

# Identifying the Interdependence between US Monetary Policy and the Stock Market\*

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December 2004

## Abstract

We estimate the interdependence between US monetary policy and the S&P 500 using structural VAR methodology. We propose a solution to the simultaneity problem of identifying the 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 (CEE 1999). We find great interdependence between interest rate setting and stock prices. Stock prices fall immediately by two percent due to a monetary policy shock that raises the federal funds rate by 10 basis points. A stock price shock that increases stock prices by one percent, leads to an immediate increase in the interest rate of 10 basis points. Stock price shocks are orthogonal to the information set in the VAR model and can be interpreted as non-fundamental shocks. We attribute a major part of the surge in stock prices at the end of 1990s to these non-fundamental shocks.

**Keywords:** VAR, monetary policy, asset prices, identification.

**JEL-codes:** E61, E52, E43.

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\* We thank Dag Morten Dalen, Petra Geraats, Steinar Holden, Jan Tore Klovland, Erling Steigum, Kjetil Storesletten, Øystein Thøgersen, seminar participants at Cambridge University, Norwegian School of Economics and Business Administration, Norwegian School of Management BI, University of Oslo for valuable comments and suggestions. Views expressed are those of the authors and should not be associated with the views of our institutions.

## 1. Introduction

Most economists acknowledge that monetary policy has strong influence on private sector decision-making. In accordance with New-Keynesian theory, the central bank exerts some control of the real interest rate due to prices being sticky in the short run. 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, in particular, stock prices, are determined in a forward-looking manner, reflecting the expected future discounted sum of return on the assets. Changes in asset prices can then either be due to changes in the expected future dividends, the expected future interest rate that serves as a discount rate or changes in the stock return 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 that influence aggregate demand. Moreover, the change in the path of profit may influence expected dividends. Monetary policy, and in particular the 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 return premium by influencing the degree of uncertainty agents are facing. On the other hand, since asset prices may influence consumption through a wealth channel and investments through the Tobin Q effect, and moreover increases firm's ability to fund operations (credit channel), the monetary policymaker that manages aggregate demand in an effort to control inflation and output 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. It is therefore likely to be a strong interdependence between stock prices and monetary policymaking.

Both the identification and the effect of monetary policy have to a large extent been addressed in terms of vector autoregressive (VAR) models, initiated by Sims (1980). The VAR literature has to a large extent disregarded the link between the asset markets and monetary policy. There may be several reasons for that. One reason might be a belief that asset-price information conveys little extra information that is not incorporated elsewhere, i.e. in other macroeconomic variables incorporated in the VAR models. Another, but related reason may be that asset price information does not provide additional information in forecasting neither the determinants of the target variables nor the target variables themselves.<sup>1</sup> A third reason may be that the empirical investigation has been hampered by a simultaneity problem: Since asset prices is likely to respond immediately to a monetary policy shock, and monetary policy may respond immediately to an asset price shock, the structural shocks cannot be recovered using recursive, short-run restrictions on the parameters in the VAR model. It can be argued, however, that the two first suggested explanations in fact form interesting hypotheses that can be investigated using empirical methods. The third explanation is a more serious obstacle that needs to be addressed before any empirical investigation can be done.

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<sup>1</sup> The empirical finance literature has focused on explaining excess returns to assets, and the risk-free return is largely taken as given or explained by a simple, exogenous process.

In this study we consider the interdependence between stock prices and monetary policy within a VAR model and take full account of the simultaneity problem. We solve the simultaneity problem by imposing a combination of short-run and long-run restriction on the parameters of the VAR model. Moreover, asset prices shocks are important factors in explaining the variability of inflation and output. Furthermore, we find that a contractionary monetary policy shock has the usual effects identified in other studies as increasing the interest rate, temporarily lowering output and has a sluggish and an eventually negative effect on consumer price inflation. Moreover, a contractionary monetary policy shock lowers real stock prices. Monetary policymaking is also influenced by the stock market, as the interest rate rises significantly in response to a positive stock market shock.

In section 2 we discuss the role asset prices may play in monetary policymaking and reviews the literature. Section 3 discusses the VAR methodology used and Section 4 discusses the empirical results. Section 5 provides robustness checks and Section 6 concludes.

## **2. What role should asset prices play in monetary policymaking?**

What role asset prices should play in the conduct of a welfare-optimising monetary policy is an important topic in current monetary-policy analysis. From a theoretical point of view there are at least two important questions that could be addressed. First, should the central bank target asset prices *per se*, i.e., should stabilization of asset prices be a separate objective of the central bank? Second, to what extent should the central bank use asset-price information as indicators of the monetary-policy stance, i.e., should the central bank respond with the monetary policy instrument to asset price movements? The start of this section discusses these questions.

### **2.1 Asset prices as separate objectives**

In providing some illumination to these questions, it is convenient to start considering the theoretical foundations of monetary policymaking. Milton Friedman (1969) shows that in a setting with no nominal rigidities, monetary policy should supply money at a rate that is consistent with having nominal interest rates at zero, implying a rate of deflation that is equal to the yield on a risk-free asset. Rotemberg and Woodford (1998) show under the assumption of Calvo (1983) type of nominal rigidities, the 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. The existence of nominal rigidities creates price dispersions that disturb the relative price signals of scarcity. By targeting inflation at the rate of zero, price dispersions are minimised, as changes in prices at firm level are not caused by the requirement to keep up with the general increase in prices.

Price stickiness is not the only market imperfection that may provide a welfare enhancing role for monetary policy. Other market imperfections may rationalize other roles for monetary policy. Bernanke and Gertler (1999) and Carlstrom and Fuerst (2001) both argue that due to imperfect credit markets, the financial position of the firm may influence the firm's ability to operate, and asset prices affecting the net worth of the firm affects this operating constraint importantly. Whereas Bernanke and Gertler conclude by using a New-

Keynesian framework where inflation are linked to real activity, that responding to the forecast of inflation is sufficient to alleviate the adverse effect of the constraint, Carlstrom and Fuerst argue that the market imperfection substantiates a separate response of monetary policy to asset prices. Allen and Gale (2001) argue that agency problems between the bank and the investors may lead the investors to choose more risky investment projects and bid up asset prices: The greater the risk, the larger the asset price bubble. Moreover, a negative bubble may occur when bank starts liquidating assets as asset prices fall. They argue that the central bank should design policy so to reduce uncertainties and to stabilize asset prices around their fundamental values.

Borio and Lowe (2002) provides evidence that high asset price growth together with rapid credit expansion is an important indication for the risk of future financial instability, motivating a response from the central bank that cares explicitly about financial stability. However, they also argue that the indicator may also indicate a threat to monetary stability since financial instability may influence aggregate demand. Bordo and Jeanne (2002a, 2002b) also explore this idea. They argue that the existence of financial market imperfections, in particular, the role collateral plays in making credit available to the firms, may be an argument in favour of the central bank restricting the expansion of credit in periods with high asset price growth. Their argument is that if asset prices suddenly fall (bust), the value of the collaterals will also fall, producing a low credit-to-collateral ratio and possibly a credit crunch associated with inefficient falls in both output and inflation. Thus, the risk of a future decline in asset prices and a credit channel of monetary policy, introduces a role for reacting “pre-emptively” in times of booms to the risk of credit crunches in the future.<sup>2</sup>

Many central banks have announced inflation-targeting policies, in which the policymaker mainly attempts to stabilize inflation around some (positive) target level and the output gap (see, e.g., Svensson 1997). These objectives can be seen from a welfare-theoretical point of view as either government adherence to the view that there are relatively few market economy inefficiencies that are addressable by monetary policy (given the present knowledge of the monetary policy transmission mechanism), or as a simplified policy to address only the more important inefficiencies in the economy that are relatively well understood. It may also reflect a view that there are little trade-offs between inflation targeting objectives and asset market targeting objectives, i.e., by addressing the market inefficiencies through inflation targeting, asset market inefficiencies will also be minimized.

## **2.2 The role of stock prices as indicator variables**

Stock and other asset price information may, however, be useful to the monetary policymaker even if asset prices are not among the target variables. Thus, the qualitative answer to the second question in the introduction is not necessarily dependent on the answer to the first question. There are at least two reasons why stock price information may influence the monetary policy stance. The first reason is stock price may be leading indicators of the target

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<sup>2</sup> Eichengreen and Arteta (2000) find that a higher credit expansion increases the likelihood of a banking crisis.

variables.<sup>3</sup> Stock prices may influence consumption through wealth effects and influence investments through the Tobin Q effect (Tobin, 1969). If stock prices fall, the expected attainable stream of future consumption services is reduced and consumers would cut back on current consumption expenditure. Moreover, the market price of capital is reduced relative to its replacement cost, reducing the investment incentives. Moreover, a fall in asset prices are likely to reduce to value of collaterals which makes it more difficult for borrowers to obtain credit, thereby restricting aggregate demand (see Bernanke, Gertler and Gilchrist, 2000, and Bernanke and Gertler, 1989). Reduced demand may imply a weakening of cash flows which again reduce spending. This is the financial accelerator effect as described in Bernanke, Gertler and Gilchrist (2000). Moreover, reduced spending and income may lead to reduced asset prices and thereby to decrease of spending. Such a “debt-deflation” mechanism is modelled in Bernanke, Gertler and Gilchrist (2000).

The second reason for using asset price information is that they provide information about the expected development of the determinants of the targeting variables. According to the traditional theory, going back to Gordon (1962), asset prices are forward-looking variables that reflect the expected future return on the asset, which again is determined by fundamental variables. If the central bank is at no informational disadvantage versus the private sector and the fundamentals are observable, the “fundamentalist view” implies that asset prices do not convey information that is not available elsewhere. Hence, asset prices should not provide additional information to the policymaker, irrespective of whether asset prices are targeting variables or not.

If the policymaker, however, is at an informational disadvantage versus the private sector or the fundamentals are not fully observable to the policymaker, asset prices may be helpful as indicator variables as they reflect private sector expectations about the state of the economy.<sup>4</sup> Hence, asset prices may help in the extraction of information about the state of the economy.<sup>5</sup> The extraction problem is however complicated by the fact that the information content of forward-looking asset prices are dependent on the particular policy implemented. The information as well as the leading indicator properties of asset prices would therefore be expected to change with the systematic part of monetary policy.

It can be argued, however, that asset prices do not only reflect the fundamentals, but also that asset prices frequently include bubble components. Given the inefficiency of such bubble components and the assumption that monetary policy may reduce their size,<sup>6</sup> the non-fundamental view implies that there is a role for the central bank contributing to stabilizing the asset prices around the efficient price level. Moreover, due to the presence of bubble

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<sup>3</sup> Goodhart and Hofmann (2000) find that housing prices, equity prices and the yield spread may help predict CPI inflation. Stock and Watson (2001) argue, however, that asset prices are not stable explanatory variables of inflation and output; asset prices provide explanatory power only in some countries and in some periods. Bordo and Wheelock (2004) also find no consistent relationship between inflation and stock market booms.

<sup>4</sup> See Vickers (2000) for an overview of the use of asset prices in guiding monetary policy at inflation-targeting central banks.

<sup>5</sup> Svensson and Söderlind (1997) review different methods in obtaining information through the use of asset-price information.

