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CASE STUDY FOR VARS WITH SIGN  
RESTRICTIONS**

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**Discussion paper**

# **Did the Fed Surprise the Markets in 2001? A case study for VARs with Sign Restrictions<sup>1</sup>**

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## **Abstract**

In 2001, the Fed has lowered interest rates in a series of cuts, starting from 6.5 % at the end of 2000 to 2.0 % by early November. This paper asks, whether the Federal Reserve Bank has been surprising the markets, taking as given the conventional view about the effect of monetary policy shocks. New econometric techniques turn out to be particularly suitable for answering this question: this paper can be viewed as a showcase and case study for their application. In order to concentrate on the Greenspan period, a vector autoregression is fitted to US data, starting in 1986 and ending in September 2001. Monetary policy shocks are identified, using the new sign restriction methodology of Uhlig (1999), imposing the "conventional view" that contractionary policy shocks lead to a rise in interest rates and declines in nonborrowed reserves, prices and output. We find that neither the Fed policy choices in 2001 nor those of 2000 were surprising. We provide a method to "explain" these interest rate movements by decomposing them into their sources. Finally, we argue that constant-interest-rate projections like those popular at many central banks are of limited informational value, can be highly misleading, and should instead be replaced by on-the-equilibrium-path projections.

Keywords: monetary policy, vector autoregression, sign restriction, identification, 2001, September 11th

JEL: E58, C32, C53

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## Introduction

In 2001, the Fed has lowered interest rates in a series of cuts, starting from 6.5 % at the end of 2000 to 2.0 % by early November. This paper asks, whether the Fed has been surprising the markets, taking as given the conventional view about the effect of monetary policy shocks. Questions like these frequently arise in practice: it is the task of academics to provide the means for answering them. This is the purpose of the paper, treating the particular time episode of 2001 as a case study for how monetary policy can be analyzed and understood, using recent tools from time series analysis. Included in our data set as the last month is September 2001, and thus the attack on the New York World Trade Center.

We start by fitting a vector autoregression to the data. Excellent surveys about this methodology and their application to monetary policy are provided by Christiano, Eichenbaum and Evans (1999), Leeper, Sims and Zha (1996) or Favero (2001): there is no need to provide an additional overview here. We restrict attention to data from 1986 to present: 15 years of data should be enough to figure out the "policy rule" of the Greenspan period. We define surprises as innovations to that policy rule, i.e. as surprise movements in, say, the Federal Funds Rate which cannot be viewed as a systematic reaction to past or other present data.

The difficulty lies in appropriately identifying the monetary policy shock. When using data for the Greenspan area alone rather than for a longer time period, many conventional identification procedures yield impulse responses which are not clearly consistent with a conventional view of the effects of monetary policy. One way to resolve this issue is to simply conclude that the conventional view is incorrect or not worry about lack of significance. But those that favor the conventional view might not be convinced by estimates of the size of the policy shocks obtained this way, fearing that something else but monetary policy shocks have been identified. Instead, they would demand an approach which delivers results consistent with the conventional view.

This is done in this paper, using the new sign restriction methodology of Uhlig (1999). The technique is closely related to the approach by Faust (1998) or Canova and de Nicolo (2000). The "conventional view" that contractionary policy shocks lead to a rise in interest rates and declines in nonborrowed reserves, prices and output, is directly used for identifying the monetary policy shocks per imposition of sign restrictions on the impulse responses.

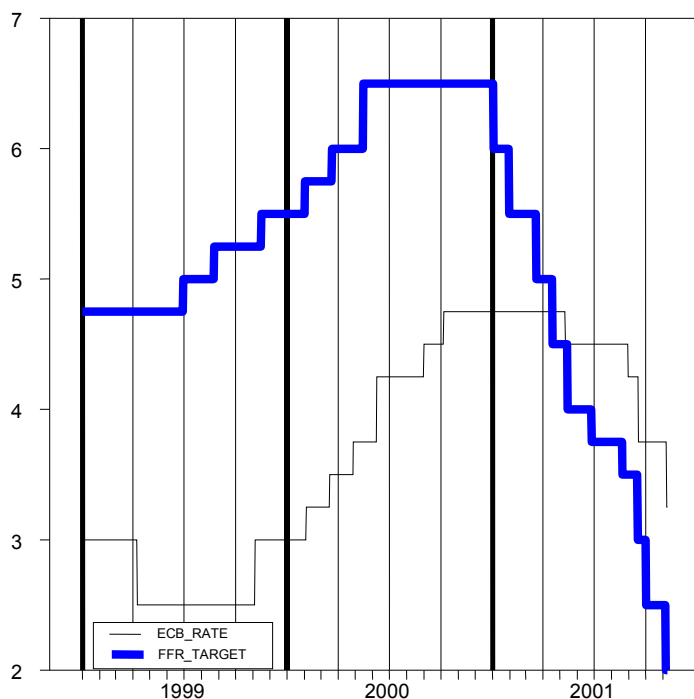
It will then be shown that neither the Fed decisions in 2001 nor in 2000 are surprising, but should instead properly be viewed as systematic reactions to developments elsewhere in the economy. This is followed by a decomposition of the interest rate moves into parts explained by innovations in other time series: we provide a methodology for performing this decomposition.

