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Stock returns and monetary policy: Are there any ties?

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ABSTRACT

This paper empirically investigates the following three questions: (i) Do stock returns respond to monetary policy shocks? (ii) Do stock returns alter the transmission mechanism of monetary policy? and (iii) Does monetary policy systematically react to stock returns? Unlike existing empirical research on these topics, we use a structural vector auto-regression that relaxes the restrictions commonly imposed in earlier studies and identify monetary policy shocks by exploiting the conditional heteroskedasticity of the structural innovations. Applying this method to US data, we find that the interaction between monetary policy and stock returns is much weaker than suggested by earlier empirical studies.

1. Introduction

This paper empirically investigates the following three questions using monthly US data: (i) Do stock returns respond to monetary policy shocks? (ii) Do stock returns alter the transmission mechanism of monetary policy? and (iii) Does monetary policy systematically react to stock returns? Using a flexible identification strategy that relaxes the commonly used identifying restrictions, we find that the interaction between monetary policy and stock returns is much weaker than suggested by earlier empirical studies.

The interdependence between asset prices and monetary policy is a central issue in financial economics, in which interest has been rekindled in light of the latest global financial crisis. Among the various aspects of this interdependence, the responsiveness of stock returns to monetary policy shocks has received relatively more attention in the empirical literature than the questions of whether stock returns matter for the conduct of monetary policy or whether they affect its propagation mechanism. Given the high relevance of the latter two questions both for academics and policy makers, this paper develops an empirical framework that allows to investigate them jointly with question (i).

Earlier research that attempted to measure the responsiveness of stock returns to monetary policy shocks generally finds that stock returns increase significantly following an unanticipated monetary policy expansion. This literature can be grouped into two strands: event studies, which rely on a narrative approach to isolate exogenous and unanticipated changes in monetary policy, and those based on estimating Structural Vector Auto-Regressions (SVAR). Event studies implicitly assume that the various shocks affecting the economy do not occur systematically on the same dates as policy announcements.

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Therefore, the effects of monetary policy shocks can be identified by aggregating over many events at different dates, even though each event may be individually contaminated by other shocks (e.g. Cook and Hahn, 1989; Kuttner, 2001; Bernanke and Kuttner, 2005).

SVAR-based studies, on the other hand, impose some exclusion restrictions that limit the interaction of economic variables in a way that is not necessarily consistent with the data. These restrictions can be of two types: those that define the policy indicator and those that determine the way in which monetary policy shocks propagate. Regarding the former, existing SVAR studies invariably define the federal funds rate as being the relevant and unique indicator of US monetary policy. As for the latter, two different schemes are found in the literature: a recursive scheme, which assumes that the federal funds rate is predetermined with respect to stock returns (e.g. Thorbecke, 1997; Patelis, 1997; Bernanke and Kuttner, 2005; and Gilchrist et al., 2009), and a simultaneous scheme, which allows for contemporaneous interactions between these two variables but which restricts their interactions with remaining economic variables (e.g. Bjørnland and Leitemo, 2009). Under the usually maintained assumption that the structural shocks are conditionally homoskedastic, none of these identification schemes is testable.

In this paper, we estimate the interdependence between stock returns and monetary policy using a methodology that relaxes the identifying assumptions commonly used in earlier studies. Instead, monetary policy shocks and their effects are identified by exploiting the conditional heteroskedasticity of the innovations to the variables included in the SVAR, as in Normandin and Phaneuf (2004) and Bouakez and Normandin (2010). The presence of conditional heteroskedasticity in the macroeconomic time series typically used in empirical work on the effects of monetary policy on stock returns has been documented by several existing studies.[1] The idea behind this approach is that time variation in the conditional volatilities of the structural innovations provides additional information that allows to identify more parameters (relative to the conventional conditionally homoskedastic case). As a result, no arbitrary restrictions need to be imposed on the contemporaneous interactions between policy instruments and the variables of interest, thus leaving unrestricted both the policy indicator and the propagation mechanism of shocks. Interestingly, the flexible system estimated in this paper nests, and hence allows to test, the various specifications proposed in existing SVAR studies. This in turn allows us to gauge the consequences of imposing counterfactual identifying restrictions and to determine the extent to which they are responsible for the established results.

We start by showing that the identifying restrictions commonly used in the literature are not supported by the data and that their implications regarding the dynamics of output and the price level are at odds with well-accepted beliefs about the effects of monetary policy shocks. For example, a surprise monetary easing implies a decline in output for the first six months after the shock and a fall in the price level over more than 24 months. In contrast, the flexible system implies that an unanticipated monetary expansion induces a positive and hump-shaped effect on output and a gradual increase of the price level, so that there is no price puzzle.

We then turn to the analysis of the relationship between stock returns and monetary policy. We find that relaxing the commonly used identifying restrictions, and especially those related to the selection of the policy indicator, yields a response of stock returns that is negative on impact but statistically insignificant at all horizons. Importantly, we show that this lack of responsiveness does not stem from aggregating individual stocks into a broad portfolio. This result is puzzling given that standard theoretical models suggest that asset prices, and thus stock returns, should increase following a monetary policy expansion, owing to an increase in firm's expected future cash flows and a decline in the rate at which those cash flows are discounted. Thus, it appears that while our agnostic methodology resolves some of the anomalies related to the response of output and the price level, it uncovers a new puzzle pertaining to the reaction of the stock market to monetary policy shocks.

Our analysis also indicates that asset prices play little role in the transmission mechanism of monetary policy. We establish this result by comparing the unrestricted responses of key macroeconomic aggregates with the responses computed by shutting down all contemporaneous and dynamic interactions between stock returns and the other variables in the system. Specifically, we find that the unrestricted responses of output, consumption, investment, and the price level are almost identical to those obtained from a system in which stock returns do not interact with any other variable. This result contrasts with the conventional wisdom that asset prices affect consumption through a wealth channel, and investment through a Tobin's Q effect (higher expected profits) and a credit channel (improvement in the firms' balance sheet).

Finally, we find little evidence that stock returns have a direct influence on US monetary policy, beyond their effects on conventional macroeconomic indicators, namely output and the price level. The parameter estimates of the monetary authority's feedback rule imply that the policy indicator is not significantly affected by current and lagged changes in stock returns. This suggests that stock returns do not carry relevant information (for monetary policy) that is not already contained in the usual macroeconomic indicators.

Our paper is closely related to the work of Rigobon and Sack (2003, 2004), who assume that the *unconditional* volatilities of the structural innovations change across pre-selected regimes.[2] Two important differences distinguish our approach from

[1] See, for example, Engle (1983), Baillie et al. (1996), Garcia and Perron (1996), Den Haan and Spear (1998), Dueker (1999), Beck (2001), Hwang (2001), Lee (2002), McQueen and Vorkink (2004), Conrad and Karanasos (2005), Demiralp and Farley (2005), Hilton (2005), Bernard et al. (2008), Grassi and Tommaso (2010), Fu (2009), Jacks et al. (2011), and Fernandez-Villaverde et al. (2011).

[2] Alternatively, the volatilities of the structural innovations may be estimated within a Markov switching framework, without pre-selecting the regimes. Lanne et al. (2010) derive the conditions under which identification can be achieved in this context. Lanne and Lütkepohl (2008) use this methodology to assess the effects of monetary policy shocks on macroeconomic aggregates.

theirs. First, in their work, the relations between stock prices and monetary policy are sequentially analyzed from two distinct definitions of regimes. On the one hand, the impact response of stock prices to a monetary policy shock is analyzed by assuming that this shock is larger on days of Federal Open Market Committee meetings and of the Chairman's semi-annual monetary policy testimony to Congress, while the variance of the stock market innovation remains constant. On the other hand, the contemporaneous effect of stock prices on the monetary policy indicator is measured by assuming that the variance of the stock market shock is larger when the 30-day rolling variances of the reduced-form residuals of the interest rate and stock returns are more than one standard deviation above their averages, whereas the monetary policy shock is homoskedastic. In contrast, our methodology allows us to assess the bidirectional relations between stock returns and monetary policy simultaneously. Second, the Rigobon-Sack definitions of the various regimes require the use of high-frequency data. This in turn impedes the analysis of the role of asset returns in the propagation mechanism of monetary policy, since data on output and the price level are not available at high frequencies. In contrast, our method can be applied to monthly data, for which measures of output and the price level exist.

This paper is organized as follows. Section 2 presents the flexible system and popular alternative specifications. Section 3 explains the empirical method to identify monetary policy shocks and estimate the system. Section 4 reports some preliminary results. Section 5 studies the interdependence between stock returns and monetary policy. Section 6 concludes.

2. Econometric framework

In this section, we present the flexible system that will be used to study the interdependence between stock returns and monetary policy. Then, we lay out the restrictions under which this system nests alternative specifications used in previous work.

2.1. Flexible system

We start with the following SVAR:

$$Az_t = \sum_{k=1}^{\tau} A_k z_{t-k} + \epsilon_t. \tag{1}$$

The vector z_t includes the variables of interest, which can be divided into three categories: the goods-market variables, the reserve variables, and the financial variables. The goods-market variables are total output, y_t, the price level, p_t, and the commodity price, cp_t. The reserve variables are the non-borrowed reserves, nbr_t, total reserves, tr_t, and the federal funds rate, ffr_t. The financial variables are the treasury bill rate, tbr_t, and stock returns, sr_t. The vector ϵ_t incorporates mutually uncorrelated structural innovations and, in particular, the monetary policy shock. The matrix $A = [a_{ij}]$ contains the parameters capturing the contemporaneous interactions among the variables. The matrices $A_k = [a_{k,ij}]$ reflect the dynamic feedbacks between these variables.