<sup>6</sup> Allen and Gale (2001) argue that an appropriately designed monetary policy may reduce the size of bubbles and that there is a welfare-improving role for monetary policymaking in doing so.

components, asset prices influence target variables more than reflected by the fundamental part of the asset price. Hence, asset prices become distinct indicators of monetary policy (see, e.g., Cecchetti et al., 2001). However, given incomplete understanding of asset price determination (i.e., the underlying model), it may be difficult to identify possible bubble components and thus provide adequate monetary-policy responses. Bernanke and Gertler (2001) argue for instance that the identification of the bubble component is difficult and the central bank is left with the opportunity to respond to the asset price itself. Using a New-Keynesian model incorporating financial accelerator mechanism caused by financial market in-efficiency, they find that if the central bank responds aggressively to expected future inflation (only), “there is no significant additional benefit to responding to asset prices” (p. 254). Their approach can, however, be criticised for not modelling optimising monetary policy, but the central bank is rather modelled according to an interest-rate responding rule with responses only to a few (but important) arguments as expected inflation, output gap and a stock market price indicator. Hence, we do not know whether the conclusions of the paper reflect an inefficient monetary policy strategy or the stock market price is a bad indicator for monetary policy. Cecchetti et al. (2000) show that once allowing for efficient responses to the three indicators within this model, the ability to react to the asset price reduce loss in terms of the weighted output and inflation variability by between 22 and 99 percent. The reaction parameter is always modest, ranging between 0.01 and 0.5. Bullard and Schaling (2002) argue within the model framework of Rotemberg and Woodford (1999) that the benefits from responding separately to the asset prices are small. Moreover, a sufficiently strong response to asset prices may lead to indeterminacy of the rational expectations equilibrium and hence endogenous expectations-driven fluctuations.

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 that stock prices are useful indicators. Indeed, there are many arguments for why stock prices should influence monetary policymaking, at least to the extent they influence the forecasts of the objectives variables. The lack of a unifying theoretical framework to study the diversity of different arguments makes it difficult, however, to concretize how these arguments in fact may have and are influencing monetary policymaking. This is clearly reflected in the empirical contributions to the literature which we turn to now.

### **2.3 Empirical evidence**

Compared to the vast amount of papers analyzing the influence of the Central Banks monetary policy actions on the macroeconomic environment, there have been relatively few papers trying to model the interactions between the Central Banks monetary policy actions on asset prices. Among the first we find are Geske and Roll (1983) and Kaul (1987). In these articles, the link in the causal chain between monetary policy and stock market returns is examined and estimated separately (see, Sellin (2001) for a comprehensive survey of this literature). However, the error term in these individual estimations will be correlated and would therefore be more precisely identified using a joint estimation scheme. Recently, empirical studies have therefore tended to use the vector autoregressive (VAR) approach,

since it involves the joint estimation of all variables in one system. The VAR approach has also been in particular influential in the analysis of monetary policy effects in more standard macroeconomic analysis, starting with Sims (1980).

### **VAR studies**

VAR studies incorporating the stock market into the more traditional monetary analysis include, among others, Patelis (1997), Thorbecke (1997) and Neri (2004). All find that stock returns respond negatively to a tightening shock of monetary policy, but monetary policy shocks account for only a small part of the variations in stock returns.<sup>7</sup> Neri (2004) finds for the US that the stock market falls immediately by around one percent due to a monetary policy shock corresponding to an increase in the interest rate of one percentage point. The effect is however considerably larger after 4 months, at 3.6 percent. The effects are insignificant after half a year.

All the above papers identify monetary policy and stock market shocks using Cholesky decomposition which impose a recursive ordering of the identified shocks. In many of these papers, the stock market is ordered last, implying that the stock market can react contemporaneously to all other shocks, but the variables identified before the stock market (i.e. monetary policy stance) reacts with a lag to stock market news. Hence, simultaneous interactions are ruled out per assumption. However, as the focus in many of these papers has been to analyse the effect of monetary policy on the stock market, and not vice versa, this restriction has seemed reasonable, at least in the analysis using monthly data. However to the extent that one want 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 still imply that the effects are not being precisely estimated. We shall see that the simple Cholesky identification scheme severely underestimates the impact of both stock market shocks and monetary policy shocks on stock returns and interest rate setting.

Rapach (2001) identifies monetary and stock return shocks without resorting to using the traditional short-run Cholesky decomposition, but instead resorts to only using long-run restrictions. Addressing the simultaneity problem in a similar vein to the approach followed in our paper, Rapach finds considerably stronger interaction effects between monetary policy and the stock market.<sup>8</sup> However, while the sole use of theoretically motivated long run restrictions may be appealing, Faust and Leeper (1997) have demonstrated that the results based on this type of restrictions may be very unreliable. In particular, there is a strong possibility the effects of the different structural shocks may be confounded. This may clearly be the case in Rapach. For instance, by making the restriction that monetary shock is the only shock that can have only temporary effects on real stock prices and interest rates, one

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<sup>7</sup> The surprisingly small impact of a monetary policy shock on the stock returns is also found by Durham (2003). He uses an error correcting co-integration approach to identifying the monetary policy shock and finds that the federal funds rate has no direct impact on stock prices. The federal funds rate does, however, affect the 10-year treasury yield, which exert some impact on stock prices in the long run.

<sup>8</sup> A monetary policy shock that raises the interest rate by one percentage point, leads to a fall in stock prices by around 6 percent. Further, an unexpected increase in the stock prices of one percent, leads to a rise in the interest rate by around 0.05 percentage points.

effectively lumps together the effects of all temporary shocks into the monetary shocks. Clearly, as aggregate demand and money demand are examples of other shocks that can have only temporary effects on these variables, the long run restriction will not be sufficient to identify the true monetary policy shock.<sup>9</sup>

### **Non-VAR studies**

The problem of simultaneity has also been addressed by Rigobon and Sack (2003). They use an identification technique based on the heteroskedasticity of stock market returns to identify the reaction of monetary policy to the stock market. They 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). In similar vein, Rigobon and Sack (2004) 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.”

Recently, the interaction between the stock market and monetary policy has also been addressed with other methods. In an event study, Bernanke and Kuttner (2004) estimate the effect of an unanticipated rate cut of 25 basis points to be 1 percent in the level of stock prices. They attribute most of the effects of the monetary policy shock on stock prices due to its effect on forecasted stock risk premiums. In a similar event study, Ehrmann and Fratzcher (2004) 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.

Fuhrer and Tootell (2004) estimate interest rate reaction functions and argue that the FOMC reacts to stock price movements only to the extent that they influence forecasts of CPI inflation and real activity, and argues that stock price stabilization is not an independent objective of monetary policy. Chadha et al. (2003) estimate augmented Taylor rules using GMM and find that both stock price and the real exchange rate deviations from their equilibrium values in addition to the instrumented future inflation and output gaps are significant in the FOMC reaction function. Stock prices and the real exchange rate enter significantly and robustly for different choices of lead lengths for both the inflation and output gaps. They argue, however, that the significance may be due to these variables proxy the part of expected inflation and output gaps that are not well explained by the instruments.

Summing up, the empirical literature seems to identify important interactions between monetary policy and the stock market. In the case where studies find small interaction effects, these studies can be criticized for failing to take full account of the possible simultaneity between these sectors.

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<sup>9</sup> Lastrapes (1998) is the first study that identifies the interaction between monetary policy and the stock market using solely long run restrictions. However, except for the money supply shock, the model is left underidentified, thereby failing to identify stock price shocks. This makes the criticism by Faust and Leeper (1997) even more relevant, as all type of temporary (demand and supply) shocks can now be effectively lumped into the identified money supply shock.



### 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 recursively a 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 the monetary policy shocks. Stock prices and monetary policy are on the other hand allowed to react simultaneously to each other. By assuming instead that monetary policy shocks can have no long run effects on interest rates, we preserve the interpretations of monetary policy shocks as the unanticipated components of interest rate movements, at the same time as we have enough restriction to identify and orthogonalize all shocks. By using only one long-run restriction, we address the simultaneity problem without deviating extensively from the established literature (i.e., Christiano et al., 1999) of identifying a monetary policy shock as an exogenous shock to an interest rate reaction function (the systematic part of monetary policy).<sup>10</sup> Once allowing 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 the log of the annual changes in the consumer price index (CPI) ( $\pi_t$ ) – referred to as inflation hereafter, 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 price index ( $s_t$ ). Industrial production and stock prices are deflated by CPI, so that they are measured in real terms. The federal funds rate and the stock price index are observed daily, but 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 will 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 but also to investigate to what extent the (systematic) monetary policy stance is influenced by stock market developments. This final issue has rarely been discussed in the applied VAR literature. As discussed above, we believe the reason being that empirical investigation has been hampered by a simultaneity problem.

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 monetary policy and stock price shocks that allow monetary policy stance and stock prices to react simultaneously to the identified shocks.

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<sup>10</sup> As opposed to Rapach (2001) who use long run restrictions to identify *money supply shocks*, which may be quite distinct from the *monetary policy shocks* traditionally identified in the literature.

### 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

$$i_t = f(\dots)_t + \sigma \varepsilon_t^{MP}, \quad (1)$$

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 that relates the instrument to the information set (feedback rule). The monetary policy shock  $\varepsilon_t^{MP}$  is normalised to have unit variance, and  $\sigma$  is the standard deviation of the monetary policy shock. Having identified the feedback rule (from the variables that are in the information set) the VAR approach concentrates on deviations from this rule. Hence, such deviations provide researchers with an opportunity to detect the responses of macroeconomic variables to monetary policy shocks that are not expected by the market.

In a similar vein, stock price shocks are identified from the equation of stock prices. To the extent that the variables in the VAR reflect true fundamental variables relevant for the stock market, any reaction above the average response in the stock market to these variables can be interpreted as a non-fundamental stock price shock and the source of possible bubbles in the stock market.

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 of the effects of the shocks onto 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, 1992), and Christiano et al. (1999) among many others. Bagliano and Favero (1998) show that when monetary policy shocks are identified in this recursive way on a *single* monetary policy regime, these shocks suggest a pattern for the monetary transmission mechanism that is consistent with the impulse responses of monetary policy shocks identified instead using financial market information from outside the VAR, as in, e.g., Rudebusch (1998). This would also limit the practical importance of the Lucas critique, since a stable regime does not require any re-parameterization.

However, as discussed above, a more profound problem with this recursive identification, is that once one include high frequency data such as stock prices into the VAR, it becomes difficult to validate that monetary policy should not be contemporaneously affected by shocks to these financial variables. To be able to solve this simultaneity problem, we therefore use instead 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 the interest rate.

Assume  $Z_t$  to be the (5x1) vector of macroeconomic variables discussed above,  $Z_t = (\Delta y_t, \pi_t, \Delta c_t, \Delta i_t, \Delta s_t)'$ , where we for simplicity now assume that all variables but inflation are difference-stationary.<sup>11</sup> The reduced form VAR can be written in matrix format as

$$A(L)Z_t = v_t, \quad (2)$$

where  $A(L) = \sum_{j=0}^{\infty} A_j L^j$  is the matrix lag operator,  $A_0 = I$  and  $v_t$  is a vector of reduced form residuals with covariance matrix  $\Omega$ . Assuming  $A(L)$  to be invertible, (2) can be written by its moving average

$$Z_t = B(L)v_t, \quad (3)$$

where  $B(L) = A(L)^{-1}$ . 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 ( $\varepsilon_t$ ) can be written as linear combinations of the innovations ( $v_t$ ), i.e.,

$$v_t = S\varepsilon_t. \quad (4)$$

The VAR can then be written in terms of the structural shocks as

$$Z_t = C(L)\varepsilon_t, \quad (5)$$

where

$$B(L)S = C(L). \quad (6)$$

Clearly, if  $S$  is identified, we can derive the MA representation in (5) 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, one needs to apply restrictions on the  $S$  matrix. Only then can one recover the relevant structural parameters from the covariance matrix of the reduced form residuals.

