Identifying the Interdependence between US Monetary Policy and the Stock Market[*]

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February 2007

Abstract

We estimate the interdependence between US monetary policy and the S&P 500 using structural VAR methodology. A solution is proposed to the simultaneity problem of identifying monetary and stock price shocks by using a combination of short-run and long-run restrictions that maintains the qualitative properties of a monetary policy shock found in the established literature (Christiano et al., 1999). We find great interdependence between interest rate setting and stock prices. Stock prices immediately fall by one-and-a-half percent due to a monetary policy shock that raises the federal funds rate by ten basis points. A stock price shock increasing stock prices by one percent leads to an increase in the interest rate of seven basis points.

Keywords: VAR, monetary policy, asset prices, identification.
JEL-codes: E61, E52, E43.

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[*] We thank the Editor Martin Eichenbaum, two anonymous referees, Ida Wolden Bache, Petra Geraats, Bruno Gerard, Steinar Holden, Jan Tore Klovland, Jesper Lindé, Roberto Rigobon, Erling Steigum, Kjetil Storesletten, Øystein Thøgersen, Karl Walentin and seminar participants at Econometric Society World Congress 2005, Annual Meeting of Norwegian Economists 2005, Cambridge University, Norwegian School of Economics and Business Administration, Norwegian School of Management BI and University of Oslo for valuable comments and suggestions. We gratefully acknowledge financial support from the *Norwegian Financial Market Fund* under the *Norwegian Research Council*. The usual disclaimer applies. The views expressed in this paper are those of the authors and should not be attributed to Norges Bank.
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1. Introduction

It is commonly accepted that monetary policy influences private-sector decision-making. If prices are not fully flexible in the short run, as assumed by the New Keynesian theory framework, the central bank can temporarily influence the real interest rate and therefore have an effect on real output in addition to nominal prices. It is commonly believed that the central banks have some objectives for their exertion of control over the real interest rates, e.g. to have low and stable inflation and production close to the natural rate. In order to best fulfill these monetary policy objectives, the central bank needs to monitor, respond to and influence private sector decisions appropriately. The central bank and the private sector will thus both affect and be affected by the other, leading to considerable interdependence between the two sectors. For the financial markets where information is readily available and prices are sensitive to agents' expectations about the future, we would expect that a large part of the interdependence is simultaneous. In view of this and the vast amount of resources spent by the financial market participants in monitoring and interpreting central bank behavior, allowing for simultaneity between monetary policy and financial markets is likely to be both quantitatively and qualitatively important when measuring the degree of interdependence.

Analyses of the effects of monetary policy have to a large extent been addressed in terms of vector autoregressive (VAR) models, initiated by Sims (1980). Yet, studies that use VAR models to identify the interdependence have found only small effects of interaction between monetary policy and asset prices, see for instance Lee (1992), Thorbecke (1997) and Neri (2004) among others. However, these conventional VAR studies have not allowed for simultaneous interdependence, as the structural shocks have been recovered using recursive, short-run restrictions on the interaction between monetary policy and asset prices. By not allowing for potential simultaneity effects in the identification of monetary policy shock, we argue that these studies are subject to a numerically important downward bias in the estimate of the degree of interdependence.

In this study we analyze the interaction between asset prices and monetary policy in the U.S., represented by the S&P 500 and the federal funds rate respectively, using a VAR model that takes full account of the potential simultaneity of interdependence. We solve the simultaneity problem by imposing a combination of short-run and long-run restrictions on the multipliers of the shocks, leaving the contemporaneous relationship between the interest rate and stock prices intact. Identification is instead achieved by assuming monetary policy can have no long-run effect on the real stock price, which is a common long-run neutrality assumption. Contrary to what is found in traditional VAR studies, we find *strong* interaction effects between the stock market and interest rate setting. A considerable part of the interaction is simultaneous. Stock prices immediately fall by one-and-a-half percent due to a monetary policy shock that raises the federal funds rate by ten basis points. A stock price shock increasing stock prices by one percent leads to an increase in the interest rate of five basis points. These results are achieved without affecting the established effects of a monetary policy shock found in the VAR literature (e.g., Christiano et al., 1999).

This present paper is not the first to propose a solution to the simultaneity problem. Recently, Rigobon and Sack (2003, 2004) have addressed the interaction between the stock market and monetary policy by using an identification technique based on the heteroscedasticity of shocks that is present in high-frequency data. By focusing on instant responses in daily data, they find strong effects of monetary policy shocks onto the stock market (Rigobon and Sachs, 2004), and an equally strong feedback in the interest rates following a stock market shock (Rigobon and Sachs, 2003). While consistent with Rigobon and Sack in allowing for full simultaneity, our framework also allows us to identify the subsequent dynamic interaction of the stock prices and the macroeconomic variables. Furthermore, by identifying monetary policy and stock price shocks jointly in the same model, the two way interaction can be addressed explicitly. Nevertheless, the Rigobon and Sack approach suggests strong simultaneity effects, confirming and robustifying our result that accounting for the simultaneity is important in measuring the interaction effects.

Section 2 gives a brief survey of theoretical, methodological and empirical arguments regarding the interaction between asset prices and monetary policy. Section 3 presents the identification scheme used for the VAR study in identifying the interdependence between the monetary policy and the stock market. Section 4 presents and discusses our empirical results. We provide some robustness checks in Section 5. Section 6 concludes.

2. Monetary policy and stock prices interaction: a short overview

2.1 Theoretical arguments of interdependence

There are several reasons why we should expect there to be interaction effects between monetary policy and asset prices, in particular, stock prices. Through its effect on both the current and the expected future real interest rate, the central bank influences both the timing of household consumption and business investment decisions through the rental rate of capital. It is commonly assumed that asset prices and, in particular, stock prices are determined in a forward-looking manner, thereby reflecting the expected future discounted sum of return on the assets. Changes in asset prices can then either be due to changes in expected future dividends, the expected future interest rate that serves as a discount rate, or changes in the stock returns premium. If goods markets are dominated by monopolistic competition and mark-up pricing, profits will, at least in the short run, be affected by all factors influencing aggregate demand. Moreover, the change in the path of profit may influence the expected dividends. Monetary policy, and in particular surprise policy moves, is therefore not only likely to influence stock prices through the interest rate (discount) channel, but also indirectly through its influence on the determinants of dividends and the stock returns premium by influencing the degree of uncertainty faced by agents. Furthermore, asset prices may influence consumption through a wealth channel and investments through the Tobin Q effect (Tobin, 1969) and, moreover, increase a firm's ability to fund operations (credit channel). The monetary policymaker that manages aggregate demand in an effort to control inflation and output thus has incentives to monitor asset prices in general, and stock prices in particular, and use them as indicators for the appropriate stance of monetary policy.

Therefore, there is likely to be considerable interdependence between stock price formation and monetary policymaking.

A further motive for why the monetary policymaker may find stock market information valuable is if the stabilization of asset prices is a separate objective of monetary policy. This is, however, controversial. Rotemberg and Woodford (1998) show that under the assumption of a Calvo (1983) type of nominal rigidities, a welfare optimizing central bank should stabilize the output gap, i.e., the deviations of actual output from the flexible-price level of output, in addition to inflation from a zero target level. If price stickiness (and monopolistic competition) is the only market imperfection, there seems to be no reason for including asset prices in the loss function.

Price stickiness may, however, not be the only market imperfection that provides a welfare-enhancing role for monetary policy. Other market imperfections may rationalize other roles for monetary policy, see e.g. Bernanke and Gertler (1999) and Carlstrom and Fuerst (2001). Allen and Gale (2004) argue that the central bank should design policy so as to reduce uncertainties and stabilize asset prices around their fundamental values. Borio and Lowe (2002) and Bordo and Jeanne (2002a, 2002b) argue that financial stability may be a prerequisite for monetary stability.[1] A fall in asset prices is likely to reduce the value of collaterals, which makes it more difficult for borrowers to obtain credit and restricts aggregate demand (see Bernanke, Gertler and Gilchrist, 2000, and Bernanke and Gertler, 1989).

Note, however, that even if asset price arguments appear in the social loss function, this is neither a sufficient nor a necessary condition for having monetary policy responding to asset prices. According to the "fundamentalist view", assets prices do not convey information that is not available elsewhere. However, this argument assumes that the central bank is at *no informational disadvantage* (with respect to the relevant information) versus the private sector, and the state determining the target variables is *observable* to the policymaker. If these conditions are not met, asset prices may contain important information since they reflect private sector expectations about the state of the economy.[2,3] Asset prices may then be leading indicators of the target variables and help guiding monetary policy in achieving its objectives.[4]

It can also be argued that asset prices do not only reflect the fundamentals, but also that they frequently include expectations-driven sunspot components. Given the inefficiency of such sunspots components and the assumption that monetary policy may reduce their size, the "non-fundamental view" implies that there is a role for stabilizing asset prices around the efficient price level that could be given to the central bank, see Allen and Gale (2004).