Denote by v_t the vector of residuals (or statistical innovations) obtained from a VAR process in which the vector z_t is projected on its own lags. These residuals are linked to the structural innovations through

$$Av_t = \epsilon_t. \tag{2}$$

Extracting the structural shocks from the residuals requires knowledge of the matrix A. As is well known, however, under conditional homoskedasticity of the structural shocks, projecting z_t on its own lags does not provide sufficient information to identify all the elements of A, such that some restrictions must be imposed. As discussed below, our empirical methodology relaxes the assumption that the structural shocks are conditionally homoskedastic, so that no restrictions need to be imposed to identify monetary policy shocks and their effects.

Nonetheless, our empirical approach places a minimal set of cross-equation restrictions to ensure that the estimated system is a coherent framework for the analysis of monetary policy. More explicitly, we consider the following simple formulation of the reserve market (Bernanke and Mihov, 1998):

$$v_{nbr,t} = \phi_d \sigma_d \epsilon_{d,t} - \phi_b \sigma_b \epsilon_{b,t} + \sigma_s \epsilon_{s,t}, \tag{3.1}$$
$$v_{tr,t} = -\alpha v_{ffr,t} + \sigma_d \epsilon_{d,t}, \tag{3.2}$$
$$(v_{tr,t} - v_{nbr,t}) = \beta v_{ffr,t} - \sigma_b \epsilon_{b,t}. \tag{3.3}$$

The structural innovation $\epsilon_{s,t}$ is the monetary policy shock representing an unexpected exogenous policy action taken by the Federal Reserve, while $\epsilon_{d,t}$ and $\epsilon_{b,t}$ denote, respectively, shocks to demand for total reserves and to the supply of borrowed reserves by commercial banks. The parameters σ_s, σ_d, and σ_b are the standard deviations scaling the structural innovations of interest, ϕ_d and ϕ_b are unrestricted parameters, and α and β are positive parameters. Eq. (3.1) describes the procedure that may be used by the Federal Reserve to select its monetary policy instruments. Eq. (3.2) represents the banks' demand for total reserves in innovation form. Eq. (3.3) is the banks' supply of borrowed reserves in innovation form, under the assumption of a zero discount-rate innovation.

Inserting the equilibrium solution of the reserve-market formulation (3) in the SVAR (1) yields:

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} & a_{17} & a_{18} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} & a_{26} & a_{27} & a_{28} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} & a_{36} & a_{37} & a_{38} \\ a_{41} & a_{42} & a_{43} & \frac{1+\phi_b}{\sigma_s} & -\frac{\phi_d+\phi_b}{\sigma_s} & \frac{\beta\phi_b-\alpha\phi_d}{\sigma_s} & a_{47} & a_{48} \\ a_{51} & a_{52} & a_{53} & 0 & \frac{1}{\sigma_d} & \frac{\alpha}{\sigma_d} & a_{57} & a_{58} \\ a_{61} & a_{62} & a_{63} & \frac{1}{\sigma_b} & -\frac{1}{\sigma_b} & \frac{\beta}{\sigma_b} & a_{67} & a_{68} \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & a_{77} & a_{78} \\ a_{81} & a_{82} & a_{83} & a_{84} & a_{85} & a_{86} & a_{87} & a_{88} \end{pmatrix} \begin{pmatrix} v_{y,t} \\ v_{p,t} \\ v_{cp,t} \\ v_{nbr,t} \\ v_{tr,t} \\ v_{ffr,t} \\ v_{tbr,t} \\ v_{sr,t} \end{pmatrix} = \begin{pmatrix} \epsilon_{1,t} \\ \epsilon_{2,t} \\ \epsilon_{3,t} \\ \epsilon_{s,t} \\ \epsilon_{d,t} \\ \epsilon_{b,t} \\ \epsilon_{7,t} \\ \epsilon_{8,t} \end{pmatrix}, \quad (4)$$

where the elements a_{ij} ($i,j = 1, \ldots, 8$) are unconstrained parameters.

System (4) is flexible in the sense that it allows, among other things, for a rich specification of the monetary authority's feedback rule. This can be seen by rewriting the fourth equation as:

$$v_{s,t} = \rho_{41} v_{y,t} + \rho_{42} v_{p,t} + \rho_{43} v_{cp,t} + \rho_{47} v_{tbr,t} + \rho_{48} v_{sr,t} + \sigma_s \epsilon_{s,t}. \quad (5)$$

The term $v_{s,t} = [(1 + \phi_b)v_{nbr,t} - (\phi_d + \phi_b)v_{tr,t} + (\beta\phi_b - \alpha\phi_d)v_{ffr,t}]$ measures the statistical innovation of the monetary policy indicator. This indicator is expressed as a linear combination of the reserve variables, reflecting the notion that the Federal Reserve might be adopting a mixed procedure whereby it targets neither the interest rate nor a monetary aggregate exclusively. The coefficients $\rho_{4j} = -a_{4j}\sigma_s$ (for $j = 1, 2, 3, 7, 8$) capture the systematic responses of the Federal Reserve to changes in the non-reserve variables. More precisely, the feedback rule implies that the Federal Reserve designs its policy by taking into account current values of all goods-market and financial variables.

System (4) is also flexible because it leaves unrestricted the contemporaneous interactions between the terms within and across the blocks of goods-market, reserve, and financial variables. These simultaneous effects imply that all variables may be contemporaneously affected by all the structural innovations and, in particular, by monetary policy shocks. Hence, system (4) allows one to capture potential interdependences between stock returns and the monetary policy indicator.

The first interdependence that we focus on is the reaction of stock returns to monetary policy. Specifically, we verify the common view that asset prices immediately increase following an expansionary monetary policy shock. The underlying intuition is that a monetary easing should raise the expected present value of dividends through its positive effect on current and future output and through its negative effect on the rate used to discount firms' future cash flows (see Patelis, 1997).

The second interdependence of interest is the role of stock returns in the propagation of monetary policy on output and the price level. In theory, asset returns play a role in the transmission of monetary policy through some components of aggregate expenditures. In particular, an unexpected expansionary monetary policy should lead to a rise in private consumption expenditures due to a positive wealth effect that arises from the increase in stock returns (e.g. Poterba, 2000). Such a policy should also lead to a rise in investement expenditures owing to the increase in the shadow price of capital, i.e. Tobin's Q (e.g. Hayashi, 1982), and to a financial accelerator effect associated with the increase of entrepreneurs' net worth (see Bernanke and Gertler, 1989).

The last interdependence that we analyze is the influence of stock returns on the orientation of the Federal Reserve's policy. Several arguments may be invoked to suggest that asset prices should be taken into account by Central Banks when they design their policies. For example, this should be the case if the monetary authority seeks to stabilize a broad measure of the cost of living that includes not only current prices of consumer goods but also those expected in the future, which, under certain conditions, can be proxied by current asset prices (e.g. Alchian and Klein, 1973). Perhaps more concretely, current stock prices may represent a good predictor of future inflation if the effects of monetary policy are first manifested in movements in asset prices and later on in changes in the prices of consumer goods (e.g. Gilchrist and Leahey, 2002). It may also be the case that the policy makers respond proactively to perceived misalignments in asset prices that could form bubbles, in order to successfully stabilize inflation and output (e.g. Cecchetti et al., 2000). Finally, the monetary authority may instead follow a reactive approach, which consists in reacting to current asset price movements only to the extent that they affect expected inflation (e.g. Bernanke and Gertler, 1999; Bernanke and Gertler, 2001).

2.2. Alternative systems

We now show how system (4) nests alternative specifications that closely resemble those used in existing studies. The alternative cases include a recursive system, labeled *R*, and a simultaneous system, labeled *S*. The detailed specifications of these systems are described below.

System R

The recursive system, *R*, is specified as:

$$\begin{pmatrix} \tilde{a}_{11} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \tilde{a}_{21} & \tilde{a}_{22} & 0 & 0 & 0 & 0 & 0 & 0 \\ \tilde{a}_{31} & \tilde{a}_{32} & \tilde{a}_{33} & 0 & 0 & 0 & 0 & 0 \\ \tilde{a}_{41} & \tilde{a}_{42} & \tilde{a}_{43} & \tilde{a}_{44} & 0 & 0 & 0 & 0 \\ \tilde{a}_{51} & \tilde{a}_{52} & \tilde{a}_{53} & \tilde{a}_{54} & \tilde{a}_{55} & 0 & 0 & 0 \\ \tilde{a}_{61} & \tilde{a}_{62} & \tilde{a}_{63} & \tilde{a}_{64} & \tilde{a}_{65} & \tilde{a}_{66} & 0 & 0 \\ \tilde{a}_{71} & \tilde{a}_{72} & \tilde{a}_{73} & \tilde{a}_{74} & \tilde{a}_{75} & \tilde{a}_{76} & \tilde{a}_{77} & 0 \\ \tilde{a}_{81} & \tilde{a}_{82} & \tilde{a}_{83} & \tilde{a}_{84} & \tilde{a}_{85} & \tilde{a}_{86} & \tilde{a}_{87} & \tilde{a}_{88} \end{pmatrix} \begin{pmatrix} v_{y,t} \\ v_{p,t} \\ v_{cp,t} \\ v_{ffr,t} \\ v_{tr,t} \\ v_{nbr,t} \\ v_{tbr,t} \\ v_{sr,t} \end{pmatrix} = \begin{pmatrix} \tilde{\epsilon}_{1,t} \\ \tilde{\epsilon}_{2,t} \\ \tilde{\epsilon}_{3,t} \\ \tilde{\epsilon}_{s,t} \\ \tilde{\epsilon}_{5,t} \\ \tilde{\epsilon}_{6,t} \\ \tilde{\epsilon}_{7,t} \\ \tilde{\epsilon}_{8,t} \end{pmatrix}. \tag{6}$$

This system, which is identical to the one used by Thorbecke (1997), assumes a specific feedback rule whereby the monetary policy indicator corresponds to the federal funds rate, and the Federal Reserve contemporaneously responds to the goods-market variables, but not to the financial variables. This feedback rule is nested in (5) under the restrictions $\phi_d = 1$, $\phi_b = -1$, and $a_{47} = a_{48} = 0$. To complete identification, the recursive system (6) places 24 additional exclusion restrictions, which are listed in Table 5. These restrictions are required to identify the system under the assumption that the structural innovations are conditionally homoskedastic. These restrictions affect the propagation mechanism of monetary policy shocks. In particular, the goods-market variables do not contemporaneously respond to these shocks, whereas the reserve and financial variables do.