To identify  $S$ , we first assume that the  $\varepsilon_t$ 's are normalized so they all have unit variance. The normalisation of  $\text{cov}(\varepsilon_t)$  implies that  $SS' = \Omega$ . With a five variable system, this

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<sup>11</sup> This assumption will be discussed further in Section 4.

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. Of these, there will be nine contemporaneous restrictions directly on the S matrix. These are consistent with a Cholesky decomposition used on the part of the S matrix that ignores the financial variables, and as discussed above, are standard in the VAR literature on monetary policy shocks. In addition we impose one commonly accepted restriction on the long run multipliers of the C(L) matrix.

With a five variables VAR, we are able to identify five structural shocks; The two first are the main focus and can be interpreted as monetary policy shocks ( $\varepsilon_t^{MP}$ ) and real stock price shocks ( $\varepsilon_t^{SP}$ ). We follow the practice in the VAR literature and only loosely identify the last three shocks as commodity price shocks ( $\varepsilon_t^{CO}$ ), inflation shocks (interpreted as cost push shocks) ( $\varepsilon_t^{CP}$ ) and output shocks ( $\varepsilon_t^Y$ ). Ordering the vector of uncorrelated structural shocks as  $\varepsilon_t = (\varepsilon_t^Y, \varepsilon_t^{CP}, \varepsilon_t^{CO}, \varepsilon_t^{SP}, \varepsilon_t^{MP})'$  and following the standard 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

$$S = \begin{bmatrix} S_{11} & 0 & 0 & 0 & 0 \\ S_{21} & S_{22} & 0 & 0 & 0 \\ S_{31} & S_{32} & S_{33} & 0 & 0 \\ S_{41} & S_{42} & S_{43} & S_{44} & S_{45} \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} \end{bmatrix}. \quad (7)$$

The standard Cholesky restriction, namely to assume that macroeconomic variables do not simultaneously react to the 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 assuming zero restrictions on the relevant coefficients in the S matrix as described in (7).

So far, output, price and commodity price shocks have only been loosely identified. However, they can be interpreted somewhat further by examining the first three columns in S. The first two columns imply that while price shocks can affect all variables but output contemporaneously, output shocks can affect both output and prices contemporaneously. Hence, it seems reasonable to interpret price shocks as a cost push shock (moving prices before output), whereas output shocks will be dominated by both demand shocks (in the short run) and supply shocks (in the long run). Consistent with the VAR literature (see Bagliano and Favero, 1998), we have placed commodity prices after output and prices in the ordering, thereby assuming that commodity prices will react to output and cost price shocks, while commodity price shocks will have no contemporaneous effect on output and prices.<sup>12</sup>

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<sup>12</sup> We have also experienced with alternating the order of the first three variables in Z, without the results being much affected.

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 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 if that makes a difference, will not produce the correct impulse responses if there is a genuine simultaneous relationship between the two variables. Most likely it will lead to the effects of the shocks being underestimated, as a recursive ordering will always either a) disregard the simultaneous reaction of the monetary policy stance to the stock price shocks, or b) exclude the simultaneous reaction of the stock price to the monetary policy shocks. This will effectively be demonstrated in the next section.

Instead, we impose the restriction that a monetary policy shock can have no long run effects on the interest rates. This can simply be found by setting the infinite number of relevant lag coefficients in (5),  $\sum_{j=0}^{\infty} C_{45,j}$ , equal to zero. By using the long run restriction rather than a contemporaneous restriction between asset prices and monetary policy shocks,  $S_{45}$  may be different from zero. Writing the long run expression of (6) as

$$B(1)S=C(1), \quad (8)$$

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  $C_{45}(1) = 0$  implies

$$B_{41}(1)S_{15}+B_{42}(1)S_{25}+B_{43}(1)S_{35}+B_{44}(1)S_{45}+B_{45}(1)S_{55}=0. \quad (9)$$

The system is now just identifiable. Note that no restrictions are placed on real stock prices, as we do not have a lot of priors as to how the stock market is affected by either of the shocks.

#### 4. Empirical modelling and results

We 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). However, we have also experimented with a starting period in 1987, thereby excluding the Volcker-period from the sample and concentrating on the Greenspan period, for reasons of being more likely to find stability in the identified monetary policy interest reaction. This did not change results in any important ways.

The variables are modelled in levels, as is standard practice in many of the VAR models.<sup>13</sup> However, Giordani (2001) has argued that if one should follow the theoretical model set up in Svensson (1997) as a data generating process in monetary policy studies, instead of including output in levels, we should either include the output gap in the VAR, or the output gap along with the trend level of output. However, as pointed out by Lindé (2003), a practical point that Giordani does not address is how to compute trend output (thereby also the output gap). We therefore instead follow Lindé (2003), and include a linear trend in the VAR along with output in levels. In that way we try to address this problem by modelling the trend implicit in the VAR. Also, the use of a trend in the VAR serves as a good approximation for assuring that the VAR is invertible if the variables are non-stationary, in particular given the short span of data we are using. Note that the inclusion of such a time trend makes the discussion of the effects of the identified shocks on different variables relative to some average development of these variables. However, in section 5 we test the robustness of our results to other VAR specifications, among other by instead first differencing the VAR. There are no qualitative changes to the impact of the shocks.

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 in the VAR, there is no evidence of autocorrelation, heteroscedasticity or non-normality in the model residuals.

#### **4.1 Cholesky decomposition**

If there is strong simultaneity between shocks to monetary policy and stock prices, we would not expect that a Cholesky decomposition of the effects on shocks would pick up this simultaneity, since one of the shocks are restricted to have no 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. They are shown for two different ordering of variables, with monetary policy and stock price shocks alternating as the penultimate and ultimate variables.<sup>14</sup>

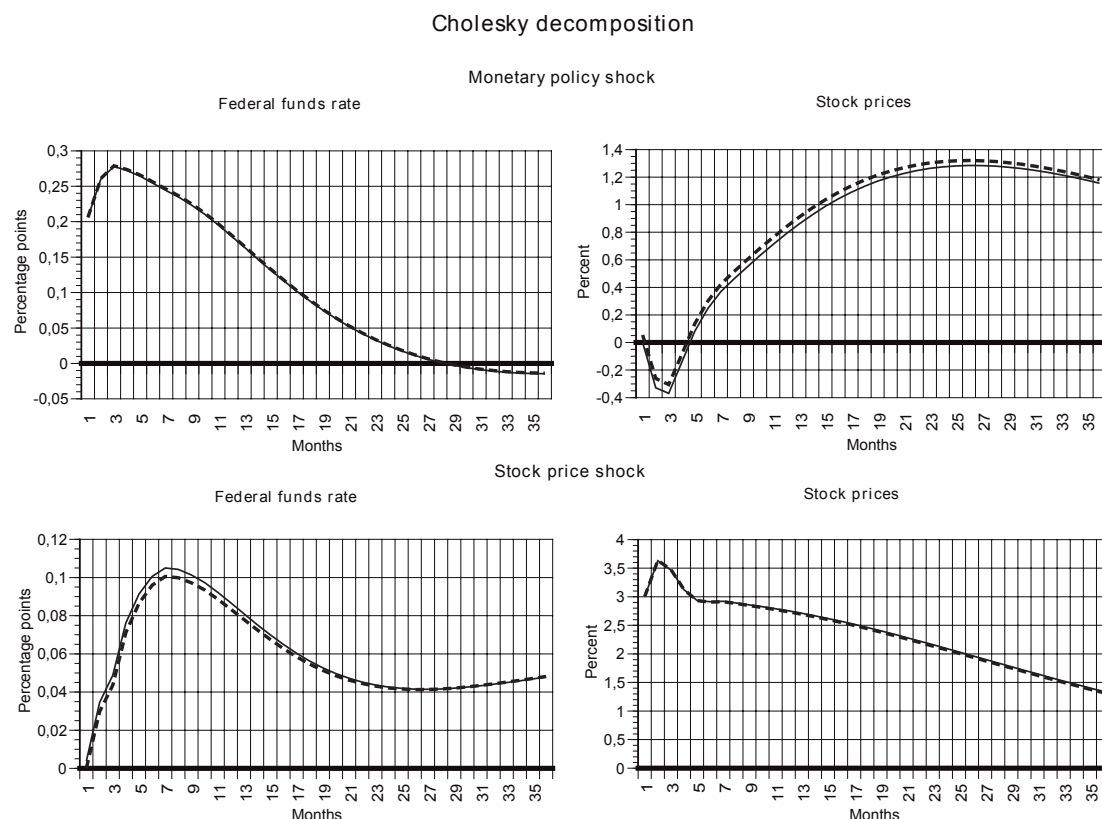
Restricting either the monetary policy shock to have no immediate effect of stock prices or the stock price shock to have no immediate effect on interest rates, we see that neither the monetary policy shock nor the stock price shock has important immediate effects on the other variables. Assuming that both the stock market and monetary policy react importantly to shocks in the other sector, and interaction is important, the restriction imposed by either Cholesky ordering will distort the estimates of the two shocks in such a way that the degree of interaction will seem unimportant.

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<sup>13</sup> Based the standard Augmented Dickey Fuller (ADF) unit root test, we can not reject that any of the variables except inflation are integrated of first order. However, none of the variables are cointegrated. The variables should therefore be represented in its first differences. However, due to the low power of the ADF tests to differentiate between a unit root and a persistent (trend-) stationary process, we can not rule out that the variables could equally well be represented in levels, but with a trend.

<sup>14</sup> The VAR model uses a time trend as we have used in our empirical modelling approach. Excluding the time trend does not change the picture in any important ways, as is illustrated below in section 5.1.

**Figure 1.** Impulse responses with two Cholesky identification schemes.



Note: The solid line represent the ordering with the federal funds rate last and the dashed line with real stock prices last.

