funds rate and stock price index. The results indicate that the stock market reacts strongly to a federal funds rate shock; there is, on average, a decline of 107 basis points in stock prices in response to a 25 basis point tightening-shock within the same month.

It is worth mentioning here that in all of the empirical analysis carried out in this study, the underlying assumption has been that there are no common unobservables that have an influence on both, the monetary policy rule and the volatility index. As mentioned in the introduction, this study follows the literature on 'monetary shocks' and claims that the monetary policy shocks in model (3) are composed of surprise changes in the preferences of FOMC members. To the extent that these preferences are not being shaped by forces that are unobservable to the econometrician, but only by the public information that is available to stock market investors, VXO can be used to create a valid instrument. However, if this assumption is violated, VXO might not be an appropriate instrument since it might be correlated with the error term of equation (1). This leaves out some scope for future research, in that, information about preference formation can be exploited to come up with new external instruments that might be better than the one used in this study. Secondly, the ordering followed in the VAR model (3) is based on the assumption that within a month, federal funds rate is independent of nonborrowed reserves. It is assumed that the federal funds rate is determined by a mechanism other than the supply and demand dynamics in the federal funds market. This would only be true if it is assumed that within any given month, the demand for reserves is perfectly elastic for any given federal funds rate. This is essentially equivalent to saying that the demand for reserves at the discount window (borrowed reserves) is negligible each month. This implies that the discount rate is assumed to be always higher than the federal funds rate. However, to the extent that the Fed is assumed to be targeting reserves, this assumption is useful in identifying the relationships that may have been true for the given sample period. An interesting avenue for future research on similar lines would be to conduct a similar study for present times, especially the period after the financial crisis of 2008-2010. Such a study would necessitate expanding the financial block of the VAR to include contagion effects and externalities of policy decisions of other countries. The years after the financial crisis have seen the Federal reserve almost hit the zero lower bound (ZLB), and resorting to unconventional monetary policies. In such a scenario, the conventional monetary policy rules like the one used in this paper would break down as the nominal federal funds rate becomes ineffective. It would be interesting to explore new proxies for stance of monetary policy and see whether pre-ZLB and ZLB relationships are the same.

Table 2. Monthly Nonborrowed Reserves

Variables	Nonborrowed Reserves(NBR_t)
Stock returns(SR_t)	-0.0029
	(0.011)
Industrial Production(IP_t)	-0.4782*
	(0.248)
Nonfarm Payrolls(NFP_t)	-0.5094
	(1.094)
Consumer Price Index(CPI_t)	1.028
	(1.084)
Observations	232

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: This regression equation is the last but one equation of the VAR model (4). Regression includes a constant, time fixed effects, and three lags of each variable. Time fixed effects and lagged variables are not shown. Standard errors are Newey-West standard error estimates.

Table 3. Monthly growth in VXO

Variables	Volatility Index (VXO_t)
EPU_t	0.1936***
	(0.063)
EPU_{t-1}	0.1349**
	(0.066)
EPU_{t-2}	0.1519***
	(0.050)
EPU_{t-3}	0.1122**
	(0.047)
VXO_{t-1}	-0.2410***
	(0.073)
VXO_{t-2}	-0.3999***
	(0.064)
VXO_{t-3}	-0.2428***
	(0.063)
VXO_{t-4}	-0.2375***
	(0.063)
Observations	232

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Regression includes a constant, time fixed effects, and four lags of each variable. Time fixed effects and insignificant lagged variables are not shown. Standard errors are Newey-West estimates.

Table 4. First stage regression of stock returns

Variables	Monthly stock returns(SR_t)
Instrument(RI_t)	-0.3396***
	(0.050)
Federal Funds rate(FFR_t)	-0.0364**
	(0.018)
FFR_{t-1}	0.0492*
	(0.028)
SR_{t-1}	-0.3076***
	(0.061)
Industrial Production(IP_{t-3})	3.0504***
	(1.006)
Observations	232
F-test	45.47

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Standard errors are Newey-West standard error estimates. Regression includes a constant, time fixed effects, and three lags of each variable. Time fixed effects and other insignificant variables are not shown.

Table 5. Monthly nonborrowed reserves

Variables	Nonborrowed reserves(NBR_t)
Stock returns (SR_t)	-0.0762**
	(0.035)
SR_{t-2}	0.0239*
	(0.012)
NBR_{t-1}	0.7100***
	(0.140)
Federal Funds rate(FFR_{t-3})	-0.0073**
	(0.003)
Industrial Production(IP_t)	-0.5923**
	(0.255)
IP_{t-1}	0.5432**
	(0.252)
Observations	232
R-squared	0.992

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: This regression equation is the last but one equation of the VAR model (4). Standard errors are Newey-West standard error estimates. Regression includes a constant, time fixed effects, and three lags of each variable. Time fixed effects and other insignificant variables are not shown.