In our case, system *R* limits the analysis of the interactions between stock returns and monetary policy. That is, although this specification admits an impact response of stock returns to monetary policy shocks, the ad hoc restrictions involved in *R* imply that stock returns do not influence contemporaneously the monetary policy indicator or its transmission mechanism.[3]

System S

The simultaneous system, *S*, takes the form:

$$\begin{pmatrix} \tilde{a}_{11} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \tilde{a}_{21} & \tilde{a}_{22} & 0 & 0 & 0 & 0 & 0 & 0 \\ \tilde{a}_{31} & \tilde{a}_{32} & \tilde{a}_{33} & 0 & 0 & 0 & 0 & 0 \\ \tilde{a}_{41} & \tilde{a}_{42} & \tilde{a}_{43} & \tilde{a}_{44} & \tilde{a}_{45} & 0 & 0 & 0 \\ \tilde{a}_{51} & \tilde{a}_{52} & \tilde{a}_{53} & \tilde{a}_{54} & \tilde{a}_{55} & 0 & 0 & 0 \\ \tilde{a}_{61} & \tilde{a}_{62} & \tilde{a}_{63} & \tilde{a}_{64} & \tilde{a}_{65} & \tilde{a}_{66} & 0 & 0 \\ \tilde{a}_{71} & \tilde{a}_{72} & \tilde{a}_{73} & \tilde{a}_{74} & \tilde{a}_{75} & \tilde{a}_{76} & \tilde{a}_{77} & 0 \\ \tilde{a}_{81} & \tilde{a}_{82} & \tilde{a}_{83} & \tilde{a}_{84} & \tilde{a}_{85} & \tilde{a}_{86} & \tilde{a}_{87} & \tilde{a}_{88} \end{pmatrix} \begin{pmatrix} v_{y,t} \\ v_{p,t} \\ v_{cp,t} \\ v_{sr,t} \\ v_{ffr,t} \\ v_{tr,t} \\ v_{nbr,t} \\ v_{tbr,t} \end{pmatrix} = \begin{pmatrix} \tilde{\epsilon}_{1,t} \\ \tilde{\epsilon}_{2,t} \\ \tilde{\epsilon}_{3,t} \\ \tilde{\epsilon}_{4,t} \\ \tilde{\epsilon}_{s,t} \\ \tilde{\epsilon}_{6,t} \\ \tilde{\epsilon}_{7,t} \\ \tilde{\epsilon}_{8,t} \end{pmatrix}. \tag{7}$$

As system *R*, the specification above implies that the monetary policy indicator corresponds to the federal funds rate, that the monetary authority does not react to current changes in the treasury bill rate, and that the goods-market variables do not respond contemporaneously to monetary policy shocks. Unlike *R*, however, *S* allows for simultaneous short-run interactions between the federal funds rate and stock returns, while imposing that monetary policy shocks have no long-run effect on real stock prices. Specifically, the cumulative responses of real stock returns are forced to be nil through the long-run restriction $b_{84} = 0$, where $B = [b_{ij}] = \left[I - A^{-1}\sum_{k=1}^{\tau} A_k\right]^{-1} A^{-1}$.

System (7) is obtained from (4) by imposing the restrictions $\phi_d = 1$, $\phi_b = -1$, and $a_{47} = 0$ on the feedback rule, the long-run restriction $b_{84} = 0$, as well as 24 additional exclusion restrictions on the short-run effects of the structural innovations to complete identification. In contrast to the recursive system, specification *S* permits to evaluate whether the conduct of monetary policy is influenced by current movements in stock returns. System (7) is closely related to that estimated by Bjørnland and Leitemo (2009), who, however, only focus on the first five variables involved in (7).

In sum, the recursive and simultaneous systems commonly used in the literature impose that the policy indicator is the federal funds rate, but rely on different assumptions regarding the information available to the Federal Reserve as well as the propagation mechanism of the structural innovations, and in particular, monetary policy shocks. In both cases, these assumptions are not testable under conditional homoskedasticity.

[3] We also considered the alternative recursive system $\tilde{A}\tilde{v}_t = \tilde{\epsilon}_t$ where the monetary policy indicator corresponds to the federal funds rate, $\tilde{A}$ is lower triangular when the VAR residuals are ordered as $(v_{ffr,t} \quad v_{y,t} \quad v_{p,t} \quad v_{cp,t} \quad v_{tr,t} \quad v_{nbr,t} \quad v_{tbr,t} \quad v_{sr,t})'$. This system is similar to the ones estimated by Sims (1992), Patelis (1997), and Bernanke and Kuttner (2005). Given that the results for stock returns are very similar than those obtained from system (6), we only report those computed from the later system.

3. Methodology

This section explains the conditions under which the flexible and alternative systems are identified. We also describe the empirical strategy and the data used to estimate each system.

3.1. Identification

Under conditional heteroskedasticity of the structural innovations, the flexible system (4), and in particular, monetary policy shocks and their effects on the various variables can be identified (see Sentana and Fiorentini, 2001). The sufficient (rank) condition for identification states that the conditional variances of the structural innovations are linearly independent. That is, $\lambda = 0$ is the only solution to $\Gamma\lambda = 0$, such that $(\Gamma'\Gamma)$ is invertible—where Γ stacks by column the conditional volatilities (for $t = (\tau + 1), \ldots, T$) associated with each structural innovation. The necessary (order) condition requires that the conditional variances of (at least) all, but one, structural innovations are time-varying.[4].

Under conditional homoskedasticity, $\frac{n(n-1)}{2}$ arbitrary restrictions need to be imposed on the elements of A in order to achieve identification. This is why each alternative system places a total of 28 restrictions, given that for specifications R and S the conventional assumption of conditional homoskedasticity of the structural innovations is systematically invoked. As stated above, these restrictions are not dictated by the data, but rather reflect the econometrician's judgement about the monetary policy indicator and its transmission mechanism.

3.2. Estimation strategy and data

The flexible and alternative systems are estimated using a two-step procedure. The first step extracts the estimates of the statistical innovations v_t, for $t = (\tau + 1), \ldots, T$. To do so, we apply the ordinary least squares (OLS) to τ-order VAR processes. For the flexible and recursive systems, the VAR include the levels of output, the price index, the commodity price, non-borrowed reserves, total reserves, as well as nominal returns on the federal funds, treasury bills, and stocks. Note that the OLS estimates are super-consistent when the VAR involves variables in levels which are first-order integrated, whether the residuals are conditionally homoskedastic or display time-varying conditional volatility (see Banerjee et al. (1994), condition (16b), p. 87, and p. 146.)

For the simultaneous system, S, there are two distinctions that are in line with the empirical analysis of Bjørnland and Leitemo (2009). First, the VAR includes the changes of output, price index, commodity price, non-borrowed reserves, and total reserves—rather than their levels—which, in the absence of cointegration relation between these variables, are the appropriate transformations to implement the long-run restriction reflecting the neutrality of monetary policy.[5]Second, the VAR involves real rather than nominal stock returns. This makes easier to implement the long-run neutrality of monetary policy on real stock prices.

The second step consists in estimating the SVAR parameters as well as those of the conditional heteroskedastic processes. For this purpose, we specify the dynamics of the conditional variances of the structural innovations as:

$$\Gamma_t = (I - \Delta_1 - \Delta_2) + \Delta_1 \bullet \left(\epsilon_{t-1}\epsilon_{t-1}'\right) + \Delta_2 \bullet \Gamma_{t-1}, \tag{8}$$

where $\Gamma_t = E_{t-1}(\epsilon_t \epsilon_t')$ is the diagonal conditional covariance matrix of the structural innovations, Δ_1 and Δ_2 are diagonal matrices of parameters, and the operator $\bullet$ denotes the element-by-element matrix multiplication. Eq. (8) involves intercepts that are consistent with the normalization $I = E(\epsilon_t \epsilon_t')$. It also implies that all the structural innovations are conditionally homoskedastic if Δ_1 and Δ_2 are null. On the other hand, some structural innovations display time-varying conditional variances characterized by univariate generalized autoregressive conditional heteroskedastic [GARCH(1, 1)] processes if Δ_1 and Δ_2—which contain the ARCH and GARCH coefficients, respectively—are positive semi-definite and $(I - \Delta_1 - \Delta_2)$ is positive definite. Furthermore, all the conditional variances follow GARCH(1, 1) processes if Δ_1, Δ_2, and $(I - \Delta_1 - \Delta_2)$ are positive definite.

For the flexible system, we estimate the (non-zero) elements of the matrices A, Δ_1, and Δ_2 by maximum likelihood (ML). This method assumes that the statistical innovations are conditionally normally distributed. In this context, the empirical likelihood function is constructed from the estimates of the statistical innovations, obtained in the first step, and the estimates of the conditional covariance matrix $\Sigma_t = E_{t-1}(v_t v_t')$. This matrix is computed recursively, for given values of the elements of A, Δ_1, and Δ_2, by exploiting (2), which implies $\Sigma_t = A^{-1}\Gamma_t A^{-1\,\prime}$, and (8) and the initialization $\Gamma_\tau = (\epsilon_\tau \epsilon_\tau') = I$. For the alternative systems, we estimate the elements of A, but set $\Delta_1 = \Delta_2 = 0$ to impose the standard assumption that the structural innovations are conditionally homoskedastic.