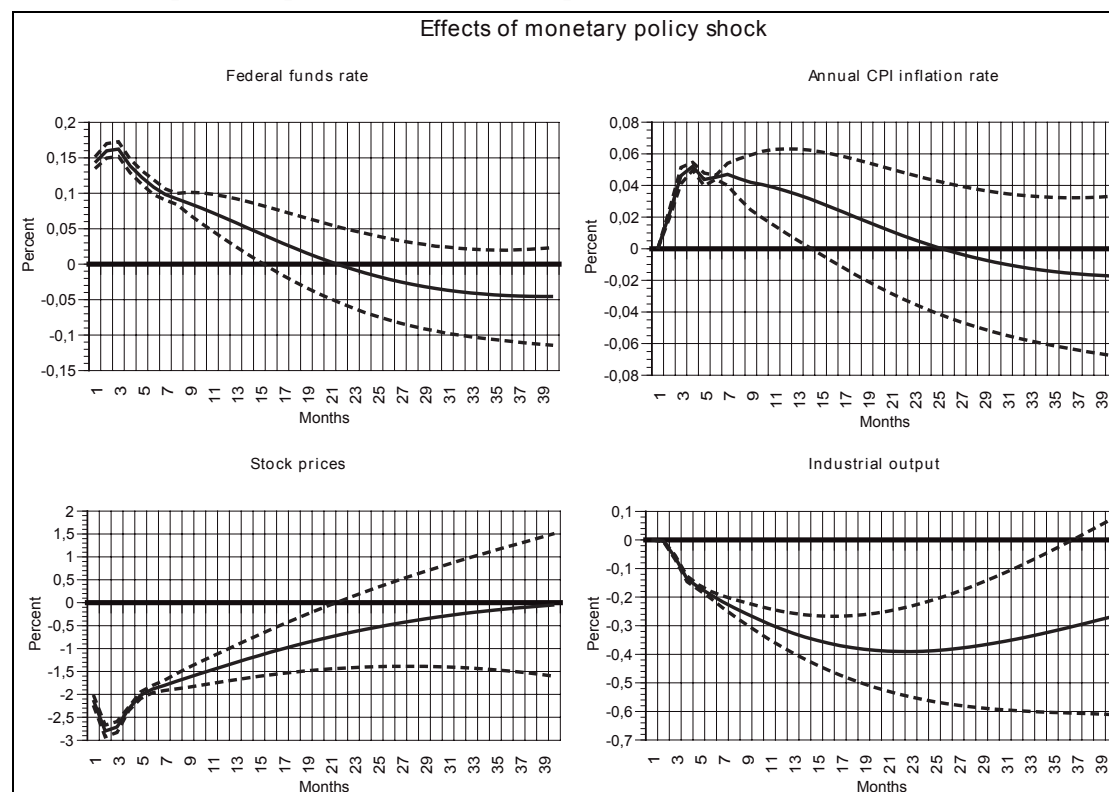
## 4.2 Our identification scheme

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 prices shock. The impact of the other shocks to the model is briefly illustrated in diagrams in the appendix.

Figures 2 and 3 show the impulse responses to the federal funds rate, stock market price, annual inflation and industrial production of a monetary policy shock and a stock market shock, respectively. The figures also give a one standard deviation band around the point estimates, reflecting uncertainty of estimated coefficients.<sup>15</sup>

<sup>15</sup> The standard errors reported are calculated using Monte Carlo simulation based on normal random drawings from the distribution of the reduced form VAR. The draws are made directly from the posterior distribution of the VAR coefficients, as suggested in Doan (2004). The standard errors that correspond to the distributions in the  $D(L)$  matrix are then calculated using the estimate of  $D_0$ .

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.

### The monetary policy shock

The effect of the monetary policy shock which increases interest rates temporary on the real economy is as expected. Output falls temporarily and reaches its minimum after a year and a half. For a monetary policy shock of a unit percentage point increase in the interest rate, output has then been reduced by a total of two percent. The effect on output is clearly significantly different from zero.

Inflation first increases, disinflation is present after half a year and prices start to fall after another a year and a half. The effect on inflation is small and not significant. The small effect of 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.. Whereas the initial increase in inflation has recently been explained (see, Ravenna and Walsh, 2003, and Chowdhury et al., 2003) by a cost channel of the interest rate (i.e., the increased interest rate increases borrowing costs for firms and therefore prices) and is less of a puzzle. The positive long-run effect of the interest rate on inflation is more difficult to explain. Neo-Keynesian (e.g, Svensson, 1997) and New-Keynesian (see, Rotemberg and Woodford, 1998, 1999, Galí et al., 1999, and Woodford, 2003b) models predict that inflation falls as a result of output deviating negatively from its potential. The puzzle has typically been addressed by adding a commodity price index to the VAR model, initially suggested by Sims (1992). The idea is that commodity prices are leading indicators of inflation and are 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 in order to extract the true monetary policy shock. As Hanson (2004) notes, however, this approach is less successful in alleviating the price puzzle in VAR models estimated using data for the past 20 years. Although our VAR model does eventually produce a reduction in inflation, it is small and the total long-run effects on prices are about neutral, broadly supporting the conclusions in Hanson.<sup>16</sup>

There is a high degree of interest-rate inertia in the model, as a monetary policy shock is only offset by a gradual lowering of 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, goes below its steady-state value. Both the interest-rate inertia and the “reversal” of the interest rate stance are consistent with what has become known to be good monetary policy conduct. As Woodford (2003a) shows, interest-rate inertia is known to let the policymaker smooth the effects of policy out 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.

The monetary policy shock has a strong impact on stock return, as stock prices immediately falls by around one and a half percent for each 10 basis point increase in the federal funds rate. The magnitude of the effect is large; in fact, it is in the upper region of the estimates found in other studies. The effect is, however, relatively short lasting, as the effect of the shock becomes insignificant after about a year and a half.

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### **Result 1**

*A monetary policy shock that initially increases the interest rate has an immediate and significant negative impact on stock prices.*

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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 is likely to reduce expected future dividends. Real stock prices are depressed for a prolonged period after the monetary policy shock.

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### **Result 2**

*Stock return is higher after the monetary policy shock and falls only gradually back to an average return.*

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Stock returns are higher for most of the year following the monetary policy shock but declines gradually towards the average level. Although interpretations of result should be made with great care, a potential explanation might be that as the interest rate gradually falls, the

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<sup>16</sup> Hanson (2004) obtains the most favourable results in reducing the prize puzzle by using the Commodity Research Bureau spot commodity price index. We have also tried using this index without the results changing importantly.

discounted value of expected future dividends increases and there is a normalization of dividends, leading to an increase in stock prices.

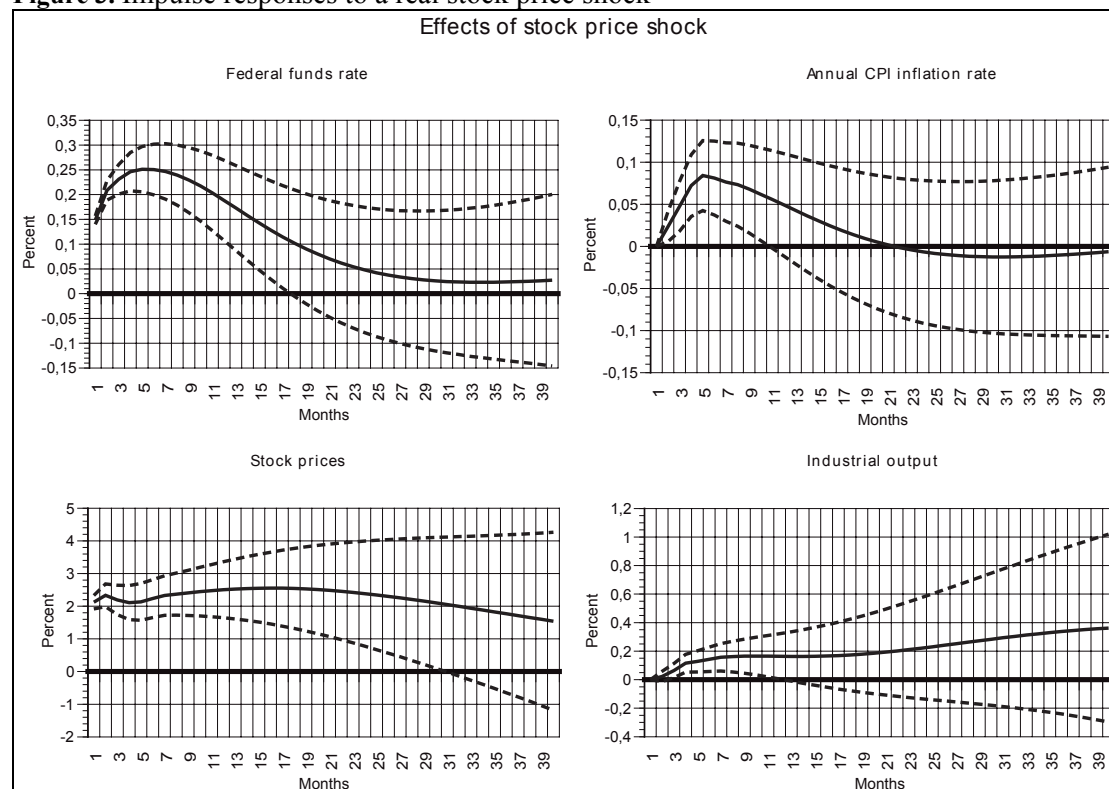
### The real stock price shock

As we have set up the VAR model, stock prices may react simultaneously to all shocks in the model. As noted in Section 3, given that choice of variables in the model gives a reasonable account of the fundamental variables determining the forward-looking stock price, the own shock to stock prices can be interpreted as a non-fundamental shock – unexplained by the other variables in the model. The impulse responses are depicted in Figure 3.

### Result 3

*A stock market shock that raises stock prices leads to an immediate increase in the federal funds rate.*

**Figure 3.** Impulse responses to a real stock price shock



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

The stock price shock increases both inflation and output in the short run, but the effect has faded out within a year and inflation and output is back in steady state. Explanations consistent with this are that the rise in the stock prices increases consumption

through a wealth effect and investment through a Tobin Q effect, affecting both aggregate demand and inflation. The stock price shock has persistent effects on stock prices. It allows for long-lasting booms in the stock market to be explained by non-fundamental factors.

We find that stock price shocks are important indicators for interest rate setting. Interest rates increase immediately by about 8 basis points to a stock price shock of one percent. The relatively strong response might be motivated both by the FOMC's concern about reducing the impact of the shock on inflation and output both by conducting a policy that will offset the effect on inflation and output through other channels, but also by reducing the stock price shock's impact on stock prices themselves – diminishing the source of the problem.

#### **4.2. The error variance decomposition**

We now turn to discuss the importance of the different shocks in accounting for the variance in the federal funds rate and in stock prices at different forecast horizons. Note that the inclusion of a time trend in the model makes the interpretation of the shocks impact on the trended stock prices and production relative to the average growth of these variables over the sample. Table 1 shows the error variance decomposition for the monetary policy, stock price, cost push and output shocks.

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. 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.

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#### **Result 4**

*Monetary policy shocks and stock market shocks are both quantitatively important in explaining variations in both the federal funds rate and stock prices.*

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To the extent that our model includes all the relevant variables for monetary policy decisions, the results indicate that the unsystematic part of policy explains a large part of interest rate movements, inducing stock prices to move extensively. Hence, making policy more transparent and reduce the surprises is likely to substantially stabilize both interest rate setting and the stock market. The value of an improvement to interest rate forecasting should be significant for agents operating in the stock market.