[1] Eichengreen and Arteta (2002) find that a higher credit expansion increases the likelihood of a banking crisis.

[2] See Vickers (2000) for an overview of the use of asset prices in guiding monetary policy at inflation-targeting central banks.

[3] Svensson and Söderlind (1997) review different methods of obtaining information through the use of asset-price information.

[4] Goodhart and Hofmann (2000) find that housing prices, equity prices and the yield spread may help predict CPI inflation. Stock and Watson (2003) argue, however, that asset prices are not stable explanatory variables of inflation and output; asset prices provide explanatory power only in some countries and some periods. Bordo and Wheelock (2004) also find no consistent relationship between inflation and stock market booms.

Moreover, due to the presence of sunspot components, asset prices influence target variables more than what is reflected by the fundamental part of the asset price (see, e.g. Cecchetti et al., 2000) and there is a potential role for responding to them. However, given the incomplete understanding of asset price determination, it may be difficult to identify possible sunspot components and thus provide an adequate real-time monetary-policy response, as shown by Bernanke and Gertler (2001). Cecchetti et al. (2000), however, show that the ability to react to asset prices reduces the loss in terms of the weighted output and inflation variability significantly.

Although there does not seem to be any clear theoretical consensus on *how* useful asset price information is for monetary policymaking, theory does not discard the possibility of stock prices being useful indicators. Empirical modelers should thus be open to its potential influence.

2.2 Empirical evidence

Compared to the vast amount of papers analyzing the influence of the monetary policy actions on the macroeconomic environment, there are relatively few papers trying to model interactions between monetary policy and asset prices. Among the first we find are Geske and Roll (1983) and Kaul (1987), that examine the causal chain between monetary policy and stock market returns separately (see Sellin (2001) for a comprehensive survey). However, the error term in these individual estimations will be correlated and therefore not precisely identified. Recent empirical studies have therefore tended to use a joint estimation scheme like the vector autoregressive (VAR) approach, since it involves the estimation of all variables in one system.

VAR studies incorporating the stock market into the more traditional monetary analysis include, among others, Lee (1992), Patelis (1997), Thorbecke (1997), Millard and Wells (2003) and Neri (2004). All these find monetary policy shocks to account for only a small part of the variations in stock returns. Furthermore, stock prices frequently display a puzzling development which is difficult to understand from the perspective of financial market theory. More important, however, the above papers identify monetary policy and stock market shocks using Cholesky decomposition, which imposes a recursive ordering of the identified shocks. In many of these papers, the stock market is ordered last, thus implying that it can react contemporaneously to all other shocks, but that the variables identified before the stock market (i.e. monetary policy stance) react with a lag to stock market news. Hence, simultaneous interdependence is ruled out by assumption. As the focus in many of these papers has been to analyze the effect of monetary policy on the stock market, and not vice versa, this restriction has seemed unproblematic, at least in the analysis using monthly data. However, to the extent that one wants to be able to account for the true simultaneous response in monetary policy and stock prices, using a recursive identification scheme in VAR models may imply that the effects can be severely biased. We shall see that the simple Cholesky identification scheme underestimates the impact of both stock market shocks and monetary policy shocks on stock returns and interest rate setting in Section 4.

Lastrapes (1998) and Rapach (2001) identify instead monetary shocks in a VAR model using solely long-run (neutrality) restrictions. Both find considerably stronger effects of the monetary shock (interpreted as a money supply shock) on the stock market. However, the reverse causation; from the stock market to systematic monetary policy is either ignored or addressed much more rudimentarily. Lastrapes (1998) do not identify stock market shocks altogether, leaving all shocks but the money supply shock underidentified. This make the analysis vulnerable to the critique of Faust and Leeper (1997), arguing that as there are many types of temporary shocks that may satisfy the characteristics of the identified (money supply) shock, there is a risk that one may be confounding shocks. Rapach (2001) provides exact identification, but has to rely on some largely ad hoc assumptions to identify all shocks. In particular, to be able to pin down the effects of the stock price shocks (interpreted as portfolio shock) he imposes that a 10 percent permanent increase in the stock marked will lead to a *constant* long run response in the interest rate of 25 basis points. No justification is made for this choice, and robustness results illustrate that the dynamic effects on the interest rate of the portfolio shock is highly sensitive to the parameter value chosen. [5]

Recently, the simultaneity problem has been addressed using high frequency observation (i.e. daily data), to analyze how asset prices are associated with particular policy actions. In an influential paper, Rigobon and Sack (2004) use an identification technique based on the heteroscedasticity of shocks that is present in high frequency data to analyze the impact effect of monetary policy on the stock marked. They estimate that "a 25 basis point increase in the three-month interest rate results in a 1.9% decline in the S&P 500 index and a 2.5% decline in the Nasdaq index." Furthermore, using the same method, but analyzing the reverse causation, Rigobon and Sack (2003) find that a "5 percent rise in stock prices over a day causes the probability of a 25 basis point interest rate hike to increase by a half" (p. 664).

These results are somewhat larger than in more conventional "event studies" such as Bernanke and Kuttner (2005). They estimate the effect of an unanticipated rate cut of 25 basis points to be a one-percent increase in the level of stock prices. They attribute most of the effects of the monetary policy shock on stock prices to its effect on forecasted stock risk premiums. However, in a similar study, Ehrmann and Fratzcher (2005) find slightly stronger effects, estimating an unexpected tightening of 50 basis points to reduce US equity returns by 3% on the day of the announcement.

Event studies are useful for quantifying the immediate effect of a specific action, such as a monetary policy surprise. However, with their exclusive focus on the immediate response, they are less useful in answering questions about the dynamic adjustments following the initial shock. Furthermore, they do not provide for two way causation, focusing exclusively either on the effect of monetary policy on stock prices, or, on the effect of stock price shocks on the (systematic) monetary policy. To do so, we need to identify monetary policy shocks in a system like the structural VARs as is done in the present study. On the

[5] Another strand of literature estimates the contribution of asset prices in interest rate reaction functions, but is subject to the same simultaneity problem as in the conventional VARs. For instance, Fuhrer and Tootell (2004) and Chadha et al. (2003) estimate augmented Taylor rules, but find mixed results. However, as emphasized in Rigobon and Sack (2003) the significance of these results will depend on whether the instruments proxy the stock prices variables correctly.

other hand, identification of the VAR system should be such that it does not violate the major finding from these event studies, as seems to be the case for the conventional VAR studies.

3. The identified VAR model

In this study, we explicitly account for the interdependence between stock prices and monetary policy within a VAR model by imposing a combination of short-run and long-run restrictions. In particular, we build on the traditional VAR literature in that we identify a recursive structure between macroeconomic variables and monetary policy, so that monetary policy can react to all shocks, but the macroeconomic variables react with a lag to monetary policy shocks. Stock prices and monetary policy operationalized through the short-term interest rates are, on the other hand, allowed to react simultaneously to each other. We make the identifying assumption that monetary policy has no long-run effects on real stock prices. It seems reasonable to assume that due to the long-run monetary policy neutrality proposition, such a restriction on the interdependence between monetary policy and stock prices is uncontroversial. Moreover, by using only one long-run restriction, we address the simultaneity problem without extensively deviating from the established literature (i.e., Christiano et al., 1999, 2005) of identifying a monetary policy shock as an exogenous shock to an interest rate reaction function (the systematic part of monetary policy). Once we allow for full simultaneity between monetary policy and the stock market, the VAR approach is likely to give very useful information about the simultaneous interaction between monetary policy and asset markets.

The VAR model comprises monthly data[6] of the log of the consumer price index (CPI) (p_t), the log of the industrial production index (y_t), the federal funds rate (i_t), the log of the commodity price index in US dollars (USA PPI Raw materials, *Source: OECD*) (c_t) and the log of the S&P 500 stock prices index (s_t). Stock prices are deflated by CPI, so that they are measured in real terms. The federal funds rate and the stock prices index are observed daily, but they are averaged over the month, so as to reflect the same information content as the other monthly variables. The first three variables are well-known variables in the monetary policy and business cycle literature. The commodity price variable is included as it has been observed that omitting an important variable from the VAR representing inflation pressure to which the FED reacts, may lead to the so-called "price puzzle" (Eichenbaum, 1992), where prices increase significantly in response to an interest rate. By including a leading indicator for inflation such as a commodity price index, one may eliminate this positive response of prices to the contractionary monetary policy shock (see e.g. Sims 1992, Leeper et al. 1996, and many subsequent studies in the VAR literature). Finally, the stock price index is included to both investigate the importance of monetary policy shocks for the stock market and to what extent the (systematic) monetary policy stance is influenced by stock market developments.