Table 6. Monthly stock returns

Variables	Stock returns(SR_t)
Nonborrowed reserves(NBR_t)	2.6831***
	(0.847)
Federal Funds rate(FFR_t)	-0.0414**
	(0.018)
FFR_{t-1}	0.0615*
	(0.031)
NBR_{t-1}	-2.2466**
	(0.994)
SR_{t-1}	-0.3282***
	(0.074)
SR_{t-2}	-0.2347***
	(0.077)
SR_{t-3}	-0.1272*
	(0.072)
IP_{t-3}	2.9566**
	(1.397)
Observations	232
R-squared	0.117

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: This regression equation is the last equation of the VAR model (4). Standard errors are Newey-West standard error estimates. Regression includes a constant, time fixed effects, and three lags of each variable. Time fixed effects and other insignificant variables are not shown.

Table 7. Contemporaneous effects on stock returns

Variables	Stock returns(SR_t)
Industrial Production ($-b_{61}$)	.9874
	(1.456)
Inflation ($-b_{62}$)	-8.738
	(7.116)
Unemployment($-b_{63}$)	-1.599
	(7.699)
Federal Funds rate($-b_{64}$)	-0.0426**
	(0.018)
Nonborrowed reserves(α)	2.683***
	(0.847)
Observations	232

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: This table show the contemporaneous-period effects of various variables on stock market returns, obtained from the structural VAR model (3). The estimates are obtained from an AB model setup of SVAR using 10000 repetitions.

Table 8. Monthly stock returns for subsample 1987-2000

Variable	Stock returns (SR_t)
Nonborrowed reserves (NBR_t)	5.0677***
	(1.080)
Federal Funds rate (FFR_t)	-0.0592***
	(0.020)
FFR_{t-1}	0.0584***
	(0.020)
NBR_{t-1}	-4.4506***
	(0.982)
SR_{t-1}	-0.2871***
	(0.083)
Observations	160

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: This table show the contemporaneous-period effects of various variables on stock market returns for the subsample 1987-2000. Standard errors are Newey-West estimates. Regression includes a constant, time fixed effects, and three lags of each variable. Time fixed effects and other insignificant variables are not shown.

Table 9. Monthly stock returns (SR_t)

Variables	T-bill rates	T-bill and M2	FFR and M2
NBR_t	3.0491***		
	(0.786)		
$Tbill_{t-2}$	0.0829**	0.0438	
	(0.038)	(0.030)	
NBR_{t-1}	-2.8059***		
	(0.899)		
CPI_t	-14.9588*	-9.3234	-9.0011
	(7.907)	(7.950)	(8.294)
$M2_t$		11.1488***	14.7946***
		(3.143)	(3.577)
$M2_{t-1}$		-10.2332***	-14.9999***
		(3.873)	(4.185)
FFR_t			-0.0465**
			(0.020)
FFR_{t-1}			0.0839***
			(0.029)
CPI_{t-2}			18.2424*
			(10.510)
Observations	232	232	232
R-squared	0.151	0.230	0.164

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: FFR denotes Federal Funds rate, NBR denotes Nonborrowed reserves Standard errors are Newey-West estimates. Regression includes a constant, time fixed effects, and three or four lags of each variable. All lags of stock returns were found to be significant. Those lags, time fixed effects, and other insignificant variables are not shown.

Table 10. First stage regression for Nonborrowed reserves

Variables	Nonborrowed reserves (NBR_t)
Instrument (PI_t)	0.8303***
	(0.044)
SR_{t-1}	0.0230***
	(0.005)
SR_{t-2}	0.0347***
	(0.005)
SR_{t-3}	0.0160***
	(0.005)
FFR_{t-2}	0.0045**
	(0.002)
FFR_{t-3}	-0.0053***
	(0.001)
IP_t	-0.4736***
	(0.117)
IP_{t-1}	0.5631***
	(0.105)
IP_{t-3}	-0.2426***
	(0.086)
NFP_{t-3}	-1.3547***
	(0.456)
CPI_t	1.0484**
	(0.457)
CPI_{t-1}	1.2423**
	(0.616)
CPI_{t-2}	-2.0702***
	(0.652)
Observations	232
F-test	358.74

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Standard errors are Newey-West estimates. Regression includes a constant, time fixed effects, and three lags of each variable. Time fixed effects, significant lags of NBR, and other insignificant variables are not shown.

Table 11. Monthly Stock returns

Contemporaneous Variables	OLS coefficients	SVAR coefficients
Nonborrowed Reserves	2.6831***	2.1473***
	(0.835)	(0.449)
Federal Funds rate	-0.0414**	-0.0437**
	(0.018)	(0.017)
Industrial Production	-0.2866	-0.6967
	(1.822)	(1.423)
Nonfarm Payrolls	0.8107	1.6854
	(11.602)	(7.388)
Inflation	-9.5085	-8.9033
	(7.372)	(6.857)
Observations	232	232

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Note: Standard errors are Newey-West estimates. OLS regression includes a constant, time fixed effects, and three lags of each variable. Time fixed effects and lagged variables are not shown.

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