Are the results obtained consistent with the systematic part of policy being in accordance with good monetary policy conduct? According to New Keynesian theory (see, Clarida et al., 1999, for an overview), a central bank that is concerned with stabilizing inflation and the output gap (actual output deviations from its potential) will try to neutralize the impact of the demand shock on the output gap completely and trade-off the impact of

**Table 1. Error variance decomposition.**

	Forecast horizon	MP-shock (%)	SP-shock (%)	Cost push - shocks (%)	Output shocks (%)
<b>Federal</b>					
<b>funds rate</b>	1	46.80	50.33	1.11	1.54
	4	31.64	54.38	3.25	6.97
	12	15.75	52.01	8.70	22.71
	24	10.15	46.90	6.42	31.77
	48	4.88	41.71	2.28	42.75
<b>Real stock</b>					
<b>prices</b>	1	48.95	48.99	1.60	0.37
	4	52.93	41.38	4.98	0.65
	12	39.99	45.99	12.59	0.30
	24	26.56	52.56	16.87	2.44
	48	14.77	59.18	17.35	6.34
<b>Inflation</b>	1	0.00	0.00	95.61	4.39
	4	0.88	1.19	93.62	3.56
	12	2.11	4.83	90.20	2.41
	24	2.78	5.36	90.09	1.37
	48	2.30	4.17	91.22	0.92
<b>Industrial</b>					
<b>output</b>	1	0.00	0.00	0.00	100.00
	4	0.68	0.74	0.84	96.80
	12	6.40	3.32	5.96	81.29
	24	11.92	3.93	21.40	59.86
	48	13.86	6.73	37.85	40.26

The Table shows how the monetary policy (MP) shocks, stock price (SP) shocks, cost-push shocks (CP) and output (Y) shocks contribute to the forecast error variance of key variables at different horizons. The remaining variability is due to non-reported commodity price shocks.

cost-push shocks between inflation and the output gap. Movements in inflation should hence only be explained by cost-push shocks, whereas output should be explained by cost-push shocks and productivity shocks (affecting potential output). We find that inflation movements are more or less only explained by cost-push shocks (always above 90 percent). As noted earlier, the output shocks are likely to represent a mixture of demand and productivity shocks. Whereas the central bank should neutralize the impact of demand shocks on output, it should accommodate productivity shocks fully and let them affect output. However, since there is clearly a lagged effect of monetary policy on output, the demand part of the output shocks can only be neutralized slowly over time. Interestingly, our results indicate that the output shocks have most effect on output in the short run, whereas the cost-push shocks dominate more in the longer run. This is at least consistent with the FOMC only letting productivity shocks affecting output in the intermediate run. Although the direction and magnitude of the responses of the FOMC seem to be in accordance with good monetary conduct, there seems to be a lagged response to variables. The federal funds rate response to output shocks are modest within a quarter of the shock. Only after a year, the response explains a quarter of the variation in the federal funds rate. Note that this caution and implementation lag in monetary

policy can be due to uncertainty about the present state as real-time estimates are subject to a great deal of measurement errors (see Orphanides, 2001, and Leitemo and Lønning, 2004)

The strong response by the FED to stock price shocks is no direct evidence of stabilization of stock prices independently from the less controversial objectives as inflation and output. It is more likely a 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 are present. It can be argued, however, that due to the stock prices explaining so little of inflation and output variability that the strong response to the stock price shock is unjustified if this is the case. This argument fails to take account for the fact that it can be a result of an appropriate systematic policy of trying to reduce the impact of these shocks on inflation and output.

Under the condition that model gives a reasonable account of the systematic part of policy by the inclusion of relevant variables in the VAR model, the hypothesis of stock price stabilization being an import independent objective is further weakened by the unsystematic part of policy is contributing so much to instability in stock prices itself. If stock price stabilization is important, then it would seem that making interest-rate setting more predictable (reducing the unsystematic part of policy) would be an important objective for the FED.

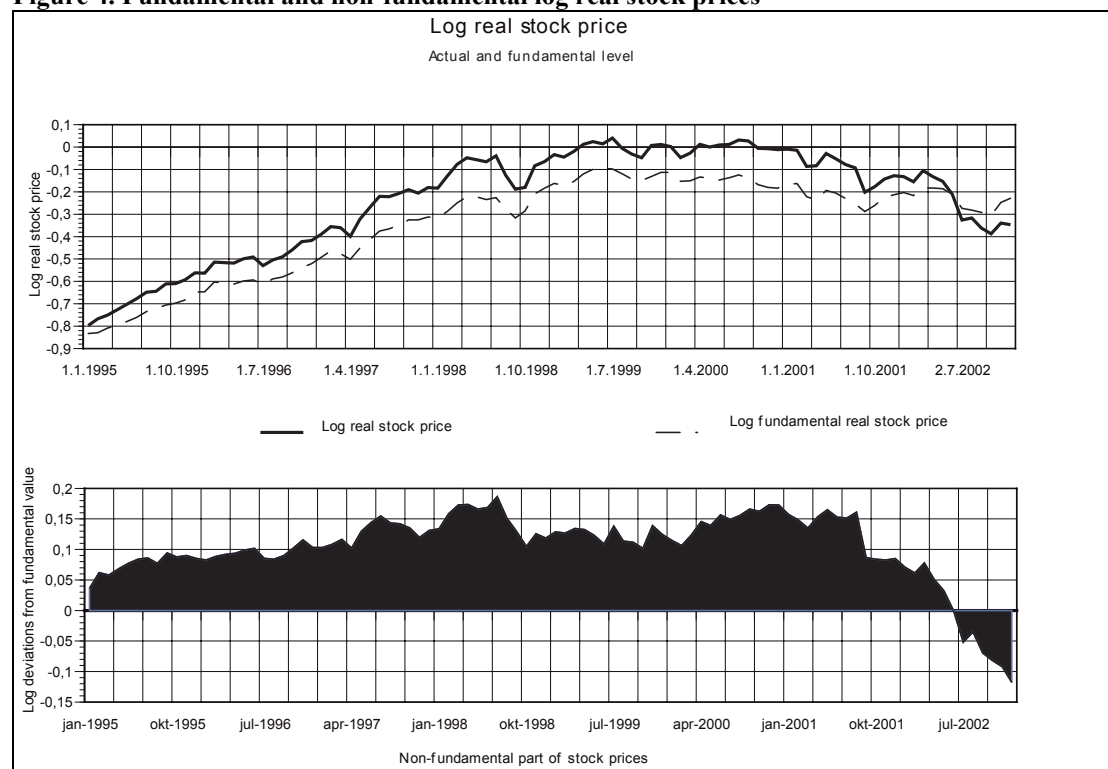
### **4.3 Historic stock price evolvement**

One interesting question is whether the relatively recent stock price up and down swing was due to fundamental or non-fundamental factors. In the upper chart of Figure 4, we plot two series. The first is the log real stock price. The second, which has been derived simulating the VAR model, shows what real stock prices had been if the non-fundamental, stock price shocks are set to zero for all periods. It has therefore the interpretation of being the fundamental stock price level. The lower chart shows the recent stock price “bubble”, that is, the contribution of the non-fundamental factors to stock prices, shown as percentage deviation log real stock prices from the fundamental level.

We see that the bubble has contributed importantly to stock prices. From the start of the period in January 1995 until July 2002, non-fundamental factors added to the fundamental level consistently above 5 per cent. In July 1998 the contribution reached a peak of 20 percent. The contribution was similarly high in the period April 2000 to October 2001, with contribution varying between 10 and 15 percent. Although the September 11, 2001 event contributed to reducing the bubble, it was not before June 2002 that non-fundamental factors drove stock prices below their fundamental level. At the end of 2002, the contribution was numerically important at -10 percent.

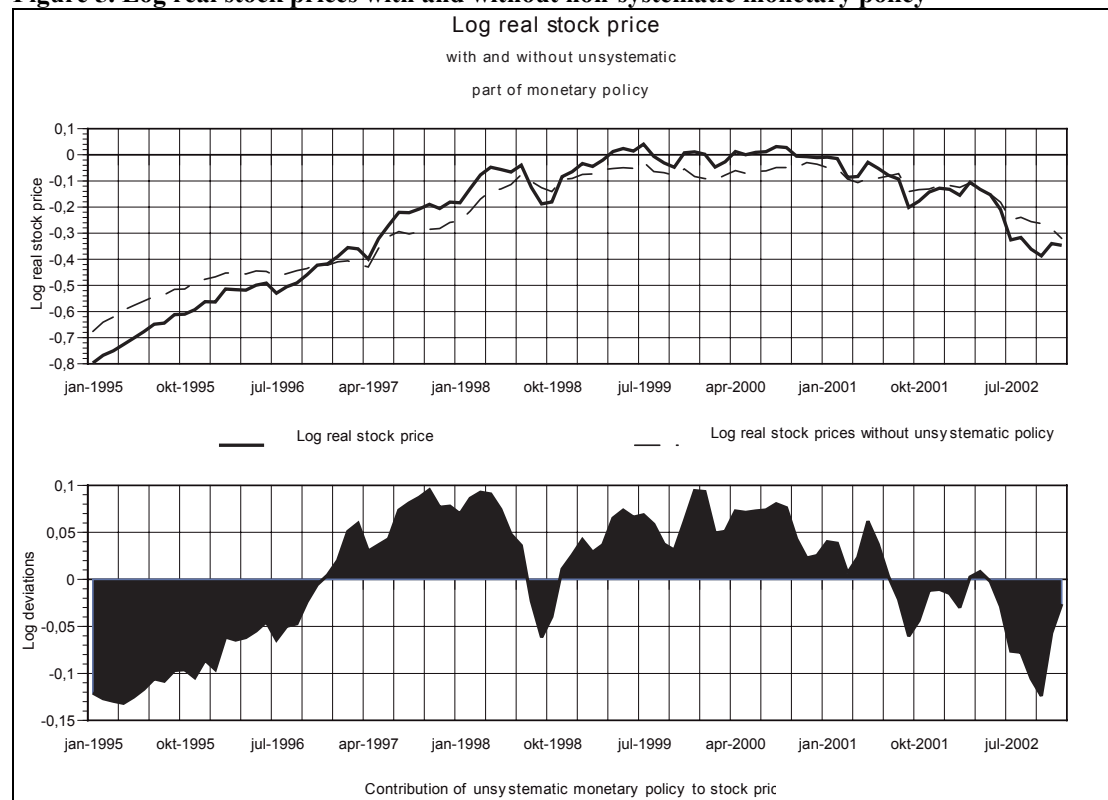
A second question is to what extent did the unsystematic part of monetary policy (the monetary policy shocks) contribute to stock price movements. Figure 5 shows the contribution of the monetary policy shocks to real stock price movements. The upper chart

**Figure 4. Fundamental and non-fundamental log real stock prices**



Note: Upper chart shows actual and fundamental log real stock prices. The lower chart shows the stock price "bubble" – the non-fundamental component of real stock prices as deviations of log real stock price from the log fundamental level.