[6] In section 5 of the paper, we test for robustness of the result at the quarterly frequency.

Below, we will show that using a combination of short-run and long-run restrictions on the estimated VAR model will be sufficient to identify all shocks, while also allowing for a simultaneous response in the monetary policy stance and stock prices to the identified shocks.

3.1 Identification

Throughout this paper, we follow what has now become standard practice in VAR analysis (see e.g. Christiano et al., 1999) and identify monetary policy shocks with the shock in an equation of the form

$$i_t = f(\Omega_t) + \sigma\varepsilon_t^{MP}, \qquad (1)$$

where i_t is the instrument used by the monetary authority (the federal funds rate in the U.S.) and *f* is a linear function (feedback rule) relating the instrument to the information set at the time of the interest rate setting (Ω_t). The monetary policy shock ε_t^{MP} is normalized to have unit variance, and σ is the standard deviation of the monetary policy shock. Having identified the feedback rule (from the variables in the information set), the VAR approach focused on the exogenous deviations from this rule. Hence, such deviations provide researchers with an opportunity to detect the responses of macroeconomic variables to monetary policy shocks not already incorporated in private agent expectations.

In a similar vein, stock price shocks are identified from the equation of stock prices, and are orthogonal to the other shocks and information in the VAR. To the extent that the macroeconomic variables in the VAR reflect true variables relevant for determining the sum of expected future discounted dividends the stock market, the stock market shocks can be interpreted as shocks unrelated to present macroeconomic conditions.

Below, we set out to follow standard practice in many recent VAR applications, namely to identify the different structural shocks through a series of contemporaneous restrictions on the effects of the shocks on the variables. In particular, it is commonly assumed that macroeconomic variables, such as output and prices, do not react contemporaneously to monetary shocks, while there might be a simultaneous feedback from the macro environment to monetary variables, see e.g. Sims (1980), and Christiano et al. (1999) among many others. Further, Bagliano and Favero (1998) show that when monetary policy shocks are identified in this recursive way on a *single* monetary policy regime, the responses of the shocks suggest a pattern for the monetary transmission mechanism that is consistent with what you would find using instead financial market information (from outside the VAR); thereby limiting the Rudebusch (1998) critique of structural VARs.[7]

However, as discussed above, a more profound problem with this recursive identification, is that once one include high frequency data such as stock prices in the VAR, it becomes difficult to validate that monetary policy should not be contemporaneously affected

[7] Rudebusch (1988) questioned the validity of using structural VARs for monetary policy analysis. He showed that the structural shocks found using a recursively identified VAR, may not be identical to the "true" monetary policy shocks identified outside the VAR.

by shocks to these financial variables, or vice versa. To solve this simultaneity problem, we therefore instead use a long-run restriction that does not limit the contemporaneous response in the variables. The restriction identifies monetary policy shocks as those shocks that have no long run effect on the level of real stock prices.

Assume Z_t to be the (5x1) vector of macroeconomic variables discussed above that are ordered as follows: $Z_t = [y_t, p_t, c_t, i_t, \Delta s_t]'$, where all variables but the real stock price are specified in levels. We assume the reduced form VAR has a MA representation,

$$Z_t = B(L)v_t, \tag{2}$$

where v_t is a (5x1) vector of reduced form residuals assumed to be identically and independently distributed, $v_t \sim iid(0,\Omega)$, with positive definite covariance matrix Ω. $B(L)$ is the (5x5) convergent matrix polynomial in the lag operator L, $B(L) = \sum_{j=0}^{\infty} B_j L^j$. The identification of the relevant structural parameters, given the estimation of the reduced form, is a traditional problem in econometrics. A structural model is obtained by assuming orthogonality of the structural shocks and imposing some plausible restrictions on the elements in $B(L)$. Following the literature, we assume that the underlying orthogonal structural disturbances (ε_t) can be written as linear combinations of the innovations (v_t), i.e.,

$$v_t = S\varepsilon_t. \tag{3}$$

where S is the (5x5) contemporaneous matrix. The VAR can then be written in terms of the structural shocks as

$$Z_t = C(L)\varepsilon_t, \tag{4}$$

where $B(L)S = C(L)$. Clearly, if S is identified, we can derive the MA representation in (4) since B(L) can be calculated from the reduced-form estimation of (2). Hence, to go from the reduced-form VAR to the structural interpretation, restrictions must be applied on the S matrix. Only then can the relevant structural parameters from the covariance matrix of the reduced-form residuals be recovered.

To identify S, we first assume that the ε_t's are normalized so that they all have unit variance. The normalization of cov(ε_t) implies that $SS' = \Omega$. With a five-variable system, this imposes fifteen restrictions on the elements in S. However, as the S matrix contains twenty-five elements, to orthogonalize the different innovations, ten more restrictions are needed.

With a five-variable VAR, we are able to identify five structural shocks; The first two are the main focus and are denoted monetary policy shocks (ε_t^{MP}) and stock price shocks (ε_t^{SP}). The remaining three can be loosely interpreted as commodity price shocks (ε_t^{CO}), inflation shocks (i.e. cost push shocks) (ε_t^{CP}) and output shocks (ε_t^{Y}). Ordering the vector of uncorrelated structural shocks as $\varepsilon_t = \left[\varepsilon_t^{Y}, \varepsilon_t^{CP}, \varepsilon_t^{CO}, \varepsilon_t^{MP}, \varepsilon_t^{SP}\right]'$, and following the standard closed economy literature in identifying monetary policy shocks, the recursive order between monetary policy shocks and the macroeconomic variables implies the following restriction on the *S* matrix

$$\begin{bmatrix} y \\ \pi \\ c \\ i \\ \Delta s \end{bmatrix}_t = B(L) \begin{bmatrix} S_{11} & 0 & 0 & 0 & 0 \\ S_{21} & S_{22} & 0 & 0 & 0 \\ S_{31} & S_{32} & S_{33} & 0 & 0 \\ S_{41} & S_{42} & S_{43} & S_{44} & S_{45} \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} \end{bmatrix} \begin{bmatrix} \varepsilon^{Y} \\ \varepsilon^{CP} \\ \varepsilon^{CO} \\ \varepsilon^{MP} \\ \varepsilon^{SP} \end{bmatrix}_t . \tag{5}$$

The standard restrictions (namely that macroeconomic variables do not simultaneously react to policy variables, while the simultaneous reaction from the macroeconomic environment to policy variables is allowed for), is taken care of by placing the macroeconomic variables above the interest rate in the ordering, and by assuming zero restrictions on the relevant coefficients in the *S* matrix as described in (5). This provides us with nine contemporaneous restrictions directly on the *S* matrix.

Regarding the order of the three variables above the interest rate, it follows standard practice in the literature. However, as it turns out, the responses to the monetary- (or stock price) shock will be invariant to the ordering of these three variables.[8] This follows from a generalizing of the well known findings in Christiano et al., (1999; Proposition 4.1), stating that when the monetary policy variable (the interest rate) is ordered last in a Cholesky ordering, the responses to the monetary policy shock will be invariant to the ordering of the variables above the interest rate. Instead, the ordering of the variables above the policy equation becomes a computational convenience with no bite. The real bite here is the assumption that the first three variables in the VAR don't respond contemporaneously to a monetary policy shock (or a stock price shock).

Still, we are one restriction short of identification. The standard practice in the VAR literature, namely to place the financial variable last in the ordering and assuming $S_{45} = 0$, (so that neither macroeconomic nor monetary variables can react simultaneously to the financial variables, while financial variables are allowed to react simultaneously to all other variables), would have provided enough restriction to identify the system, thereby allowing for the use of the standard Cholesky recursive decomposition.

However, if that restriction is not valid, the estimated responses to the structural shocks will be severely biased. The standard test in the literature, namely to include one variable above the other and then rearrange the order to test whether that makes a difference, will not produce the correct impulse responses if there is a genuine simultaneous relationship between the two variables. Most likely, this will lead to the effects of the shocks being underestimated, as a recursive ordering will always either a) disregard the simultaneous

[8] These results can be obtained at request from the authors.

reaction of the monetary policy stance to the stock price shocks, or b) exclude the simultaneous reaction of stock prices to the monetary policy shocks. This will be effectively demonstrated in the next section.