Our empirical analysis is based on monthly US data covering the 1982:11–2007:11 period. As is common practice, the starting date of the sample is selected so as to avoid the atypical Federal Reserve operating procedures pursued under the 1979:10–1982:10 episode, where little effort, if any, went into stabilizing either the federal funds rate or the borrowed reserves (see Strongin, 1995). The series used in the analysis are constructed as follows: y_t is measured by the industrial-pro-

[4] For a discussion of the intuition underlying identification through conditional heteroskedasticity, see Bouakez and Normandin (2010)

[5] Applying Johansen's trace and maximum eigenvalue tests indicates that there is no cointegration relation among these variables.

Table 1
Ljung-Box tests.

Lags	$v_{y,t}$	Lags	$v_{tr,t}$
1	0.752	1	0.616
3	0.693	3	0.583
6	0.917	6	0.544
12	0.519	12	0.492
18	0.362	18	0.478
Lags	$v_{p,t}$	Lags	$v_{ffr,t}$
1	0.796	1	0.854
3	0.979	3	0.591
6	0.955	6	0.476
12	0.529	12	0.253
18	0.341	18	0.479
Lags	$v_{cp,t}$	Lags	$v_{tbr,t}$
1	0.784	1	0.957
3	0.968	3	0.643
6	0.999	6	0.963
12	0.997	12	0.294
18	0.989	18	0.260
Lags	$v_{nbr,t}$	Lags	$v_{sr,t}$
1	0.536	1	0.698
3	0.661	3	0.979
6	0.723	6	0.994
12	0.425	12	0.971
18	0.417	18	0.842

Notes: Entries are the *p*-values associated with the χ^2-distributed Ljung-Box test statistic applied to the VAR residuals. $v_{y,t}$, $v_{p,t}$, $v_{cp,t}$, $v_{nbr,t}$, $v_{tr,t}$, $v_{ffr,t}$, $v_{tbr,t}$, and $v_{sr,t}$ represent the residuals associated with output, the price level, the commodity price, non-borrowed reserves, total reserves, the federal funds rate, the treasury bill rate, and stock returns. The sample period is 1982:11–2007:11.

duction index; p_t is the all-item, all-urban-consumer, price index; cp_t is the world-export commodity-price index; nbr_t denotes the non-borrowed reserves; tr_t denotes the total reserves adjusted for changes in reserve requirements; ffr_t is the nominal rate on the federal funds; tbr_t is the nominal rate on the one-month treasury bills; and sr_t is the nominal value-weighted return (including dividends) associated with the global index of the NYSE, NASDAQ, and AMEX markets.[6] All data are seasonally adjusted and expressed in logarithms, except for the federal funds rate, treasury bill rate, and stock returns. Throughout the analysis, we include six lags ($\tau = 6$) in the flexible and alternative systems, in accordance with standard practice.

4. Preliminary diagnostics and estimation results

The objective of our preliminary analysis is threefold. First, we perform several tests to assess the appropriateness of our empirical specification and to detect the presence of conditional heteroskedasticity, which is central for the identification of the flexible system. Second, we perform a statistical test of the parametric restrictions used to identify the alternative specifications. Third, we check whether the flexible system yields plausible estimates of the dynamic effects of monetary policy shocks, and compare the results to those obtained from the alternative systems.

4.1. Test results and parameter estimates

We start by performing a Ljung-Box test to determine whether the statistical residuals of the estimated VAR associated with (1) display any serial correlation. The results, shown in Table 1, indicate that the null hypothesis of no serial correlation cannot be rejected at any conventional level of significance, which confirms the appropriateness of our VAR(6). Next, we conduct a preliminary analysis to document the presence of conditional heteroskedasticity in the series used in estimation. This analysis is performed by applying the multivariate ARCH test proposed by Fiorentini and Sentana (2009) to the statistical residuals obtained from the VAR. The test is applied both to the diagonal and off-diagonal elements of the matrices of the ARCH coefficients at a given lag.[7] Empirically, the test results confirm the presence of cross-correlation in the squared statistical

[6] The series y_t, nbr_t, tr_t, and ffr_t are released by the Federal Reserve Board of Governors, tbr_t and sr_t are taken from the Center for Research in Security Prices, while p_t and cp_t are collected from the US Bureau of Labor Statistics and the International Financial Statistics.

[7] This is a Lagrange multiplier (or score) test of serial correlation in the squares of statistical residuals. The χ^2-distributed test statistics involve the sample autocovariances of the squares and cross-products of the estimated statistical innovations, as well as weighting matrices reflecting the unobservability of these innovations. Intuitively, this Lagrange multiplier test can be interpreted as a test based on the orthogonality conditions: $E[(v_t v_t' - \Sigma)(v_t v_{t-k}' - \Sigma)] = 0$, where $\Sigma = E(v_t v_t')$ and k is a given lag.

Table 2
Multivariate ARCH tests.

Lags	VAR residuals	Lags	Structural shocks
1	0.000	1	0.000
3	0.000	3	0.000
6	0.000	6	0.000
12	0.000	12	0.000
18	0.000	18	0.000

Notes: Entries are *p*-values of the χ^2-distributed Lagrange multiplier test statistics. The sample period is 1982:11–2007:11.

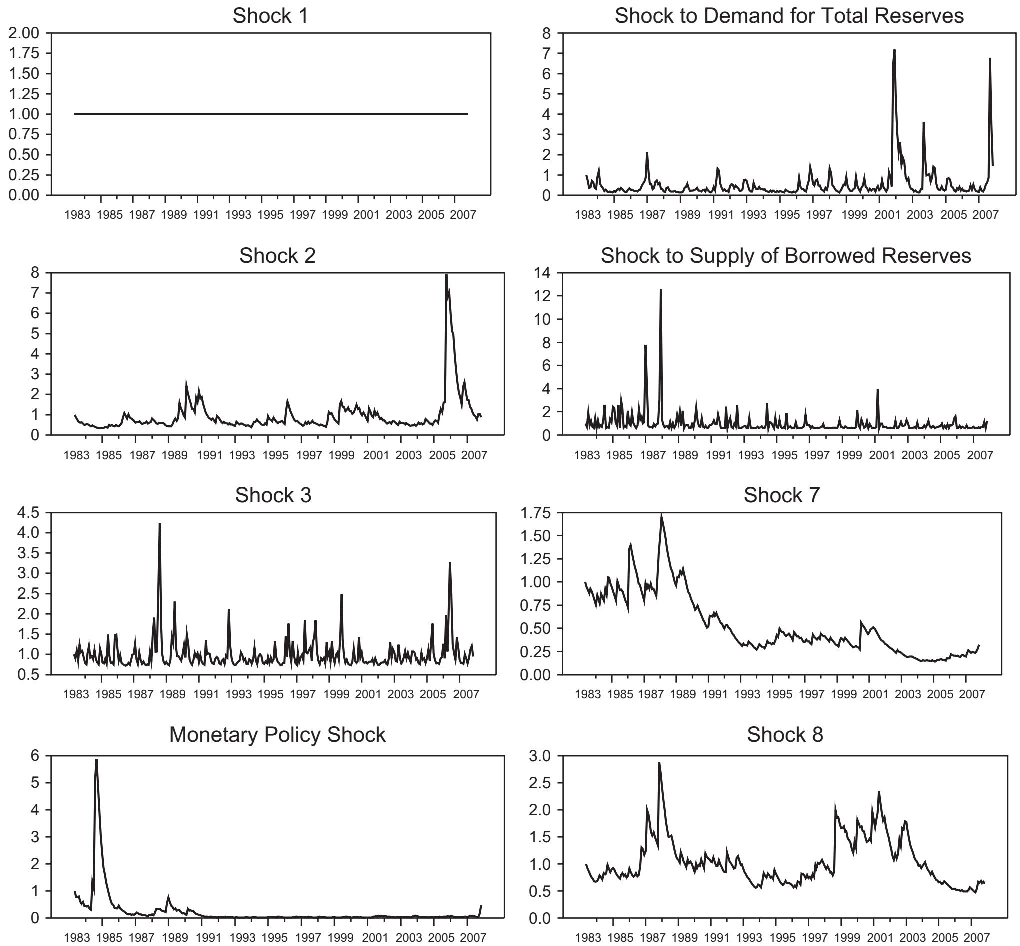

Fig. 1. Conditional variances of the structural shocks. *Notes*: The solid lines correspond to the conditional variances of the structural shocks recovered from the flexible system (4). Shock *i* represents the structural innovation associated with the *i*th equation of the flexible system. The sample period is 1982:11–2007:11.

residuals at several lags (see Table 2). Importantly, the rejection of the null hypothesis that the ARCH coefficients are jointly insignificant suggests the presence of conditional heteroskedasticity in the statistical innovations, which is likely to reflect time-varying conditional variances of the structural shocks.

Fig. 1 displays the conditional variances of the structural shocks extracted from the flexible system. Although there is one structural shock that is characterized by a constant conditional variance, the remaining shocks, including the monetary policy shock, exhibit significant conditional heteroskedasticity, characterized by alternating episodes of high and low conditional volatility. This suggests that the order condition for identification is satisfied, given that all but one structural shocks are conditionally heteroskedastic. Interestingly, these findings corroborate the results of earlier work documenting time-varying conditional volatility in many of the time series used in our analysis. Specifically, conditional heteroskedasticity has been detected in the series of inflation (Engle, 1983; Baillie et al., 1996; Hwang, 2001; Conrad and Karanasos, 2005; Grassi and Tommaso, 2010), commodity prices (Beck, 2001; Bernard et al., 2008; Jacks et al., 2011), the federal funds rate

(Dueker, 1999; Lee, 2002; Demiralp and Farley, 2005; Hilton, 2005), interest rates (Garcia and Perron, 1996; Den Haan and Spear, 1998; Fernandez-Villaverde et al., 2011), and stock returns (McQueen and Vorkink, 2004; Fu, 2009).