Finally, we present an analysis, comparing the actual time series behavior to a projection, in which it is assumed that the Fed had kept interest rates unchanged at the beginning of 2001. This type of exercise is now popular at many central banks. However, this exercise effectively assumes hugely counterfactual errors. For this reason and the reason that off-equilibrium behavior is artificially constrained in these exercises, I argue that these kinds of projections offer limited insight, can be highly misleading, and should be replaced by "on-the-equilibrium-path" projections instead.

Some of the results in this paper, using a somewhat shorter data set, have been used in the MECB 3 Update report, see Alesina et al (2001).

## Fed Activism

During the first eleven months of 2001 and following a fairly steep upward movement of interest rates in 2000, the Federal Reserve Bank has drastically cut the Federal Funds Rate from 6.5 percent to 2.0. By comparison, the ECB has roughly followed the movements of the Federal Reserve with a lag of 4 to 5 months during this episode.



Looking at this picture and recalling the casual newspaper evidence, one may get the impression that this drastic series of cuts was rather surprising and unexpected. Was it? Did the Federal Reserve surprise the markets in 2001? Or were these cuts simply the usual, systematic response to developments elsewhere in the economy?

To answer that question, one needs to make it more precise. In particular, one needs to clarify the meaning of the word "surprising" in this context. One can probably not expect to predict this sequence of interest rate cuts based on data up to, say, November 2000 alone: in that obvious sense, these cuts were surprising. More interesting, however, is to think about monetary policy surprises, as other data about the economy keeps coming in, and to ask, whether Alan Greenspan has reacted any differently in the year 2001 to that data than in the past. The following decomposition is therefore standard in the VAR literature.

Taking the Federal Funds Rate  $r_t$  as the monetary policy instrument, consider a policy rule of the form

$$r_t = f(z_t, y_{t-1}, y_{t-2}, \dots) + \varepsilon_t$$

where  $y_t$  is data at date  $t$ ,  $z_t$  are surprises to these data in the economy other than monetary policy surprises, and  $\varepsilon_t$  are the monetary policy surprises. The function  $f(z_t, y_{t-1}, y_{t-2}, \dots)$  is the systematic reaction of monetary policy to past and present data. We call monetary policy unsurprising, if  $\varepsilon_t = 0$ . If monetary policy is unsurprising, then the failure to predict choices for the Federal Funds Rate are entirely a consequence of failing to predict developments elsewhere in the economy, to which monetary policy reacts in a systematic way.

We wish to understand whether the  $\varepsilon_t$ 's were sizeable or not during 2001. One can make this formal, using the approach in Leeper and Zha (2001): as we shall see, this is hardly necessary in this context.

## A VAR perspective

To provide an answer, we use a vector autoregression, using a set of variables commonly used in this literature. Monthly data on the log of the Federal Funds Rate [FEDFUNDS], CPI inflation (calculated as the difference between logs of the data [CPIAUCSL] at date  $t$  and  $t-12$ ), the log of oil prices [OILPRICE], the log of nonborrowed reserves [BOGNONBR], the log of M1 [M1SL], the log of real GDP [GDP96] ("interpolated" to obtain monthly data, by predicting its monthly growth, using INDPRO and CPIAUCSL as regressors) and the log of real personal consumption expenditure [PCENDC96] has been obtained from the Federal Reserve Bank of St. Louis Web Site, with the names in square brackets indicating the label of the series used, and undertaking the indicated transformation. E.g. Christiano, Eichenbaum and Evans (1999) or Bernanke and Mihov (1998) have used the commodity price index rather than oil prices and generally do not include real personal consumption expenditure. We have included it here because of its known predictive powers for output, see Cochrane (1994). For an additional set of results, the log of the cumulated returns on the SP 500 under dividend reinvestment [TRSP500] has been added and indicated in the description below. Note that all variables have been used in log-levels, only the log-CPI has been differenced in order to obtain inflation. In particular, we have taken logarithms in particular of the Federal Funds Rate in order to avoid negative territory in some of the projections below.