**Figure 5. Log real stock prices with and without non-systematic monetary policy**

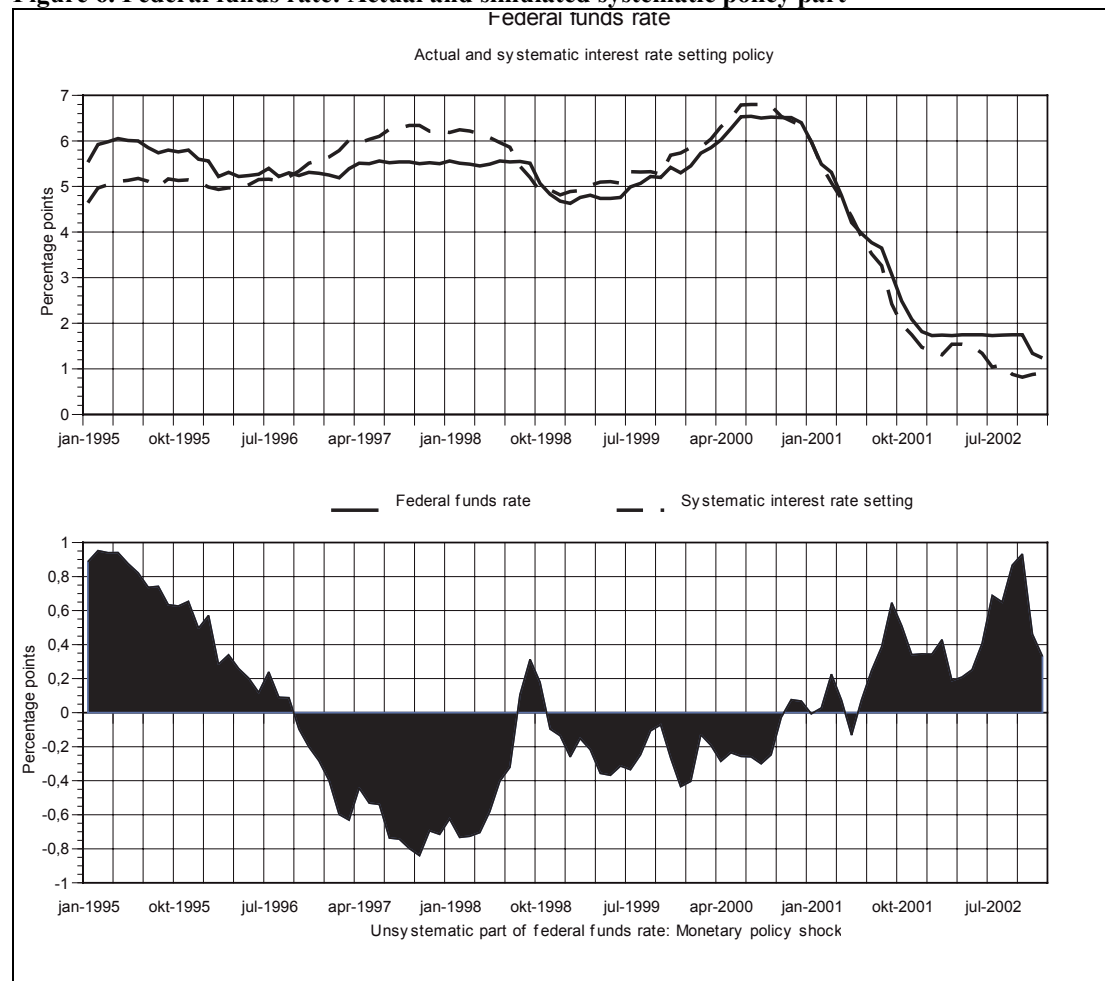


Note: Upper chart shows actual log real stock price and simulated log real stock prices with the non-systematic part of monetary policy (MP shocks) set to zero for all periods. The lower chart shows the contribution of the non-systematic part of monetary policy to stock prices.

shows the log real stock price together with the simulated stock prices without the contribution of the monetary policy shocks. The lower chart shows the deviations of these series, representing how monetary policy shocks have contributed to stock prices.

The unsystematic part of policy contributed importantly to keeping stock prices low at the start of the period, and the contributing to increasing stock prices until the end of 1997. Thereafter, it contributed to high and variable stock prices until around September 2001, except for a considerable dip in the second half of 1998. After September 2001, somewhat surprisingly, the unsystematic part of policy contributed to lowering stock prices, especially in the second half of 2002.

**Figure 6. Federal funds rate: Actual and simulated systematic policy part**



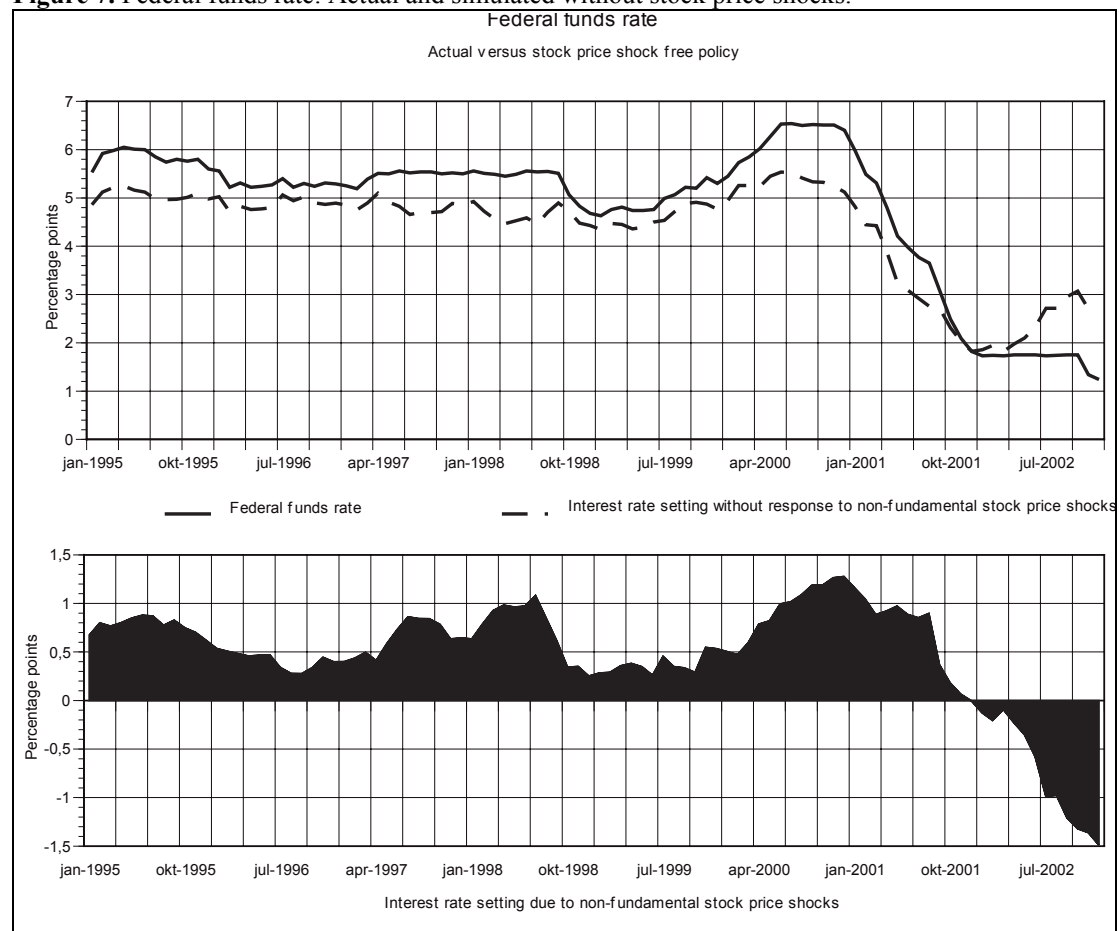
Note: The upper chart shows the actual federal funds rate and the simulated federal funds rate without the unsystematic part of interest rate setting. The lower chart shows the contribution of the unsystematic part of monetary policy to interest rate setting.

Yet another interesting question is how systematic and unsystematic monetary policy has affected interest rate setting in the period. We can answer this question by removing the monetary policy shocks for the VAR model and simulate the model over the period. The simulated interest rate path will then be the systematic part of monetary policy that responded to the state and shocks of the model. These time series are plotted in the upper chart of Figure

6. The deviation of the two, the unsystematic part of interest rate setting, is plotted in the lower chart.

In the first part of the period, unsystematic policy kept interest rates above the systematic policy part. The unsystematic policy contributed however to lowering interest rates from the start of the period until the beginning of 1998. Thereafter, the unsystematic part of policy contributed much less to interest rate setting, and policy is more systematic in the period from mid-1998 until mid-2001. At the end of the period, the unsystematic part of policy was yet again contributing to higher interest rates.

**Figure 7.** 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 any response to the non-fundamental stock price shocks. The lower chart shows the part of the federal funds rate devoted to responding to the non-fundamental stock price shocks.

Figure 7, upper chart shows the federal funds rate together with the simulated rate with the stock price shocks set to zero. The lower chart shows the contribution of the stock price shock to interest rate setting. Stock price shocks have contributed to higher interest rate throughout the period 1995-2001. In 2002, however, stock price shocks have contributed to lowering interest rates. We take this as evidence of the FOMC has been substantially involved in counteracting the effects of the stock price bubble and the subsequent burst on the central bank objectives in this period.



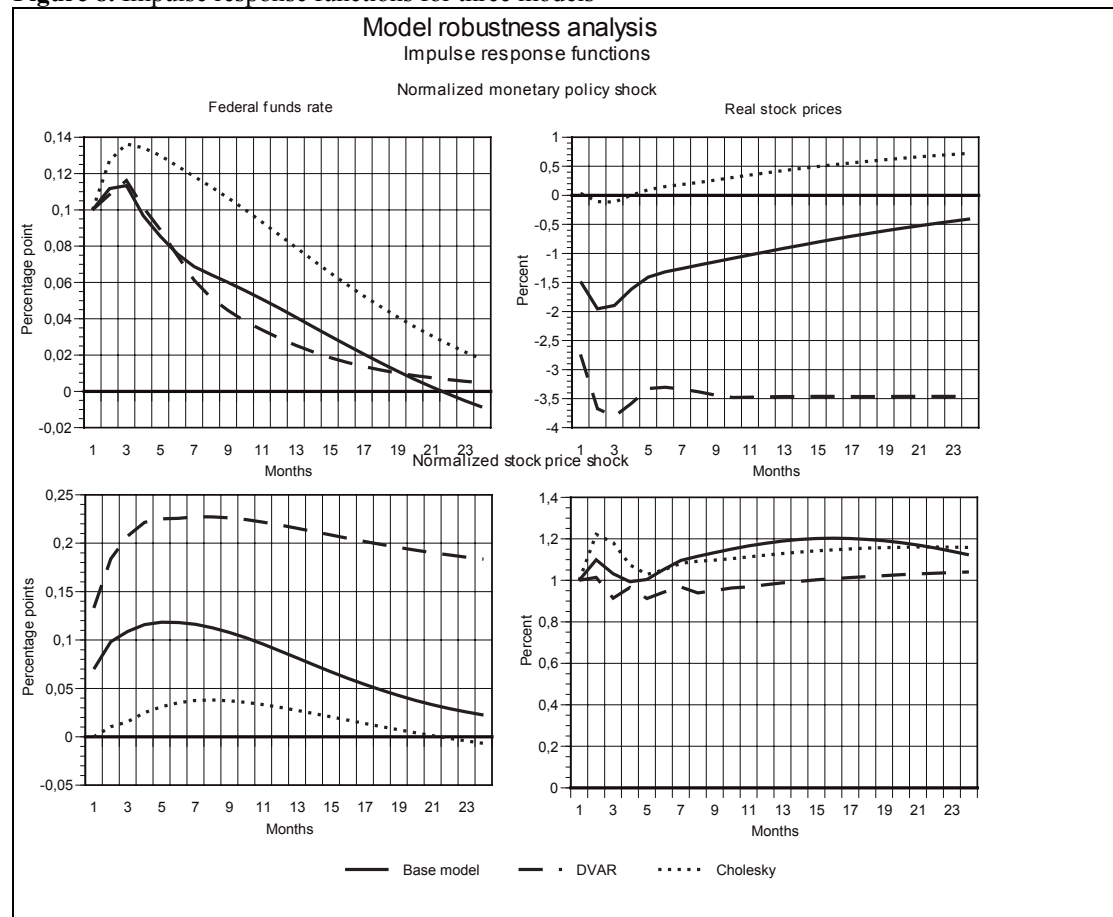
## 5. Robustness of results

The robustness of the results reported above deserve further discussion on at least three issues: time series properties of data and implication for specification of VAR, sample stability and the importance of a few stock market crashes for the average results. This is being examined next.