Table 2 also reports the results of the Fiorentini-Sentana multivariate ARCH test to verify the presence of conditional heteroskedasticity in the structural shocks. Note that the test is applied only to the diagonal elements of the matrices of the ARCH coefficients at a given lag, since the structural shocks are orthogonal. The test is performed for many lags, given that an ARCH process with a sufficiently high order represents a good approximation of a GARCH process. However, our application focuses on the structural shocks extracted from system R, rather than those computed from the flexible system. The reason is that the joint significance of the ARCH coefficients of the structural shocks cannot be tested in the latter case, because conventional critical values are invalid under the null hypothesis of conditional homoskedasticity (given that system (4) becomes under-identified). Empirically, the test results indicate that the null hypothesis that the ARCH coefficients are jointly equal to zero at lags 1, 3, 6, 12, and 18 is always overwhelmingly rejected by the data. This suggests that the conditional variances of the structural shocks are time-varying.

Table 3 presents the McLeod-Li test results to determine whether the GARCH(1, 1) specification provides an adequate description of the process that governs the conditional variances of the structural shocks associated with the flexible system. This test verifies whether there is any autocorrelation in the ratio of the squared structural shocks relative to their conditional variances. We find that the null hypothesis of no autocorrelation cannot be rejected at any conventional level of significance for 1, 3, 6, 12 and 18 lags. This suggests that the GARCH(1, 1) process is well specified.

Turning to the estimation results, Table 4 presents the estimates of the reserve-market parameters of the flexible system. The estimates of ϕ_d and ϕ_b reveal that the Federal Reserve offsets almost entirely shocks to demand for total reserves, but accommodates only modestly shocks to the supply of borrowed reserves. The estimates of the slope of the demand for total reserves, $-\alpha$, and that of the supply of borrowed reserves, β, display the predicted signs, but are imprecise.

Next, we test the validity of the restrictions imposed in the flexible and alternative systems using Wald tests. Table 5 shows the results. For the flexible system, recall that evaluating the reserve-market specification (3) at equilibrium imposes the linear restrictions $a_{54} = 0$ and $a_{64} = -a_{65}$. These restrictions are never rejected either jointly or individually at any conventional level of significance, thus suggesting that the flexible system provides an empirically plausible description of the reserve market. In contrast, the joint identifying restrictions associated with the alternative systems R and S are overwhelmingly rejected. In particular, the data do not support the hypothesis that the federal funds rate is the single and unique target for US monetary policy over the sample period. It should be emphasized that this result does not necessarily

Table 3
McLeod-Li tests.

Lags	$\epsilon^2_{1,t}$	Lags	$\epsilon^2_{d,t}$
1	0.183	1	0.829
3	0.230	3	0.909
6	0.465	6	0.962
12	0.709	12	0.997
18	0.712	18	0.998
Lags	$\epsilon^2_{2,t}$	Lags	$\epsilon^2_{b,t}$
1	0.862	1	0.639
3	0.886	3	0.846
6	0.487	6	0.601
12	0.831	12	0.325
18	0.972	18	0.131
Lags	$\epsilon^2_{3,t}$	Lags	$\epsilon^2_{7,t}$
1	0.758	1	0.944
3	0.899	3	0.942
6	0.975	6	0.907
12	0.926	12	0.754
18	0.978	18	0.425
Lags	$\epsilon^2_{s,t}$	Lags	$\epsilon^2_{8,t}$
1	0.202	1	0.749
3	0.233	3	0.879
6	0.255	6	0.993
12	0.262	12	0.765
18	0.633	18	0.432

Notes: Entries are the p-values associated with the χ^2-distributed McLeod-Li test statistic applied to the squared structural shocks relative to their conditional variances. $\epsilon_{s,t}$ is the monetary policy shock, $\epsilon_{d,t}$ is the shock to demand for total reserves, $\epsilon_{b,t}$ is the shock to the supply of borrowed reseves, and $\epsilon_{i,t}$ represents the structural innovation associated with the ith equation of the flexible system (4). The sample period is 1982:11–2007:11.

Table 4
Estimates: reserve-market parameters.

α	0.062 (0.079)	σ_s	0.025 (0.017)
β	5.089 (2.847)	σ_d	0.022 (0.013)
ϕ_d	0.922 (0.028)	σ_b	0.073 (0.044)
ϕ_b	0.014 (0.017)		

Notes: Entries are estimates of the structural parameters of the reserve market for the flexible system (4). Numbers in parentheses are standard errors. The sample period is 1982:11–2007:11.

Table 5
Test results: identifying restrictions.

Restrictions	Simultaneous:		Recursive: R
	Flexible	S	
Reserve market	0.461	–	–
$a_{54} = 0$	0.850	–	–
$a_{64} = -a_{65}$	0.217	–	–
Feedback rule	–	0.000	0.000
Monetary indicator	–	0.000	0.000
Systematic component	–	0.295	0.576
Others	–	0.000	0.000
Short run	–	0.001	0.000
Long run	–	0.227	–
Conditional homoskedasticity	–	0.000	0.000
Joint	–	0.000	0.000

Notes: Entries are the *p*-values of the χ^2-distributed Wald test statistics. For the flexible case (4), the reserve-market restrictions are tested from the estimates of the associated unconstrained system. For the alternative cases (6) and (7), the various sets of restrictions are tested from the estimates of the flexible system. Specifically, the restrictions associated with the monetary indicators are $\phi_d = 1$ and $\phi_b = -1$ for systems S and R. The restrictions related to the systematic components of the monetary authority's feedback rule are $a_{47} = 0$ for S, and $a_{47} = a_{48} = 0$ for R. The other short-run restrictions are $a_{12} = a_{13} = a_{14} = a_{15} = a_{16} = a_{17} = -$ $_{12} = a_{13} = a_{14} = a_{15} = a_{16} = a_{17} = a_{18} = a_{23} =$ $a_{24} = a_{25} = a_{26} = a_{27} = a_{28} = a_{34} = a_{35} = a_{36} =$ $a_{37} = a_{38} = a_{54} = a_{57} = -$ $_{37} = a_{38} = a_{54} = a_{57} = a_{67} = a_{84} = a_{85} = a_{87} = 0$ for S, and $a_{12} = a_{13} = a_{14} = a_{15} = a_{16} = a_{17} = a_{18} = a_{23} = a_{24} = a_{25} = a_{26} = a_{27} = a_{28} = a_{34} = a_{35} = a_{36} = a_{37} = a_{38} = a_{54} = a_{57} =$ $a_{58} = a_{67} = a_{68} = a_{78} = 0$ for R. The long-run restriction is $b_{84} = 0$ for S, where $B = [b_{ij}] = \left[I - A^{-1}\sum_{k=1}^{\tau} A_k\right]^{-1} A^{-1}$. The restrictions that the structural innovations are conditionally homoskedastic are $\Delta_1 = \Delta_2 = 0$ for the alternative systems. The sample period is 1982:11–2007:11.

contradict the fact that the Federal Reserve announced explicit targets for the federal funds rate during the largest part of the sample period. It rather suggests that the monetary authority may also have had implicit targets for borrowed and non-borrowed reserves, such that the relevant policy indicator is a combination of all these policy variables. Note also that the data soundly reject the additional short-run restrictions required to complete identification as well as the assumption that the conditional variances of the structural innovations are constant.

4.2. Dynamic responses of selected variables

We now turn to the analysis of the dynamic effects of US monetary policy shocks on output, the price level, and the nominal interest rates. The aim of this exercise is to demonstrate that our approach yields sensible results regarding the effects of monetary policy on US economic activity.

Fig. 2 depicts the dynamic responses of selected variables following a positive, one unconditional standard deviation, monetary policy shock. The flexible system yields an output response that is positive and hump shaped, reaching its peak around 15 months after the monetary policy shock. The price level exhibits a fairly muted response in the first months, but eventually increases to reach a plateau. The federal funds rate declines during the first five months, before returning to its pre-shock level. The response of the treasury bill rate is similar in shape to that of the federal funds rate, except that the impact response is slightly positive. Note that the responses of the federal funds and treasury bill rates are indicative of a short-lived liquidity effect, which lends support to the so-called vanishing-liquidity-effect hypothesis, according to which the fall in interest rates following an unexpected monetary expansion has become smaller in the post-1982 period (e.g. Christiano, 1995; Pagan and Robertson, 1995). In sum, the responses of output and the price level generated by the flexible