Instead, we therefore impose the restriction that a monetary policy shock can have no long-run effects on the level of real stock prices which, as discussed above, is a plausible neutrality assumption when we measure stock prices in real terms. The restriction can be applied by setting the infinite number of relevant lag coefficients in (4), $\sum_{j=0}^{\infty} C_{54,j}$, equal to zero. Using the long-run restriction, S_{45} is now allowed to differ from zero.[9] Writing the long-run expression of $C(L)$ as

$$B(1)S = C(1), \quad (6)$$

where $B(1) = \sum_{j=0}^{\infty} B_j$ and $C(1) = \sum_{j=0}^{\infty} C_j$ indicate the (5x5) long-run matrix of $B(L)$ and $C(L)$, respectively, the long-run restriction that $C_{54}(1) = 0$ implies

$$B_{51}(1)S_{14} + B_{52}(1)S_{24} + B_{53}(1)S_{34} + B_{54}(1)S_{44} + B_{55}(1)S_{54} = 0\,. \quad (7)$$

The system is now just identifiable and the parameters can be identified in two steps. First, using the recursive Cholesky restriction identifies the non-zero parameters above the interest rate equation. Second, the remaining parameters can be uniquely identified using the long run restriction (7), where $B(1)$ is calculated from the reduced form estimation of (2). Note that (7) reduces to $B_{54}(1)S_{44} + B_{55}(1)S_{54} = 0$ with the zero contemporaneous restrictions applied.

4. Empirical modeling and results

The model is estimated using monthly data from 1983M1 to 2002M12. Using an earlier starting period will make it hard to identify a stable monetary policy stance, as monetary policy prior to 1983 has experienced important structural changes and unusual operating procedures (see Bagliano and Favero, 1998, and Clarida et al., 2000). We follow the standard practice in many VAR models on monetary policy and set out to model all variables (but real stock prices) in levels. This implies that any potential cointegrating relationship between the variables will be implicitly determined in the model (see Hamilton, 1994). Sims, Stock and Watson (1990) also argue for using VAR in levels as a modeling strategy, as one avoids the danger of inconsistency in the parameters caused by imposing incorrect cointegrating restrictions; though at the cost of reducing efficiency. The stock price index is clearly non-stationary (t_{ADF} =-0.859) and is specified using first differences in the VAR. That way we can apply long-run restrictions to the first-differenced stock price, which implies that the sum of

[9] Note that the joint use of short-run and long-run constraints used in the VAR model should also be sufficient to side-step some of the criticism of Faust and Leeper (1997), stating that for a long-run identifying restriction to be robust, it has to be tied to restriction of finite horizon dynamics.

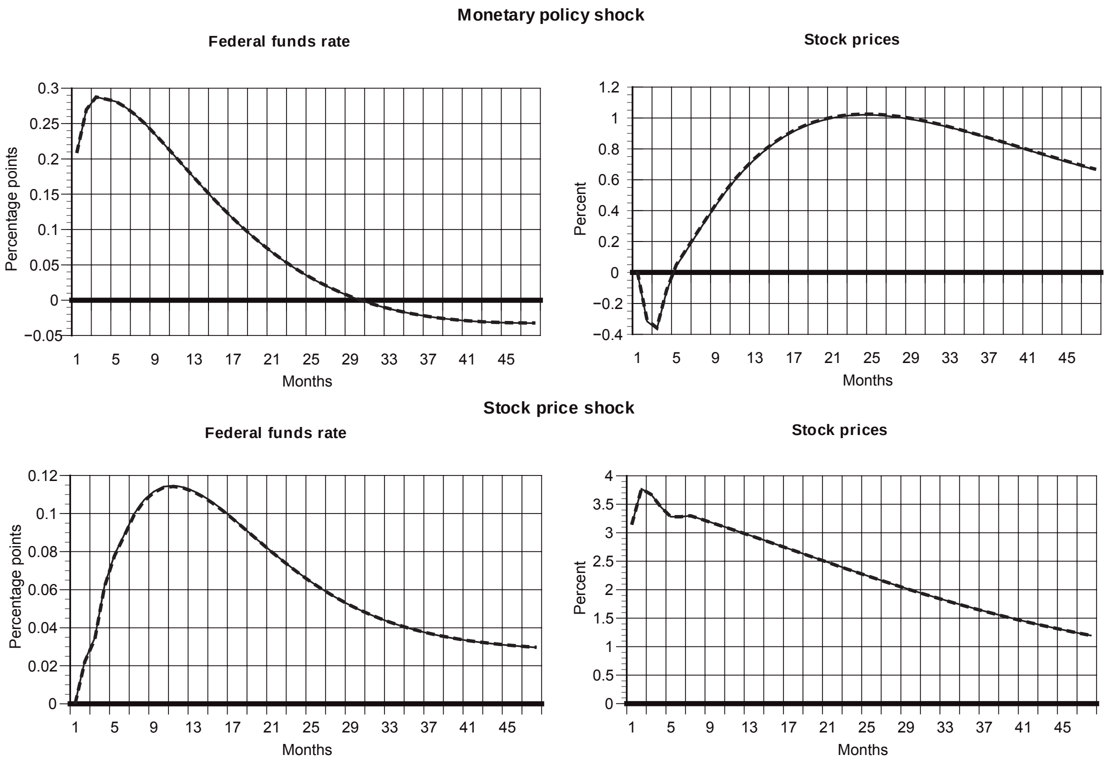
the effects of monetary policy shocks on the *level* of the stock price will eventually be zero (c.f. Blanchard and Quah, 1989).

The lag order of the VAR-model is determined using the Schwarz and Hannan-Quinn information criteria and the F-forms of likelihood ratio tests for model reductions. A lag reduction to four lags could be accepted at the one-percent level by all tests. Using four lags, there is no evidence of autocorrelation, heteroscedasticity or non-normality in the model residuals. Below, however, we report robustness results to among other the chosen lag length.

4.1 Cholesky decomposition

If there is strong simultaneity between shocks to monetary policy and stock prices, we would not expect a Cholesky decomposition of the effects of shocks to pick up this simultaneity, since one of the shocks is always restricted from having an immediate effect on one of the variables. Figure 1 gives an account of the impulse responses of interest rates and stock prices to both a monetary policy shock and a stock price shock. These are shown for two different orderings of variables, with the interest rate and the stock price alternating as the penultimate and ultimate variables.

Figure 1. Impulse responses with two Cholesky identification schemes.



Note: Although the curves almost completely overlap and are difficult to distinguish, a solid line represents the ordering with the federal funds rate last and the dashed line the ordering with real stock prices (SP) last.

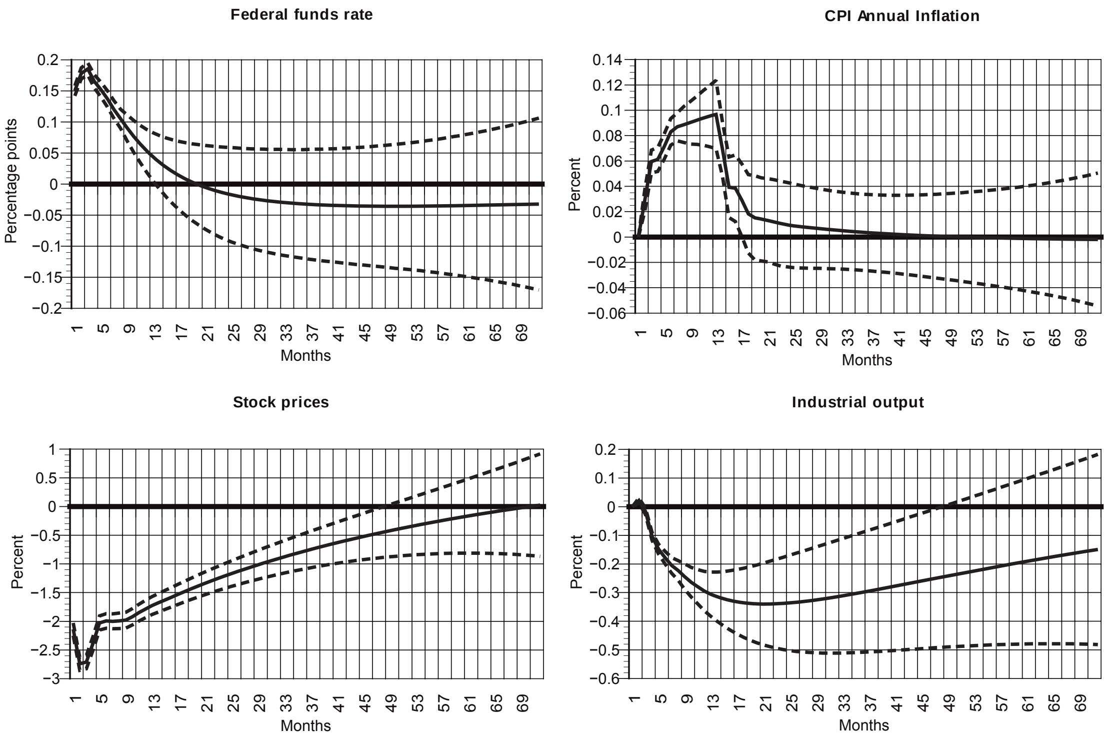
Restricting either the monetary policy shock to have no immediate effect on stock prices or the stock price shock to have no immediate effect on interest rates, we see that neither the monetary policy shock nor the stock price shock has any important contemporaneous effects on the other variables, as found in most conventional VAR studies (e.g. Lee, 1992, Thorbecke, 1997 and Neri, 2004). In addition, the effect of a monetary policy shock on stock prices is counterintuitive, increasing stock prices by more than one percent after a year. Assuming that both the stock market and the monetary policymaker react to shocks in the other sector so that interaction is important, the restriction imposed by either Cholesky ordering distorts the estimates of the two shocks in such a way that the degree of interaction will seem unimportant.