### 5.1 DVAR versus VAR in levels

In the base model, variables are modelled in levels (but with a time trend), as is standard practice in many VAR models of monetary policy. However, these are mainly being identified using contemporaneous restrictions on the S matrix directly. The use of long run restrictions on the moving average representation in (5) requires  $A(L)$  to be invertible. As is well known, standard univariate unit root tests like the Augmented Dickey Fuller (ADF) tests have low power to differentiate between a unit root and a persistent stationary stochastic process.

**Figure 8.** Impulse response functions for three models



Note: The figure shows the impulse responses to the federal funds rate and real stock prices of normalized monetary policy and stock price shocks for three models: VAR identified using Cholesky decomposition (no trend in the model), the baseline VAR model and the DVAR model.

The use of a level specification in the VAR could therefore be an appropriate approximation, in particular given the relatively short time span being examined. Below we analyse the

robustness of this assumption by instead using a VAR model that has been subjected to first differencing (DVAR) and compare the results. Hence, we are then effectively assuming that all variables are best represented as non-stationary I(1) variables, but not cointegrated. The model is estimated using two lags, as in the base model.

Figure 8 compares the baseline model with the DVAR and the Cholesky decomposition using levels (but now without the time trend) when the effect of a monetary policy shock on the interest rate is normalised to be 0.1 (10 basis points) and the effect of a stock price shock on real stock prices is normalised to be 1 percent. The results are very supportive of our earlier conclusion of strong simultaneity between the sectors, and furthermore, there are no qualitative changes to the impact of the shocks. The DVAR model suggests, indeed, that the degree of simultaneity between the sectors could be even stronger. However, some of these results may be driven from the fact that we now let all shocks potentially contribute to the non-stationary part of the variables, whereas previous we had aggregated away some of the long run effects by including a trend in the VAR. In the end, it is reasonable to assume that the true responses may lie somewhere in between the results predicted by the VAR in levels and the DVAR.

## **5.2 Sample stability – Greenspan period**

Above we argued that the choice of 1983 as a starting period reflected the need of having a statistical model with stable parameters (see, e.g., Bagliano and Favero, 1998, and Clarida et al., 2000). However, Bagliano and Favero also found some evidence of instability in 1988, and by starting the estimation in late 1988 (denoted the Greenspan period), no sign of misspecification could be detected. However, the evidence was not overwhelming and in the end they found the impulse responses from a period starting in 1983 not to be statistically different from a period starting in 1988.

Nevertheless, it is interesting to analyse the effects of monetary policy in the period after Greenspan took office, so as to investigate the significance of monetary policy in more recent time. Below the model is estimated from 1987M1 to 2002M12. We choose 1987 as the starting year as this is when Volcker resigned and Greenspan took office (August 1987). We believe that any instability prior to 1988 may well reflect unusual shocks in that period, rather than the actual monetary policy stance. The stock market crash in October 1987 is a candidate for such a shock that is being investigated explicitly in section 5.3 below.

Impulse responses confirm the picture from above, and are reported in Figure A1 in the appendix. Table 2 reports the variance decomposition over this shorter period. Generally, the results support the previous analysis. 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 more intermediate run. However, monetary policy shocks are slightly less important for explaining the variances in stock prices than in the base model, leaving more room for fundamental variables like output. With regards the federal fund rate, output shocks also explain somewhat more of the interest rate movements in the intermediate run than in the previous analysis. Hence, the results show even stronger

evidence now than before that the FED is pursuing inflation and output (gap) stabilization in an efficient way.

**Table 2. Error variance decomposition – model from start of Greenspan period**

	Forecast horizon	MP-shock (%)	SP-shock (%)	Cost push - shocks (%)	Output shocks (%)
<b>Federal funds rate</b>	1	62.01	34.73	1.17	1.90
	4	24.61	44.20	9.26	21.36
	12	8.32	31.17	6.56	46.07
	24	6.47	19.06	4.00	57.82
	48	8.37	16.46	9.46	53.39
<b>Real stock prices</b>	1	44.82	52.65	2.01	0.10
	4	45.83	43.21	9.83	0.46
	12	29.66	46.08	20.01	3.23
	24	18.66	51.82	17.25	10.27
	48	13.84	48.92	13.94	18.88
<b>Inflation</b>	1	0.00	0.00	92.10	7.90
	4	0.56	0.12	90.36	6.82
	12	3.83	0.30	86.85	6.09
	24	5.93	3.15	74.67	12.94
	48	9.65	5.91	68.87	12.34
<b>Industrial output</b>	1	0.00	0.00	0.00	100.00
	4	3.12	2.77	1.26	90.22
	12	11.71	8.35	13.18	60.92
	24	17.24	14.92	27.40	36.09
	48	15.27	31.21	26.53	23.79

Note: Estimation period is 1987M1-2002M12.

### 5.3 Stock market crashes

An interesting question is whether our results are 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 where the stock market fell severely (without fundamentals changing significantly), while at the same time monetary policy turned accommodating to counteract the negative effects from the stock market. The stock market crash in October 1987 is one example and the September 11, 2001, terror attack is another. Below we report the variance decomposition when these events are represented with dummy variables in the VAR analysis. The impulse responses are qualitatively unchanged (see appendix A) and the variance decomposition below supports the main conclusions from above. Hence, our reported results are not driven by these events, but more likely by a continuous interaction between monetary policy and stock market developments.

**Table 3. Error variance decomposition – model with dummies for financial episodes**

	Forecast horizon	MP-shock (%)	SP-shock (%)	Cost push - shocks (%)	Output shocks (%)
<b>Federal funds rate</b>					
	1	64.78	32.56	1.04	1.48
	4	43.06	38.28	5.82	12.80
	12	23.76	37.40	9.75	25.15
	24	18.57	34.33	8.13	30.86
	48	17.11	30.02	14.63	30.82
<b>Real stock prices</b>					
	1	34.74	62.95	1.98	0.34
	4	35.70	55.03	6.55	0.88
	12	24.17	58.14	13.35	1.19
	24	16.11	64.17	14.00	3.43
	48	10.75	68.97	12.31	5.75
<b>Inflation</b>					
	1	0.00	0.00	95.03	4.97
	4	2.71	1.71	90.30	4.32
	12	4.65	4.33	87.16	2.98
	24	4.73	4.01	86.53	2.56
	48	5.17	4.07	85.61	2.66
<b>Industrial output</b>					
	1	0.00	0.00	0.00	100.00
	4	1.31	1.96	1.44	93.38
	12	7.15	5.31	13.01	70.05
	24	12.47	6.24	33.59	45.16
	48	12.32	14.60	41.65	30.27

Note: Estimation period: 1983M1 to 2002M12. Dummy variable used in 1987M10 and 2001M9.

## 6. Concluding remarks

Interest rate decisions are followed closely by the financial market and a vast amount of resources is going into monitoring and interpreting the decisions that are taken. Our empirical study supports that monetary policymaking is indeed important for the stock market: We find a substantial degree of interdependence between monetary policy decisions and stock prices. Working both ways, a shock to either sector has a strong and immediate impact on the other. The results appear to be robust.

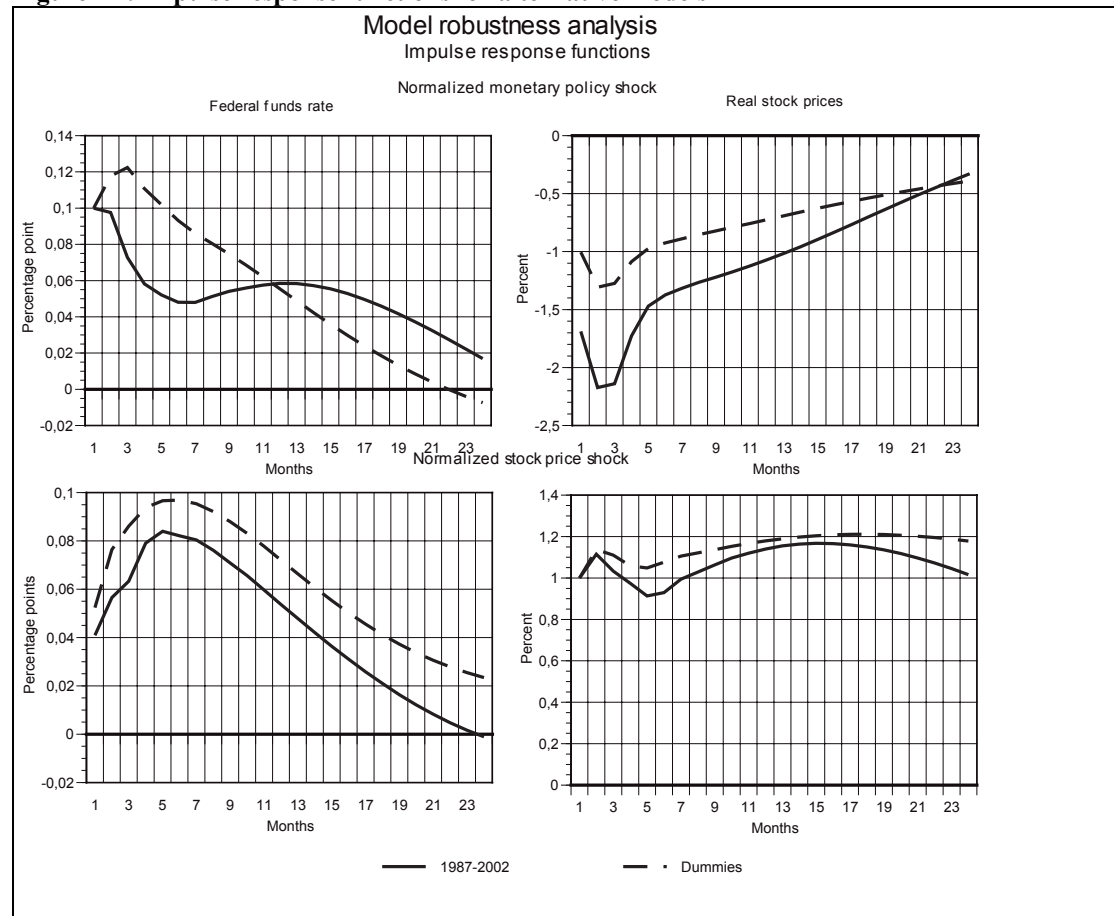
We find evidence that the systematic part of interest rate setting has contributed to stabilizing inflation and output in an efficient manner over the estimation period, the non-systematic part of policy is an important source of volatility in the stock market and in interest rates. Moreover, we attribute a substantial part of the upswing and subsequent downswing in stock prices over the period 1995-2002 to non-fundamental factors. The systematic part of policy responded to the bubble by keeping interest rates higher and thereby reducing both the size of the bubble and its consequence for inflation and output. This is no evidence of the FOMC targeting stock price *per se*, as the monetary policy response to stock price shocks can be rationalized by their property of being leading indicators of inflation and output.