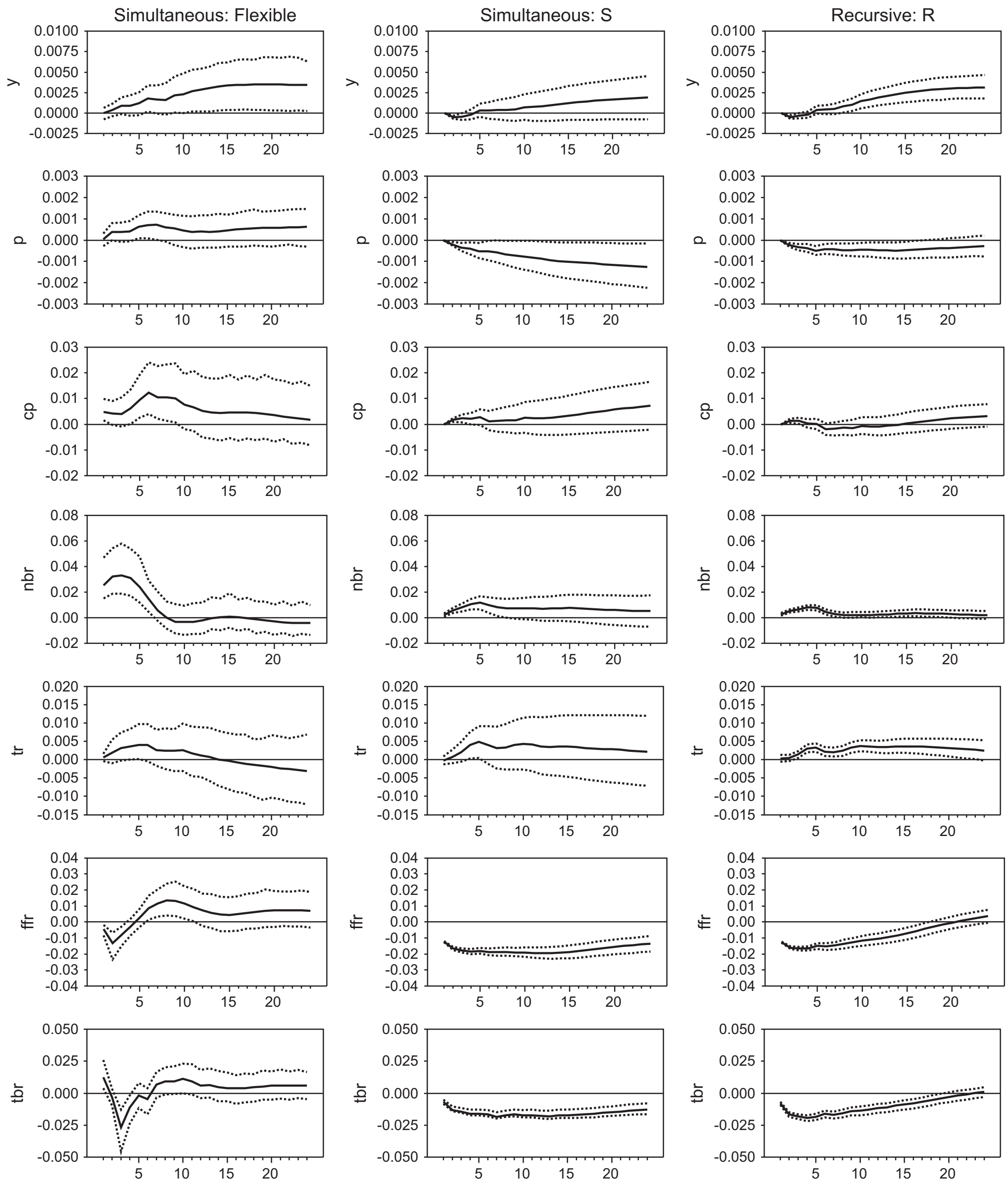

Fig. 2. Responses: selected variables. *Notes*: The solid lines correspond to the dynamic responses of selected variables to an expansionary monetary policy shock extracted from the various systems. The dotted lines are the 68% confidence intervals computed using the Sims and Zha (1999) Bayesian procedure. y_t is output, p_t is the price level, cp_t is the commodity price, nbr_t is non-borrowed reserves, tr_t is total reserves, ffr_t is the federal funds rate, and tbr_t is the treasury bill rate. The sample period is 1982:11–2007:11.

system are consistent with well-accepted beliefs about the dynamic effects of a monetary policy shock on aggregate quantities and prices.

In comparison, the two alternative systems imply that the responses of output and the price level are nil on impact (by construction) and negative in the subsequent months. The output response turns positive after roughly six months, but the fall in the price level persists for several quarters. This anomalous response of the price level, often referred to as the price puzzle, is common to several empirical studies (e.g. Sims, 1992).[8] Finally, the responses of the federal funds and treasury bill rates are negative on impact and remain negative for at least 20 months after the shock. Overall these results differ substantially

[8] Note that Bjørnland and Leitemo (2009) highlight the existence of a price puzzle in a simultaneous system like *S*. Unfortunately, Thorbecke (1997) does not report the response of the price level associated with a recursive system identical to *R*.

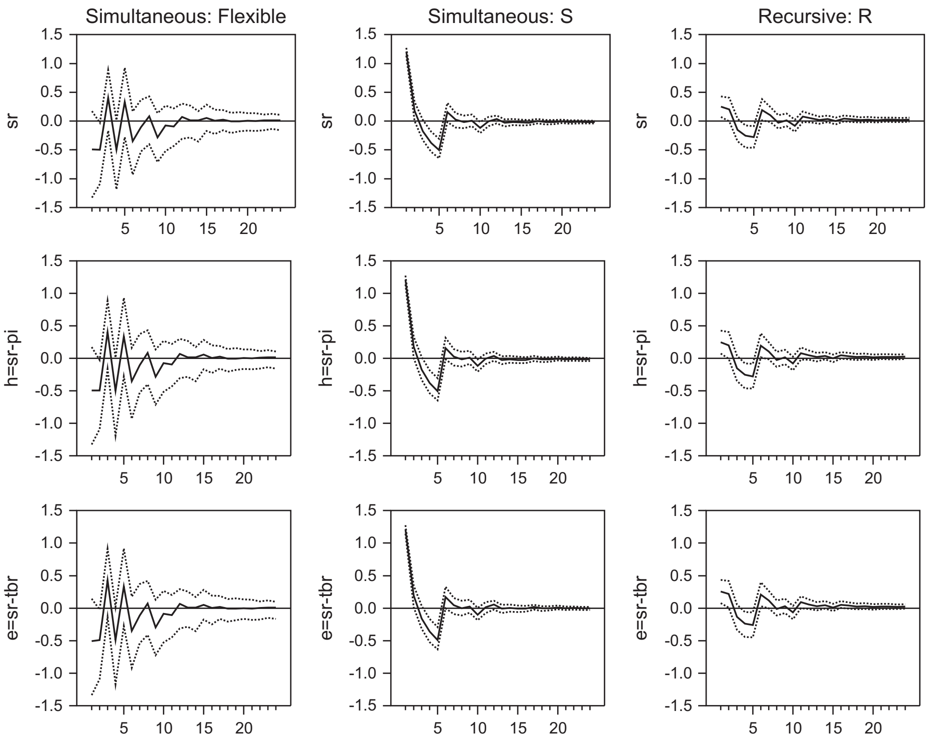

Fig. 3. Responses: stock returns. *Notes*: The solid lines correspond to the dynamic responses of stock returns to an expansionary monetary policy shock extracted from the various systems. The dotted lines are the 68% confidence intervals computed using the Sims and Zha (1999) Bayesian procedure. sr_t is stock returns, h_t is real stock returns, e_t is excess stock returns. The sample period is 1982:11–2007:11.

from those obtained from the flexible system and, more importantly, some of them do not accord with conventional views about the effects of monetary policy.

5. Stock returns and monetary policy

In this section, we study the relation between stock returns and monetary policy along three different dimensions. First, we measure the extent to which stock returns react to monetary policy shocks. Second, we determine the role played by the stock market in the transmission of monetary policy. Finally, we investigate whether stock returns directly influence the conduct of monetary policy in the US. Throughout the analysis, we compare the results obtained from the flexible system with those implied by existing approaches.

5.1. Do stock returns react to monetary policy shocks?

We assess the reaction of the stock market to monetary policy by evaluating its effects on nominal stock returns, sr_t, excess stock returns, $e_t = (sr_t - tbr_t)$, and real stock returns, $h_t = (sr_t - \pi_t)$, where $\pi_t = (p_t - p_{t-1})$ is the inflation rate. Fig. 3 presents the dynamic responses of each of these variables to a positive monetary policy shock. It is straightforward to construct these responses from the flexible and alternative systems.

For the flexible system, the response of nominal stock returns is negative at impact, oscillates during the subsequent 12 months, and becomes nil afterwards. The response is much larger than those of the price level and treasury bill rate. Consequently, the responses of nominal, real, and excess stock returns are numerically almost identical. However, these responses are imprecisely estimated, and, as a result, none of them is statistically significant. In contrast, the two alternative systems, *R* and *S*, yield a positive response of stock returns during the first three months after the shock. The response then oscillates for about a year before dying out (see Fig. 3). Again, the responses of nominal, real, and excess stock returns are almost identical within each system. These findings are in line with those reported in earlier work relying on recursive and simultaneous systems similar to *R* and *S*, which document a significant current increase in stock returns after a surprise monetary easing (e.g. Bjørnland and Leitemo, 2009; Bernanke and Kuttner, 2005; Thorbecke, 1997).

Unlike the results obtained from the restricted systems, those implied by the flexible system are puzzling given that standard theoretical models suggest that asset prices, and thus stock returns, should increase following a monetary policy expansion, owing to an increase in firm's expected future cash flows and a decline in the rate at which those cash flows are

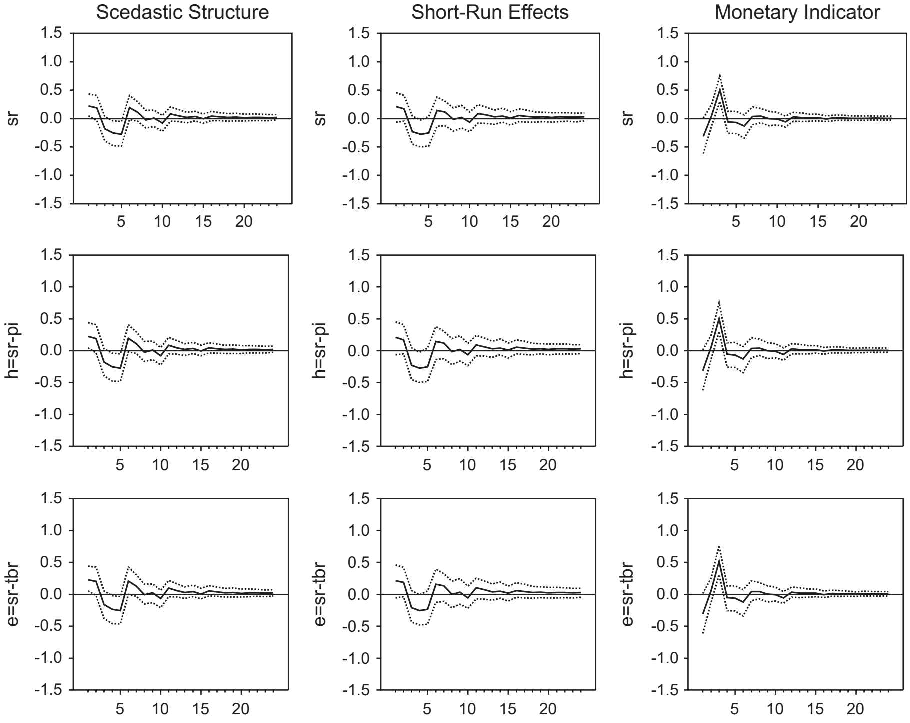

Fig. 4. Responses implied by variants of system *R*: stock returns. *Notes*: The solid lines correspond to the dynamic responses of stock returns to an expansionary monetary policy shock extracted by successively relaxing from system *R* the restrictions associated with (i) the conditional homoskedasticity of the structural shocks (column 1), (ii) the zero short-run effects of the monetary policy shock (column 2), and (iii) the definition of the monetary policy indicator (column 3). The dotted lines are the 68% confidence intervals computed using the Sims and Zha (1999) Bayesian procedure. sr_t is stock returns, e_t is excess stock returns, and h_t is real stock returns. The sample period is 1982:11–2007:11.

discounted. Thus, it appears that while our agnostic methodology resolves some of the anomalies related to the response of output and the price level, it uncovers a new puzzle pertaining to the reaction of the stock market to monetary policy shocks.