4.2 Structural identification scheme

The alternative to the simple Cholesky decomposition was outlined in Section 3. Since our prime interest is to understand the interaction between monetary policy and the stock market, we focus on illustrating the impact of the monetary policy shock and the stock price shock.

Figures 2 and 3 show the impulse responses to the federal funds rate, the stock market price, annual inflation and the industrial production of a monetary policy shock and a stock price shock, respectively. The figures also give a one standard deviation band around the point estimates, reflecting the uncertainty of the estimated coefficients.[10]

Figure 2. Impulse responses to a monetary policy shock.



Note: The charts show the impulse responses of a monetary policy shock to the federal funds rate, real stock prices, inflation and industrial output with a standard error band.

The monetary policy shock

[10] This is the Bayesian simulated distribution obtained by Monte Carlo integration with 2500 replications, using the approach for just-identified systems. The draws are made directly from the posterior distribution of the VAR coefficients (see Doan, 2004). The standard errors that correspond to the distributions in the C(L) matrix are then calculated using the estimate of S.

The monetary policy shock temporarily increases interest rates, as expected. There is a high degree of interest-rate inertia in the model, as a monetary policy shock is only offset by a gradual reduction in the interest rate. The federal funds rate returns to its steady-state value after a year and a half and then, (although not significantly so), falls below its steady-state value. The monetary policy reversal combined with the interest-rate inertia is consistent with what has become known as good monetary policy conduct. As shown by Woodford (2003a), interest-rate inertia is known to let the policymaker smooth out the effects of policy over time by affecting private-sector expectations. Moreover, the reversal of the interest rate stance, though arriving late, is consistent with the policymaker trying to offset the adverse effects of the initial policy deviation from the systematic part of policy.

As is commonly found in the literature, output falls temporarily and reaches its minimum after a year and a half. The negative effect on output is clearly significantly different from zero, but after four years, the effect has essentially died out. Inflation increases first but stabilizes and starts to decline after a year. However, the effect on inflation is small, and eventually not significantly different from zero. The small effect of a monetary policy shock on inflation has also been found in many traditional VAR studies of the US economy, such as Christiano et al. (1999), but also recently by Faust et al. (2004), who identify monetary policy shocks based on high frequency futures data. The initial increase in prices is more of a puzzle. Neo-Keynesian (e.g, Svensson, 1997) and New-Keynesian (see, Rotemberg and Woodford, 1998, 1999, Clarida et al., 1999, and Woodford, 2003b) models predict that inflation falls as a result of output deviating negatively from its potential. However, more recently the price increase has been explained (see, Ravenna and Walsh, 2005, and Chowdhury et al., 2003) by a cost channel of the interest rate (i.e., the increased interest rate increases the borrowing costs for firms and therefore prices) and is therefore less of a puzzle.

Empirical studies have addressed the puzzle in a variety of ways, most notably by adding a commodity price index to the VAR model, see Sims (1992). The idea is that commodity prices are leading indicators of inflation and likely to be important indicators for the monetary policymaker in setting interest rates, thus affecting the systematic part of monetary policy. Including the commodity price index is therefore important to extract the true monetary policy shock. As noted by Hanson (2004), however, this approach is less successful in alleviating the price puzzle in VAR models estimated with data for the past twenty years.[11]

The monetary policy shock has a strong impact on stock returns. Stock prices immediately fall by about one-and-a-half percent for each (normalized) ten basis-point increase in the federal funds rate. The result of a fall in stock prices is consistent with the increase in the discount rate of dividends associated with the increase in the federal funds rate, but also with the temporarily reduced output and higher cost of borrowing which are likely to reduce expected future dividends. Real stock prices remain depressed for a prolonged period after the monetary policy shock.

[11] We have also tried to use the same commodity price index as in Hanson (2004), without that changing the overall results. However, using quarterly data (see Section 5), the analysis yields results suggesting less evidence of this puzzle.

After the initial negative jump, stock returns are higher immediately after a monetary policy shock, but gradually decline towards the average level as the long run restriction bites. Although interpretations of this result should be made with great care, a potential explanation might be that as the interest rate gradually falls, the discounted value of expected future dividends increases while output and profits build up, leading to an increase and normalization of stock prices.

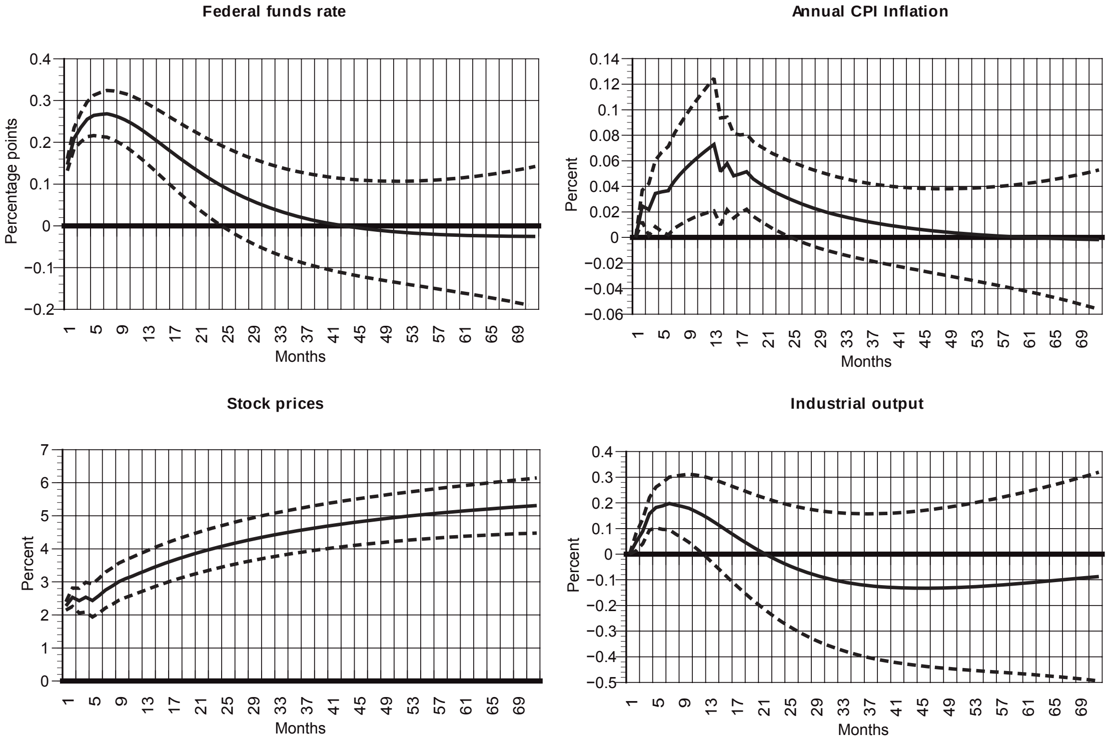
The real stock price shock

The way we have set up the VAR model, stock prices may react simultaneously to all shocks in the model. As noted in Section 2, given that the choice of macroeconomic variables in the model reflects the true macroeconomic variables relevant for determining the market value of the firms, the (real) stock price shock is unrelated to the present macroeconomic fundamentals. The shock can then either be interpreted as a "news" shock which contains information about the future that is not yet incorporated in current macroeconomic variables (see Beaudry and Portier, 2006) or a non-fundamental shock (sunspot), i.e. an innovation in stock prices that is driven purely by expectations. Under both of these interpretations, the shock may contain vital information to the central bank for reasons outlined in Section 2. It would nevertheless be interesting to be able to distinguish between the two interpretations and more precisely classify the shock. Under the "news" interpretation of Beaudry and Portier, the shock is an anticipated productivity shock leading to a delayed but permanent change in productivity. Their results indicate that most of the productivity shocks are anticipated by the stock market long before it is materialized. In the sunspot interpretation, it is more difficult to conceive of stock prices having permanent or even very persistent effects on output. The inspection of the impulse responses due to the stock price shock can thus guide the interpretation. The impulse responses are shown in Figure 3.