Although our results indicate that the inclusion of stock market information in the VAR model seems important for identifying monetary policy, we find little evidence that

leads us to rethink the effects of a monetary policy shock on macroeconomic variables. This is more or less unchanged from previous studies.

## Appendix – Extra Figures

**Figure A1. Impulse response functions for alternative models**



Note: The figure shows impulse response functions of the federal funds rate and real stock prices due to normalized monetary policy and stock prices shocks for the model with estimation period 1987M1-2002M12 and model with dummies in 1987M10 and 2001M9.

## References

- Allen, Franklin and Douglas Gale (2000), "Asset Price Bubbles and Monetary Policy," in Meghnad Desai and Yahia Said (eds), *Global Governance and Financial Crises*, pp. 19-42.
- Bagliano, Fabio C. and Carlo A. Favero (1998), "Measuring monetary policy with VAR models: An evaluation", *European Economic Review*, 42, 1069-1112.
- Bernanke, Ben S. and Mark Gertler (1989), "Agency Costs, Net Worth, and Business Fluctuations," *American Economic Review* 79 (1), pp. 14-31.
- Bernanke, Ben S. and Mark Gertler (1999), "Monetary Policy and Asset Volatility," *Federal Reserve Bank of Kansas City Economic Review*, Fourth Quarter 1999, 84(4), pp. 17-51.
- Bernanke, Ben S. and Mark Gertler (2001), "Should Central Banks Respond to Asset prices?" *American Economic Review*, May 2001, 91(2), pp. 253-57.
- Bernanke, Ben S., Mark Gertler and Simon Gilchrist (2000), "The Financial Accelerator in a Quantitative Business Cycle Framework," in John B. Taylor and Michael Woodford, eds., *Handbook of Macroeconomics*. Volume 1C. New York: Elsevier Science, 2000, pp. 1341-93.
- Bernanke, Ben S. and Kenneth N. Kuttner (2004), "What explains the Stock Market's Reaction to Federal Reserve Policy?", NBER Working paper no. 10402.
- Blanchard, Olivier and Danny Quah (1989), "The Dynamic Effects of Aggregate Demand and Supply Disturbances", *American Economic Review*, 79, 655-73.
- Bordo, Michael D. and Olivier Jeanne (2002a), "Monetary Policy and Asset Prices: Does 'Benign Neglect' Make Sense?" *International Finance* 5 (2), pp. 139-64.
- Bordo, Michael D. and Olivier Jeanne (2002b), "Boom-busts in Asset Prices, Economic Instability, and Monetary Policy," NBER Working Paper No. 8966.
- Bordo, Michael D. and David C. Wheelock (2004), "Monetary Policy and Asset Prices: A Look back at Past U.S. Stock Market Booms," NBER Working paper 10704, August 2004.
- Borio, Claudio and Philip Lowe (2002), "Asset Prices, financial and monetary stability: exploring the nexus," BIS Working Paper no. 114.
- Bullard, James B. and Eric Schaling (2002), "Why the Fed Should Ignore the Stock Market", *The Federal Reserve Bank of St. Louis Review*, March/April 2002.

Carlstrom, Charles T. and Timothy S. Fuerst (2001), "Monetary Policy and Asset Prices with Imperfect Credit Markets," *Federal Reserve Bank of Cleveland Economic Review* 37(4), Fourth Quarter 2001, pp. 51-59.

Carlstrom, Charles T. and Timothy S. Fuerst (2002), "Imperfect Capital Markets and Nominal Wage Rigidities," Federal Reserve Bank of Cleveland Working Paper 02-05.

Cecchetti, Stephen G., Hans Genberg, John Lipsky and Sushil Wadhvani (2000), "Asset Prices and Central Bank Policy," The Geneva Report on the World Economy No. 2, ICMB/CEPR.

Chadha, Jagjit S., Lucio Sarno and Giorgio Valente (2003), "Monetary policy rules, Asset Prices and Exchange Rates," CEPR Discussion paper No. 4114.

Chowdhury, Ibrahim, Mathias Hoffmann and Andreas Schabert (2003), "Inflation Dynamics and the Cost Channel of Monetary Transmission," manuscript University of Cologne.

Christiano, Laurence J., Martin Eichenbaum and Charles L. Evans (1999), "Monetary Policy Shocks: What Have we Learned and to What End?," in John B. Taylor and Michael Woodford, eds., *Handbook of Macroeconomics*. Volume 1A. New York: Elsevier Science, 1999, pp. 65-148.

Christiano, Lawrence J., Eichenbaum, Martin and Charles L. Evans, (2001), "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy", Federal Reserve Bank of Cleveland Working Paper No. 0107.

Clarida, Richard, Jordi Gali and Mark Gertler (1999), "The Science of Monetary Policy: A New Keynesian Perspective," *Journal of Economic Literature* 37 (4), pp. 1661-1707.

Clarida, Richard, Jordi Gali and Mark Gertler (2000), "Monetary policy rules and macroeconomic stability: evidence and some theory," *Quarterly Journal of Economics*, 115 147-180.

Doan, Thomas (2004), *Rats Manual*, Version 6, Estima, Evanston, IL.

Durham, Benson J. (2003), "Does Monetary Policy Affect Stock Prices and Treasury Yields? An Error Correction and Simultaneous Equation Approach," Board of Governors of the Federal Reserve System, Finance and Economics Discussion Series: 2003-19.

Ehrmann, Michael and Marcel Fratzscher (2004), "Taking Stock: Monetary Policy Transmission to Equity Markets," European Central Bank Working Paper no. 354.



- Eichenbaum, Martin (1992), "Comment on Interpreting the macroeconomic time series facts: the effects of monetary policy," *European Economic Review* 36 (5), 1001–1011.
- Faust, Jon and Eric M. Leeper (1997) "When Do Long-Run Identifying Restrictions Give Reliable Results?" *Journal of Business and Economic Statistics*, 15, 345-353.
- Faust, Jon, Eric T. Swanson and Jonathan H. Wright (2004), "Identifying VARS based on high frequency futures data", *Journal of Monetary Economics*, 51, 1107-1131.
- Filardo, Andrew (2000), "Monetary Policy and Asset Prices," *Federal Reserve Bank of Kansas City Economic Review*, Third Quarter 2000, 85(3), pp. 11-37.
- Friedman, Milton (1969), "The Optimum Quantity of Money," in *The Optimum Quantity of Money and other essays*. Chicago: Aldine
- Fuhrer, Jeff and Geoff Tootell (2004), "Eyes on the Prize: How Did the Fed Respond to the Stock Market?", Federal Reserve Bank of Boston Public Policy Discussion Papers no. 04-2.
- Geske, Robert and Richard Roll (1983) "The fiscal and monetary linkage between stock returns and inflation, *Journal of Finance*, 38, 1-33.
- Giordani, Paolo (2004), "An alternative explanation of the price puzzle, *Journal of Monetary Economics*, 51, 1271-1296.
- Goodhart, Charles and Boris Hofmann (2000), "Do Asset Prices Help to Predict Consumer Prices Inflation?" *Manchester school*, 68 (0), pp. 122-40.
- Gordon, M.J. (1962), *The Investment, Financing and Valuation of the Corporation*, Irwin, Homewood, Ill.
- Hanson, Michael S. (2004), "The "price puzzle" reconsidered," *Journal of Monetary Economics*, 51, pp. 1385-1413.
- Kaul, Gautam (1987), Stock returns and inflation: The role of the monetary sector, *Journal of Financial Economics*, 18, 253-276.
- Lastrapes, W.D. (1998), "International evidence on equity prices, interest rates and money," *Journal of International Money and Finance* 17, pp. 377-406.
- Lee, Bong-Soo (1992), "Causal Relations Among Stock Returns, Interest Rates, Real Activity, and Inflation", *Journal of Finance*, 47, pp. 1591-1603.

Leeper, Eric M., Sims, Christopher A. and Tao Zha, (1996), "What does monetary policy do?" *Brookings Papers on Economic Activity*, 2, 1-78.

Leitemo, Kai and Ingunn Lønning (2004), "Simple Monetary Policymaking without the Output Gap," manuscript Norwegian School of Management BI.

Lindé, Jesper (2003), "Monetary Policy Shocks and Business Cycle Fluctuations in a Small Open Economy: Sweden 1986-2002", Sveriges Riksbank Working Paper Series No.153.

Neri, Stefano (2004), "Monetary Policy and Stock Prices," Bank of Italy Working paper No. 513, July 2004.

Orphanides, Athanasios (2001). 'Monetary Policy Rules Based on Real-Time Data', *American Economic Review*, Vol. 91, 4, pp. 964-985.

Patelis, Alex D. (1997), "Stock Return Predictability and the Role of Monetary Policy," *The Journal of Finance* 52 (5), pp. 1951-1972.

Ravenna, F., and C.E. Walsh (2003), "The Cost channel in a New Keynesian Model: Evidence and Implications", University of California, Santa Cruz.

Rapach, David E. (2001), "Macro shocks and real stock prices," *Journal of Economics and Business* 53 (1), pp. 5-26.

Rigobon, Roberto and Brian Sack (2004), "The Impact of Monetary Policy on Asset Prices," *Journal of Monetary Policy*, 51, 1553-1575.

Rigobon, Roberto and Brian Sack (2003), "Measuring the Reaction of Monetary Policy to the Stock Market," *The Quarterly Journal of Economics* 118 (2), pp. 639-69.

Rotemberg, Julio and Michael Woodford (1998), "An Optimizing-Based Econometric Framework for the Evaluation of Monetary Policy: Expanded version." NBER Working Paper No. t0233, May 1998.

Rotemberg, Julio and Michael Woodford (1999), "Interest Rate Rules in an Estimated Sticky Price Model," in John Taylor, ed., *Monetary Policy Rules*, Chicago: University of Chicago Press, 1999, pp. 57-119.

Rudebusch, Glenn D. (1998), "Do Measures of Monetary Policy in a VAR Make Sense?," *International Economic Review*, 39, pp. 907-931.

Sellin, Peter (2001), "Monetary Policy and the Stock Market: Theory and Empirical Evidence", *Journal of Economic Surveys*, 15, pp. 491-541.

Sims, C. A. (1980), "Macroeconomics and Reality," *Econometrica* 48, pp. 1-48.

Sims, Christopher A. (1992), "Interpreting the Macroeconomic Time Series Facts: The Effects of Monetary Policy", *European Economic Review*, 36, 975-1011.

Stock, James H. and Mark W. Watson (2001), "Forecasting Output and Inflation: The Role of Asset Prices," National Bureau of Economic Research Working Paper No. 8180.

Svensson, Lars E.O. (1997), "Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets," *European Economic Review* 41 (6), pp. 1111-46.

Thorbecke, Willem (1997), "On Stock Market Returns and Monetary Policy," *The Journal of Finance*, 52 (2), pp. 635-654.

Tobin, James (1969), "A General Equilibrium Approach to Monetary Policy," *Journal of Money, Credit, and Banking* 1, pp. 15-29.

Vickers, John (2000), "Monetary Policy and Asset Prices," The Manchester School Supplement 2000, pp. 1-22.

Woodford, Michael (2003a), "Optimal Interest-Rate Smoothing," *Review of Economic Studies* 70 (4), pp. 861-86.

Woodford, Michael (2003b), *Interest and Prices*, Princeton and Oxford: Princeton University Press.