What explains the differences in results?

At this stage, it is useful to understand which type of restrictions is responsible for the discrepancies between the effects of monetary policy on asset returns obtained in this paper and those implied by the alternative systems. For this purpose, Fig. 4 depicts the dynamic responses of stock returns generated by successively relaxing from system *R* the restrictions associated with (i) the conditional homoskedasticity of the structural shocks (column 1), (ii) the zero short-run effects of the monetary policy shock (column 2), and (iii) the selection of the monetary policy indicator (column 3)—where these three sets of restrictions are strongly rejected by the data (see Table 5).[9] Fig. 4 shows that relaxing either the restrictions (i) or (ii) yields responses of stock returns that are virtually identical to those obtained from system *R*. In contrast, relaxing the restrictions (iii) induces responses of stock returns that closely resemble those implied by the flexible system. This suggests that the difference in the effects of monetary policy on stock returns is mainly due to the restrictions constraining the policy indicator to be entirely and uniquely summarized by the federal funds rate.

Are the results robust across various portfolios?

So far, the results indicate that once one relaxes the commonly used identifying restrictions, the effect of monetary policy shocks on stock returns becomes statistically insignificant. An interesting question, however, is whether the lack of responsiveness of the global index of stock returns is a robust empirical fact or just an artifact of aggregating individual stocks into one coarse portfolio. Indeed, it could be the case that stock returns exhibit strong positive responses in some sectors of the economy, which are offset by negative responses in other sectors.

To verify this conjecture, we estimate the responses of stock returns associated with portfolios sorted by industries, size, and book-to-market. To the extent that these portfolios have different risk characteristics, such an exercise can provide useful information on a potential relationship between the responsiveness of a given portfolio to monetary policy shocks and its idiosyncratic characteristics. The dynamic response of each portfolio return is computed from the flexible system, where the global-index stock return is replaced by the portfolio return of interest. For all portfolios, the monthly nominal value-

[9] For briefness, we focus on system *R* because the responses are similar to those obtained from system *S* and the three sets of restrictions that we consider are rejected in both specifications. Note that we allow for conditional heteroskedasticity when we relax the restrictions (ii) and (iii), since the system becomes under-identified otherwise.

weighted returns (including dividends) are constructed for the NYSE, NASDAQ, and AMEX markets and cover the 1982:11–2007:11 period.

To construct industry portfolios, we sort firms based on their four-digit Standard Industrial Classification (SIC) codes, as in Fama and French (1988).[10] We also classify industries using the input-output accounts of the National Income and Product Accounts (NIPA), as recently proposed by Gomes et al. (2009).[11] To construct portfolios by size and book-to-market, we proceed as follows. First, we sort firms into five quintiles based on their market-value equity (i.e. the number of shares outstanding times the price per share), which is a proxy for the firm size. Second, we sort firms into five quintiles based on their ratio of book-value equity to market-value equity, which is a proxy for the degree of financial distress. The size and book-to-market criteria are then combined to select firms with specific size characteristics and growth phases. These data are collected from the Fama-French data library.

The responses associated with the various portfolio categories closely resemble those obtained using the broad equity index, being negative but statistically insignificant on impact and oscillating for a few months before dying away. Interestingly, the responses tend to be more pronounced for small firms than for large ones, suggesting that the former are more sensitive to unanticipated monetary policy actions. To conserve space, these results are not reported but are available upon request.

Using a recursive system similar to *R*, Thorbecke (1997) and Bernanke and Kuttner (2005) find that the impact responses of stock returns associated with various industry portfolios are systematically positive following an expansionary monetary policy shock. Thorbecke (1997) also finds for ten portfolios sorted by size that monetary policy shocks have a stronger contemporaneous effect on the stock returns of small firms than on those of large firms. However, his results indicate that expansionary monetary policy shocks have a positive and statistically significant effect on the stock returns of small firms.

In sum, our results indicate that the unresponsiveness of stock returns to monetary policy is robust to considering various portfolio compositions and does not stem from aggregation.

5.2. Do stock returns influence the propagation of monetary policy?

We now turn to the question of whether stock returns alter the transmission mechanism of monetary policy. For this purpose, we focus on specifications that involve the global-index stock returns, rather than portfolio returns. Occasionally, we consider specifications in which output is replaced by a selected component of aggregate expenditure. The components of interest are private consumption of durable goods, and non-durable goods and services, as well as investment expenditures.[12]

To evaluate the role of stock returns as a propagation channel of monetary policy, we compare the unrestricted responses of the price level, output, and the components of aggregate expenditure with the responses obtained by excluding the indirect effects associated with stock returns. These indirect effects are eliminated by shutting down all contemporaneous and dynamic interactions between stock returns and the other variables of the system: $a_{ij} = a_{k,ij} = 0$ for $k = 1, \ldots, \tau$, $i = 1, \ldots, 7$ and $j = 8$ as well as for $i = 8$ and $j = 1, \ldots, 7$. Note that these restrictions imply, among other things, that stock returns do not react to monetary policy shocks at any horizon. Also, it is easy to show that these restrictions lead to a reduced form that is composed of two independent subsystems: (i) an unrestricted τ-order VAR for all variables except stock returns, and (ii) an unrestricted τ-order univariate AR process for stock returns. In practice, we estimate by OLS the coefficients of the VAR and AR processes, extract the implied residuals, and estimate by ML the relevant contemporaneous interactions involved in *A*.

Fig. 5 confronts the responses of the selected variables with and without the indirect effects associated with stock returns. For the flexible system, the unrestricted responses of the price level, consumption of durables and non-durables, and investment are very close to those obtained by imposing the requirement that current and future stock returns are unaffected by monetary policy. This result is at odds with the conventional wisdom that asset prices affect consumption through a wealth channel, and investment through both a Tobin's Q effect and a credit channel. The response of output is actually smaller when the effects related to stock returns are accounted for. This runs against the belief that the effects of monetary policy shocks on output should be magnified by the adjustment of the stock market.

For the recursive system, *R*, the responses of the price level, output, consumption of durables and non-durables, and investment are virtually identical to those obtained when the indirect effects are ignored. For the simultaneous system *S*, the responses of output, consumption of durables, and investment are larger in magnitude when the indirect effects are taken into account, whereas the response of the price level changes sign. The latter observation might suggest that the price puzzle is induced by the adjustment of the stock market. However, this conjecture is difficult to reconcile with the view that the reaction of asset prices magnifies the effects of monetary policy shocks on both output and the price level.

To summarize, using the flexible system, we find that stock returns do not alter the transmission mechanism of monetary policy. This result also holds when using a recursive identification scheme.

[10] The Fama-French portfolio data are available from French's web page (mba.tuck.dartmouth.edu/ pages/faculty/ken.french).

[11] This classification identifies each SIC industry by its primary contribution to final demand in order to form portfolios representing the three broad categories of personal consumption expenditures (i.e. durable goods, non-durable goods, and services), and investment expenditures.

[12] Private consumption is measured by monthly real personal expenditures, released by the US Department of Commerce. Investment is measured by monthly total construction spending, published by the US Census Bureau. Consumption and investment data are seasonally adjusted and expressed in logarithms.