From the inspection of the impulse response to industrial production, we see that the stock market shock does not have a significant permanent effect on output. Hence, the point estimate suggests that a sunspot interpretation is the most appropriate: the average shock contains information about factors that do not have a permanent impact on production. The confidence intervals are, however, large and the estimates are not precise enough to rule out the "news" interpretation with confidence. Further, as will be discussed in the robustness tests below, small changes in the specification of the model may allow for somewhat more persistent responses in output; although eventually all yield responses not significantly different from zero. We therefore cautiously conclude that our results are more consistent with the stock price shock being a non-fundamental shock rather than an anticipated technology shock. In this respect, the results differ from that of Beaudry and Portier.

Although to scrutinize the source of difference between our studies are outside the scope of this paper, we highlight two issues. In the study of Beaudry and Portier, there is little simultaneous interaction between stock prices and TFP, as the identified shocks explain most of their "own" variation. In particular, the "stock price shock" identified in Beaudry and Portier explains almost 100 percent of the variation in stock prices at all horizons, but less than 10 percent of productivity (TFP) variation the first five years, increasing to 20-30 percent after 10 years. When Beaudry and Portier extend their model with consumption and investment, the long-run effect of their "stock price shock" on TFP becomes less significant. This suggests that expanding the model with other relevant variables questions the result that stock prices shocks are primarily anticipated technology shocks.

Figure 3. Impulse responses to a stock price shock.



Note: The figure shows the impulse responses of a real stock price shock to the federal funds rate, real stock prices, inflation and industrial output, with a standard error band.

Second, Beaudry and Portier allows for cointegration between productivity and stock prices by estimating both in levels and using a vector error correction model (VECM) with an imposed co-integration vector. While the reported error bands shows that the long-run (5 years) response of productivity to a stock price shock for the VECM model is (just) significant at a 10% level, the level model (assuming no cointegration) is known for wider error bands (not reported) which may indicate a non-significant long-run response. From both of these perspectives, the difference between their and our results appears smaller. This suggests, however, that we want to be cautious in making strong conclusions about the nature of the shock and the issue deserves further research.

One potentially important objection to our identification of the stock price shock is that the shock should have an immediate effect on other variables like employment, production and consumption (i.e., Jaimovich and Rebelo, 2006). This is ruled out by our identification scheme. However, it can be argued that it is not unlikely that the greater part of consumer prices together with consumption and investment decisions are subject to implementation lags of length similar to the model's monthly frequency (see, Woodford, 2003b, and Svensson and Woodford (2005), for arguments) and thus the impact restrictions used to identify the stock price shock may not be important for the results.

The stock price shock increases both inflation and output in the short run. An explanation that is consistent with this is that the rise in stock prices increases consumption through a wealth effect and investment through a Tobin Q effect, thus affecting aggregate demand. In the "news" interpretation of the stock market shock, technology may be implemented with a lag in the production process. In the sunspot interpretation, there are no changes in potential output. Under either interpretation, however, there is a period where aggregate demand is greater than potential output. Due to nominal rigidities, prices react slowly and inflation rises in the intermediate run. An inflation-targeting central bank would have a reason for raising interest rates as is confirmed in the model. Our analysis suggests that stock price shocks are important indicators for the interest rate setting. A stock price shock of one percent causes the interest rates to increase immediately by seven basis points and a further five basis points within a year. By increasing the interest rate, the FOMC achieves the reduction in aggregate demand through the usual interest rate channels and by reducing the positive impact on stock prices.

To sum up, the results presented so far suggest great interdependence between the effects of the shocks. How is it possible to reconcile the zero interdependence found using the Cholesky decomposition above, with that of large interdependence found in the present structural model? To see this, assume for simplicity a system in two variables, the interest rate (i_t) and the real stock price (s_t) The reduced form residuals will be linear relationship of the structural shocks, that is, the structural monetary policy shock and the stock price shock that are orthogonal,

$$\begin{aligned} u_{i,t} &= \varepsilon_t^{MP} + \alpha \varepsilon_t^{SP} \\ u_{s,t} &= \beta \varepsilon_t^{MP} + \varepsilon_t^{SP} \end{aligned}$$

with covariance given by $\operatorname{cov}(u_{i,t}, u_{s,t}) = E\left[(\varepsilon_t^{MP} + \alpha\varepsilon_t^{SP})(\beta\varepsilon_t^{MP} + \varepsilon_t^{SP})\right] = \beta\omega_{MP}^2 + \alpha\omega_{SP}^2$. Hence, a covariance close to zero implies either that the interdependence is zero, $\operatorname{cov}(u_{i,t}, u_{s,t}) = 0$, implying $\alpha = \beta = 0$ (as imposed using the Cholesky decomposition), or that the effects are opposite in signs and cancel out $\beta = -\left(\omega_{SP}^2 / \omega_{MP}^2\right)\alpha$. From the structural impulse responses reported above, the latter seems to be the case.

4.3. The error variance decomposition

We now turn to discussing the importance of the different shocks in accounting for the variance in the federal funds rate and in stock prices at different forecast horizons. The error variance decomposition may tell us more about the importance of stock market shocks as indicators for interest rate setting as well as for movements in stock prices themselves. Table 1 shows the error variance decomposition for the monetary policy and stock price shock.

In the short run, the monetary and stock price shocks account for almost all variation in the federal funds rate and stock prices, leaving the other shocks to influence these variables only in the longer run. This reflects the strong simultaneity between monetary policy and stock markets. Monetary policy shocks are important for explaining the variances in stock prices and the stock market conveys information that is important for explaining variations in the federal funds rate.

The strong response by the FED to stock price shocks is not direct evidence of the stabilization of stock prices independent of the less controversial objectives such as inflation and output. More likely, it is the result of stock prices being leading indicators of inflation and output, and the monetary policymaker reacting to stock prices due to the monetary policy lag in influencing these objective variables. From Figure 2, we see that a stock price shock raises both inflation and output which justifies a strong monetary policy response in itself as no trade-off between these typical objective variables is present. However, it can be argued that due to the stock prices explaining so little of inflation and output variability, the strong response to the stock price shock is unjustified if this is the case. This argument fails to take account of the fact that it can be the result of an appropriate systematic policy of trying to reduce the impact of these shocks on inflation and output.

Table 1. Error variance decomposition.

	Forecast horizon	MP-shock (%)	SP-shock (%)	Other shocks (%)
Federal funds rate	1	49.75	47.44	2.80
	6	25.88	53.65	20.46
	12	15.19	52.97	31.84
	24	9.80	48.28	41.92
	48	9.56	44.16	46.28
Real stock prices	1	45.55	51.38	3.07
	6	39.14	43.04	17.82
	12	28.66	47.45	23.89
	24	17.70	56.23	26.07
	48	8.58	66.64	24.78
CPI	1	0.00	0.00	100.00
	6	6.93	1.68	91.39
	12	10.16	3.65	86.19
	24	13.01	8.04	78.95
	48	15.24	13.57	71.19
Industrial production	1	0.00	0.00	100.00
	6	3.02	4.81	92.17
	12	7.40	4.87	87.73
	24	13.95	2.85	83.2
	48	20.74	3.55	75.71

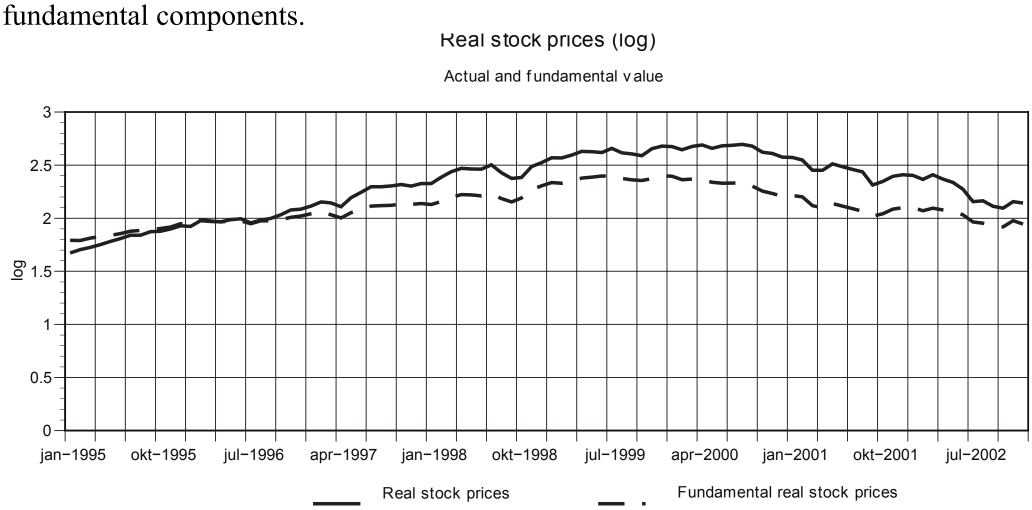
The table shows how monetary policy (MP) shocks, stock price (SP) shocks and remaining shocks contribute to the forecast error variance of key variables at different horizons.

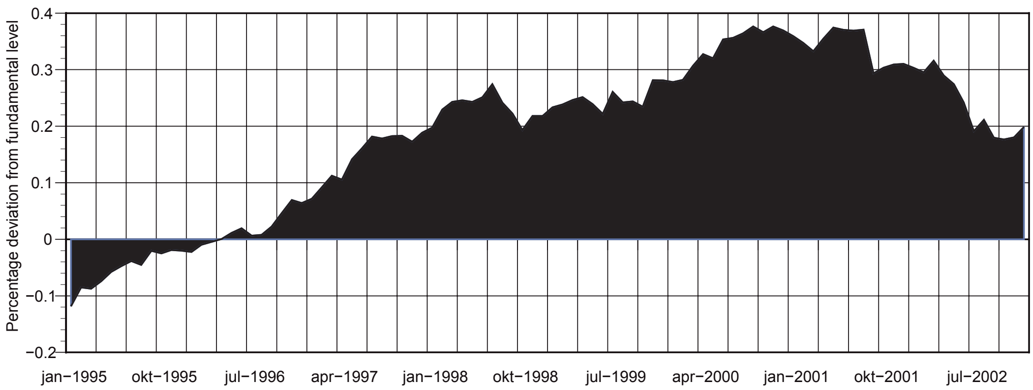
The results indicate that the unsystematic part of policy explains a large part of the interest rate movements in the short run, inducing stock prices to move extensively. Making policy more transparent and reducing the surprises are likely to induce greater interest rate and stock market stability. The importance of monetary policy shocks in explaining short-term stock market variations is also indirect evidence that stock market stabilization *per se* is of minor importance.

4.3 Historical decomposition

The previous section discussed the average impact of shocks on the variables. In this section, we discuss the contribution of stock price shocks on the federal funds rate and real stock prices in each period. To focus the discussion, we consider the booming period 1995 to 2002. Although we choose to refer to the stock price as a non-fundamental shock, we remind the reader that this interpretation in subject to a great deal of uncertainty and is open to alternative interpretations.

Figure 4. Historical decomposition of actual stock prices into fundamental and non-fundamental components.





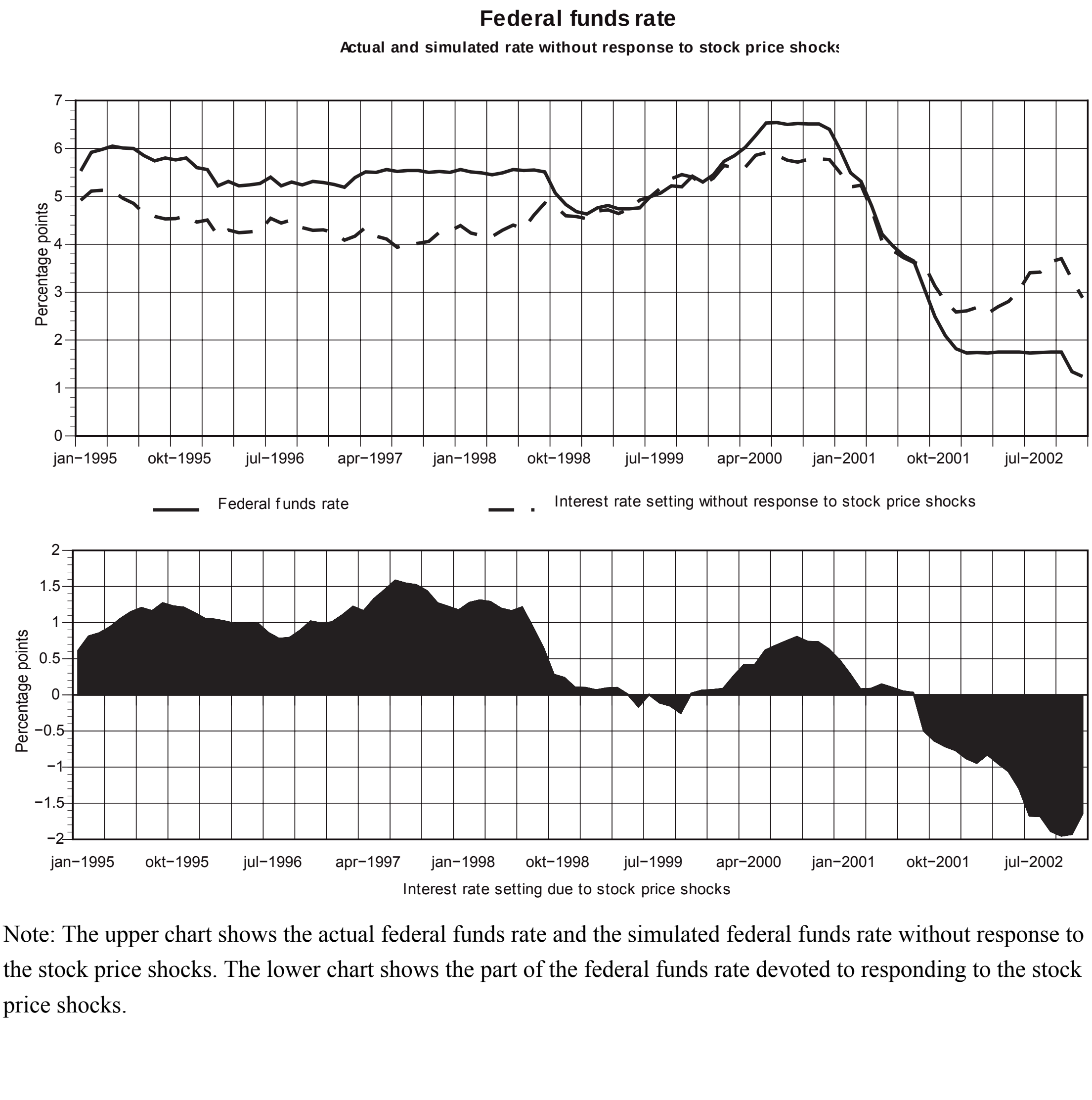
Note: The upper chart shows actual log real stock prices and the simulated log real stock prices under the condition that the stock prices shocks are set to zero in all periods. The lower chart shows the contribution of the stock price shocks to stock prices, measured in deviations from the simulated log real stock prices (as above).

The historical decomposition can illuminate several interesting questions: How much was the build up of stock prices in the greater part of this period driven by the non-fundamental factors? How would the evolvement of stock prices have been without these factors? Furthermore, how much did the buildup and ensuing fall contribute to interest rate setting in this period? The latter questions explicitly addresses how information in stock prices was used in the conduct of monetary policy.

In the upper chart of Figure 4, we plot two series. The first is the log real stock prices. The second, which has been derived simulating the VAR model, shows what real stock prices would be if the stock price shocks were set to zero for all periods. We denote this as the fundamental real stock price. The lower chart is the difference between these series and can be interpreted as the non-fundamental part of the stock price measured in deviation from the fundamental price.

The historical decomposition suggests that the buildup of stock prices in the second part of the 1990s was driven not only by fundamental factors, as non-fundamental factors also played an important role. In the middle of 2000, when stock prices peaked, we estimate that non-fundamental factors added about 35% to stock prices. The contribution of the non-fundamental factors remained high and started to decline at the time of the September 11 terror attack. At the end of 2002, the stock market still remained overvalued.

Figure 5. Federal funds rate: Actual and simulated without stock price shocks.



Note: The upper chart shows the actual federal funds rate and the simulated federal funds rate without response to the stock price shocks. The lower chart shows the part of the federal funds rate devoted to responding to the stock price shocks.

A similar historical decomposition of the Federal funds rate in Figure 5 suggests that the stock market shock has been important for interest rate setting in the period. As a result of stock price shocks, the Federal funds rate was kept on average 1 percentage point higher in the period 1995-1998. At the end of 1998 and corresponding with a fall in stock prices, there was a fall in the contribution of stock price shocks to the Federal funds rate. Throughout 1999 there was close to no contribution. In the year 2000 when stock prices were peaking, the contribution increased and decreased and shows a similar shape as stock prices. Since the terror attack of September 2001, the stock price shocks contributed to lowering the interest rate. We interpret the interest rate setting over this period as attempting to mitigate the effects of stock price shocks on central bank objectives. The historical decomposition suggests that stock market information have been an important source of information for the FOMC over the recent history.

5. Robustness of results

In this section we study the robustness of the result that there is strong simultaneous interaction between the stock market and monetary policy by using plausible alternative models. In the first section we study the robustness properties with respect to alternative monthly specifications of the model. In the second section we use a quarterly model that allows us to check whether the results are robust to using data on GDP instead of industrial production, and expanding the dimension of the model by including consumption and investment data.