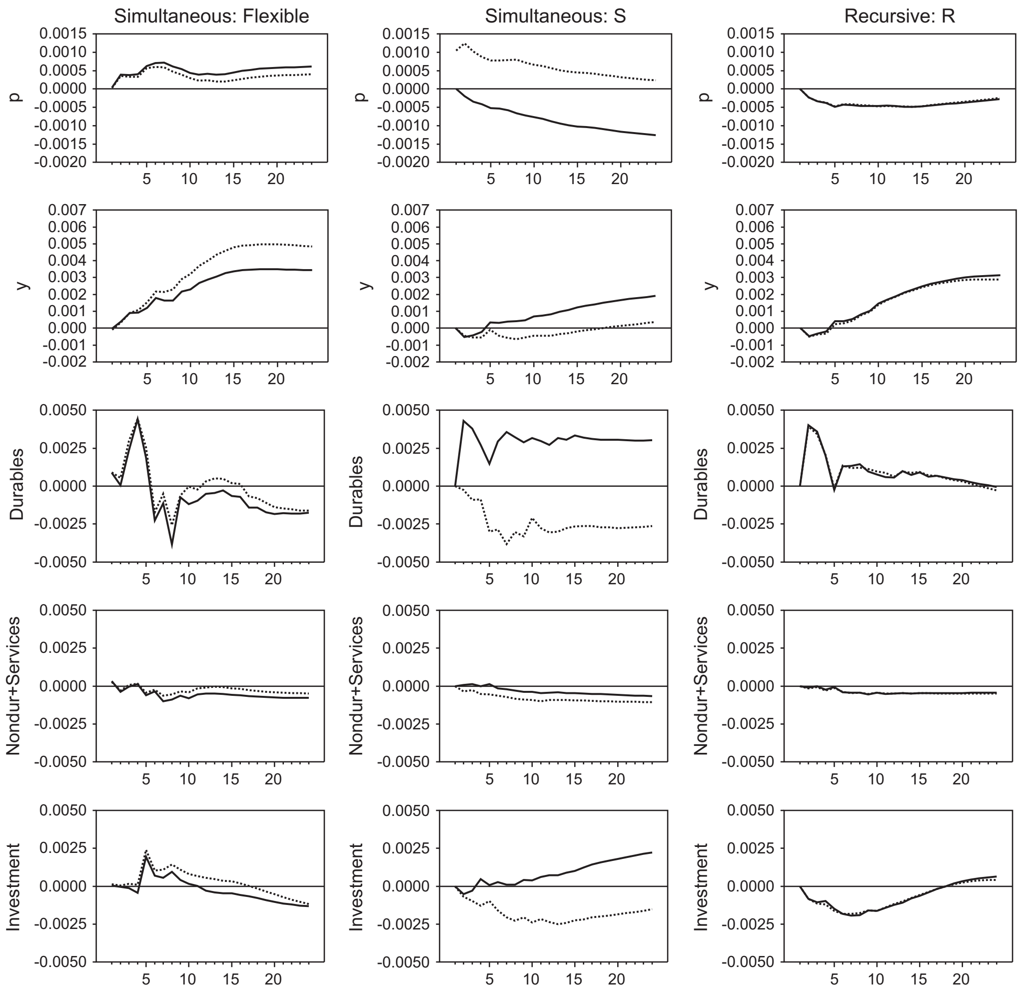

Fig. 5. Responses: price level, output, and components of aggregate expenditures. *Notes*: The solid lines correspond to the dynamic responses of selected variables to an expansionary monetary policy shock extracted from the various systems. The dotted lines represent the dynamic responses of selected variables to an expansionary monetary policy shock obtained by imposing that the response of stock returns is nil at all horizons. p_t is the price level and y_t is output. The sample period is 1982:11–2007:11.

5.3. Do stock returns directly influence the conduct of monetary policy?

Finally, we investigate whether monetary policy systematically reacts to stock returns. To this end, we evaluate the endogenous adjustments of the monetary policy indicator to current and lagged changes in asset prices. For the flexible system, the sensitivities of the policy indicator to current nominal stock returns, excess stock returns, and real stock returns are respectively summarized by the coefficients ρ_{48}, $(\rho_{48} - \rho_{47})$, and $(\rho_{48} - \rho_{42})$ of the monetary authority's feedback rule (5). Recall that for the flexible system, the indicator corresponds to a linear combination of all the reserve variables (i.e. non-borrowed reserves, total reserves, and the federal funds rate). In contrast, for the two alternative systems, the monetary policy indicator is exclusively summarized by the federal funds rate. The identifying restrictions imply that the federal funds rate may be affected by current nominal stock returns in the simultaneous specification *S*, but not in the recursive case *R*.

Table 6 reports estimates of the feedback rule. For the flexible system, none of the estimates affecting current or lagged stock returns is significant, so that there is no systematic endogenous response of monetary policy to asset returns, whether these returns are measured in nominal or real terms, or as a deviation from the treasury bill rate. For system *R*, the identifying restrictions imply that $\rho_{48} = (\rho_{48} - \rho_{47}) = 0$ and the estimate of the coefficient $(\rho_{48} - \rho_{42})$ is not statistically different from zero, whereas the estimates associated with lagged nominal and excess stock returns are jointly significant. Finally, in system *S*, all coefficients related to current stock returns are found to be significant, and those associated with lagged excess stock returns are jointly statistically different from zero. The latter results are consistent with those reported by Rigobon and Sack (2003), who find that the federal funds rate responds positively to stock returns. Note, however, that Rigobon and Sachs' results are based on high-frequency (daily) data.

Table 6
Estimates: feedback-rule parameters.

	Simultaneous:		Recursive: *R*
	Flexible	*S*	
Current variables			
sr_t	−0.0001	0.0009	–
	(0.0001)	(0.0003)	
$e_t = (sr_t - tbr_t)$	0.0262	0.0009	–
	(0.0176)	(0.0003)	
$h_t = (sr_t - \pi_t)$	0.3215	−1.1841	−0.7971
	(0.2798)	(0.6336)	(0.5775)
Lagged variables			
sr_t	0.0010	−0.0035	−0.0032
	(0.0007)	(0.0033)	(0.0039)
	[0.190]	[0.107]	[0.045]
$e_t = (sr_t - tbr_t)$	0.0469	−0.0202	0.5257
	(0.0569)	(0.1519)	(0.2506)
	[0.237]	[0.000]	[0.000]
$h_t = (sr_t - \pi_t)$	−0.8601	3.2692	2.9005
	(0.5284)	(4.1046)	(4.9341)
	[0.661]	[0.459]	[0.316]

Notes: Entries are estimates of the coefficients associated with the current variables and of the sum of the coefficients associated with the lagged variables involved in the monetary authority's feedback rule (5). Numbers in parentheses are standard errors. Numbers in brackets are the *p*-values of the χ^2-distributed joint test that the coefficients are zero. The feedback rule is $s_t = \rho x_t + \sum_{k=1}^{\tau} \theta_k z_{t-k} + \sigma_s \epsilon_{s,t}$, where s_t is the policy indicator, x_t is a subset of z_t, and z_t includes all the variables of the system. For the flexible case, $s_t = [(1+\phi_b)nbr_t - (\phi_d + \phi_b)tr_t + (\beta\phi_b - \alpha\ \phi_d)ffr_t]$ and $x_t = (y_t \quad p_t \quad cp_t \quad tbr_t \quad sr_t)'$. For system *S*, $s_t = -(\beta+\alpha)ffr_t$ and $x_t = (\Delta y_t \quad \Delta p_t \quad \Delta cp_t \quad sr_t)'$, where Δ is the first difference operator. For specification *R*, $s_t = -(\beta+\alpha)ffr_t$ and $x_t = (y_t \quad p_t \quad cp_t)'$. y_t is output, p_t is the price level, cp_t is the commodity price, nbr_t is non-borrowed reserves, tr_t is total reserves, ffr_t is the federal funds rate, tbr_t is the treasury bill rate, sr_t is stock returns, e_t is excess stock returns, and h_t is real stock returns. The sample period is 1982:11–2007:11.

Table 7
Estimates: regression parameters relating output and the price level to stock returns.

Current and lagged variables	y_t	p_t
sr_t	−0.0003	0.0020
	(0.0014)	(0.0005)
	[0.112]	[0.000]
$e_t = (sr_t - tbr_t)$	−0.1366	−0.0209
	(0.0829)	(0.0345)
	[0.000]	[0.001]
$h_t = (sr_t - \pi_t)$	0.4421	−6.8145
	(0.7021)	(0.3406)
	[0.529]	[0.000]

Notes: Entries are estimates of the sum of the coefficients associated with the current and lagged variables involved in the following regression: $w_t = \beta x_t + \sum_{k=1}^{\tau} \theta_k z_{t-k} + u_{w,t}$, where $w_t = y_t$ or p_t is the regressand, $x_t = sr_t$, e_t, or h_t are instrumented using the first lag of all the structural shocks ϵ_{t-1} of the flexible system (4), z_t includes all the variables of the flexible system, and $u_{w,t}$ is an error term. y_t is output, p_t is the price level, sr_t is stock returns, e_t is excess stock returns, and h_t is real stock returns. Numbers in parentheses are standard errors. Numbers in brackets are the *p*-values of the χ^2-distributed joint test that the coefficients are zero. The sample period is 1982:11–2007:11 period.

We emphasize that the lack of significance of stock returns in the estimated policy rule need not imply that they do not convey useful information to the Federal Reserve. Instead, it may reflect the fact that this information is to a large extent contained in the remaining arguments of the feedback rule, and in particular, output and inflation. To verify this conjecture, we regress output and the price level on current stock returns as well as on lags of all the variables included in the system. Table 7 indicates that the coefficients associated with current and lagged nominal, real, or excess stock returns in the price equation are jointly significant at the 1 percent level or lower. In the output equation, the coefficients are jointly statistically different from zero for excess returns.[13]

[13] Our findings tend to corroborate the normative implications of the model developed by Gilchrist and Leahey (2002), who find that policy rules that focus solely on output and inflation achieve most of the gains from reacting to a larger set of variables that includes asset prices, since the latter tend to be strongly correlated with output and inflation.

6. Conclusion

In this paper, we have estimated the interdependence between stock returns and monetary policy using a flexible SVAR. Our approach identifies monetary policy shocks and their effects by exploiting the conditional heteroskedasticity of the innovations to the variables included in the system. This methodology leaves unrestricted both the policy indicator and the propagation mechanism of structural shocks. In turn, it allows to relax and test the identifying restrictions commonly used in the literature. Our analysis shows that the usual identifying restrictions are not supported by the data, and that relaxing them yields more plausible effects of monetary policy shocks on output and the price level than those estimated using the restricted systems.

Our main conclusion is that the interaction between monetary policy and stock returns is much weaker than suggested by earlier empirical studies. In particular, using data prior to the latest financial crisis, we find that stock returns are not very sensitive to US monetary policy and have little effect on its propagation at a monthly frequency. In future work, it will be interesting to apply the methodology developed in this paper to determine whether the interaction between stock returns and monetary policy has changed in the aftermath of the latest financial crisis. In particular, our approach could be used to evaluate the extent to which the Federal Reserve has directly taken into consideration movements in stock returns during the financial turmoil.

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