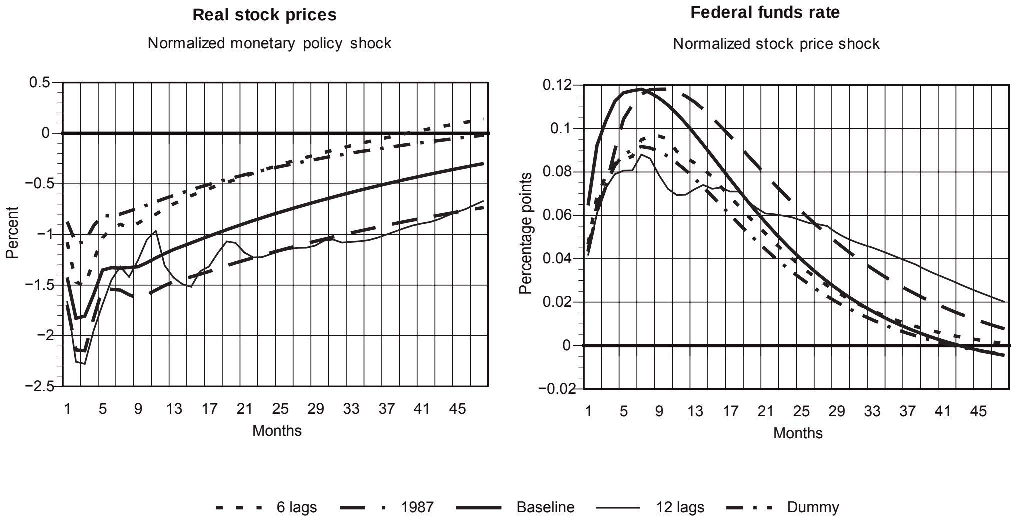
5.1 Robustness to alternative monthly specifications

In checking for robustness of our findings, it is important to establish whether the strong interdependence found is driven by a few extreme events of strong and simultaneous responses between stock prices and monetary policy. Throughout the period examined, there have been a few periods were the stock market fell severely (without the fundamentals changing significantly) while, at the same time, monetary policy became accommodating to counteract the negative effects of the stock market fall. The stock market crash in October 1987 is one example and the September 11, 2001 terror attack is another. Furthermore, it is important to establish whether our results can also be found in the period starting in 1987 when Greenspan took office. Finally, regarding model specification, is the choice of lag length in the VAR model important for our result?

To investigate the robustness of our results along these dimensions, we re-estimate the model (i) using two dummies for the suggested stock price collapses, (ii) focusing on more recent time, i.e. the Greenspan period 1987M1 to 2002M12 and (iii) choosing 6 or 12 lags for the VAR. Figure 6 reports the impulse responses of a normalized unity monetary policy shock to stock prices (left panel) and the effect of a normalized stock price shock on the federal funds rate (right panel).

We see from the impulse responses that across the models, there is a substantial and immediate fall in stock prices due to the monetary policy shock (that increases the interest rate with ten basis points initially). The baseline model has about the average response across the models. All models suggest that stock prices returns to the steady state at approximately the same speed.

Figure 6. Impulse responses in alternative monthly model specifications.



Note: The impulse response of the real stock prices to a monetary policy shock (left panel) and the federal funds rate to a stock price shock (right panel), under different monthly specifications of the model (see the main text for explanations)

There is a similar picture with respect to how the federal funds rate reacts to the stock price shock (that increases the real stock price with one percentage initially). Although our baseline model has the strongest immediate response, all models suggest that the interaction is quantitatively important and unrelated to model specification and sample period.[12]

5.2 Robustness to alternative quarterly specifications

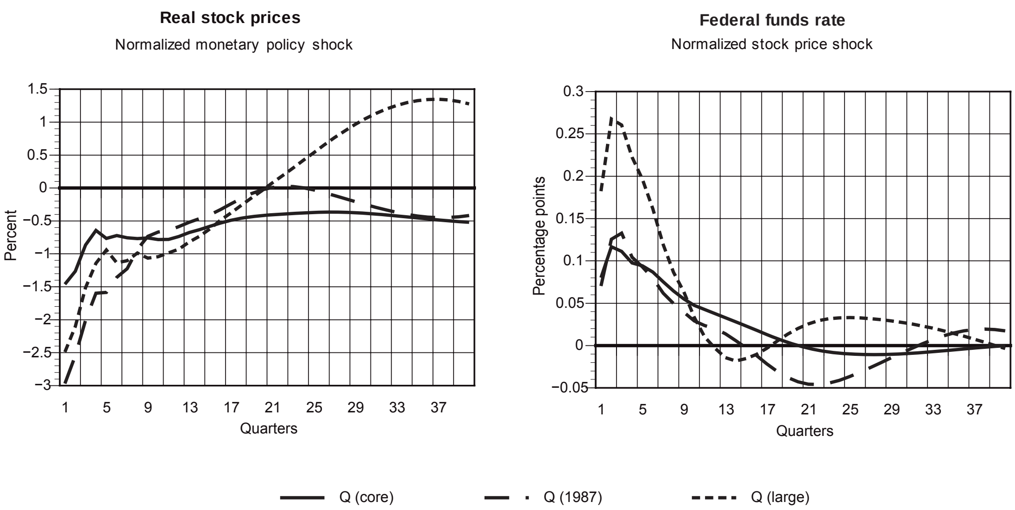
Although we believe that the interaction between monetary policy and asset markets is best modeled at a rather high frequency, a quarterly specification allows us to use other macroeconomic series arguably more important for monetary policy and aggregate stock prices. Our results are, however, confirmed in a robust manner also at this frequency. We consider several specifications of the quarterly model. We estimate the quarterly VAR model from both 1983 and 1987 with GDP replacing industrial production. In a third specification, we augment the VAR by replacing GDP with aggregate private consumption and investment. Throughout the analysis we use 4 lags in the VAR.

The impulse responses for these three models are plotted in Figure 7. In all quarterly models, the response of stock prices to a normalized monetary policy shock (that increases the

[12] Several other model specifications were also tried out. For instance, specifying the VAR in first differences, adding a trend or using annual inflation rather than the price level in the VAR, all produced qualitatively the same results.

interest rate with ten basis points initially) is even stronger than in the monthly models. The significant deviation from steady state is of a similar duration across all the models.[13]

Figure 7. Impulse responses in alternative quarterly specifications.



Note: The impulse response of the real stock prices to a monetary policy shock (left panel) and the federal funds rate to a stock price shock (right panel), under different quarterly specifications of the model, i.e. with sample starting in 1983 (Q core) and 1987 (Q 1987) and an alternative larger model with private consumption and investment replacing GDP (Q large).

The responses to the federal funds rate of a normalized stock price shock (that increases stock prices initially with one percent) are of similar magnitude, duration and shape both across monthly and quarterly specifications.[14] Note, however, that the positive response in GDP to a stock price shock is more persistent in the quarterly than in the monthly models, although the effect eventually dies out. The inclusion of the private consumption and investment series in the model do not change the response of the federal funds rate to the stock market shock. This indicates that the shock includes information important for monetary policy that is not available in the consumption or investment series. The impulse response of consumption and investment to a stock price shock shown in Figure A1 in the appendix suggests that investment is the variable more sensitive to non-fundamental factors in stock prices. However, the effect eventually dies out. We conclude that the strong interdependence result found between interest rate setting and the stock market is not accidental but seems to be a rather robust finding.

[13] The effect of the monetary policy shock on the other variables remains as before, although there is now much less of an initial puzzle in inflation than in the monthly model. However, the effect on inflation is still small.

[14] Note that we included a trend in the models containing GDP. The quarterly models without time trends were internally more sensitive to model specification, suggesting that there could be an omitted variable problem. However, excluding the trend, the results would suggest an even stronger immediate interaction that reported here. Replacing GDP with consumption and investment produces no longer such an instability problem and results for the larger VAR is therefore presented without the trend.

6. Concluding remarks

We find that there is a substantial simultaneous interaction between interest rate setting and the stock prices. Just as monetary policy is important for the determination of stock prices, the stock market is an important source of information for the conduct of monetary policy. This result is found in a many plausible and alternative model specifications that allows for the possibility of simultaneous interaction. We conclude therefore that the strong interaction is a reasonably robust finding.

Over the recent period, our results suggest that stock market information has been quantitatively important for the FOMC. The interest rate was used actively in mitigating the effects of the build-up and eventual fall of stock prices over the period 1995-2002. Our analysis also suggests that the stock market boom and bust over this period was driven to a large extent by fundamentals but also by factors that is likely to be sunspots.

Although our results indicate that the inclusion of stock market information in the VAR model is important for identifying monetary policy, we find little evidence leading us to reconsider the effects of a monetary policy shock on macroeconomic variables. This remains consistent with the results from previous studies.

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Appendix – extra figures

Figure A1. Impulse response of consumption and investment from a normalized stock price shock (that increases stock prices with one percent initially) in the quarterly model (Q large)