The data has been restricted to start in January 1986 in order to concentrate on the Greenspan era: with now 15 years of data, it should in principle be possible to "calculate" his policy rule reasonably precisely. The data stops in September 2001: this was the most recent data available when the results were calculated in November 2001. I.e., the month with the terrorist attack on the New York World Trade Center on September 11th, 2001 is the last month of the data set. As time passes, the results here offer the advantage of hindsight in evaluating some of the projections.

Write the vector autoregression as

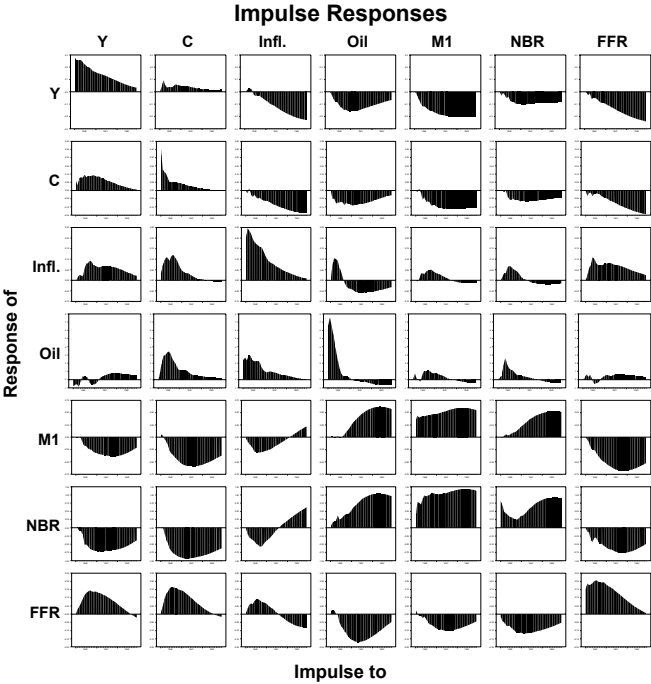
$$Y(t) = c + B(L)Y(t-1) + u(t)$$

where  $Y(t)$  is the data vector,  $c$  is the vector of constants,  $B(L)$  is a finite-order matrix lag polynomial and  $u(t)$  is the one-step ahead prediction error with some variance-covariance matrix  $\Sigma$ .

The key is now in identifying the monetary policy shock. What needs to be done is to find a column vector  $a$  of some matrix  $A$  with  $AA'=\Sigma$ , which satisfies suitable identifying restrictions. The column vector  $a$  is then a monetary policy shock one standard-deviation in size, which we shall call the monetary policy impulse vector. Its entries provide us with the within-month reaction of all variables to a monetary policy surprise, one standard deviation in size. Replacing  $u(t)$  with  $a$  in the VAR above, impulse responses to a monetary policy shock one standard deviation in size can be calculated.

Identifying the monetary policy impulse vector turns out to be particularly tricky for the Greenspan area. Standard identification exercises often deliver results, which stand in contrast to the conventional wisdom, that a surprise tightening of monetary policy leads to a reduction in output, a reduction in prices and a reduction in nonborrowed reserves.

One such example can be seen in the next plot (calculated using RATS), where a Cholesky decomposition has been used, with the Federal Funds Rate ordered last. The response to the Federal Funds Rate, i.e., the last column, is sometimes used to identify a restrictive monetary policy shock. As one can see, this generates a price puzzle (comp. Sims, 1992): CPI inflation moves up, rather than down in response to a contractionary monetary policy shock.



One way to resolve this issue is to simply conclude that the conventional view is incorrect or, at least, that not much should be read into the inflation response, because it may be insignificant. E.g., one can certainly provide sensible reasons for why one might think that prices should initially rise rather than fall, following a surprise rise in interest rates. But those that favor the conventional view may not be convinced by estimates of the size of the policy shocks obtained this way, fearing that something else might have been identified instead. Rather, they would demand an approach which delivers results consistent with the conventional view. What is needed is an approach that can answer questions about monetary policy shocks, taking the conventional view as given.

We therefore discard the VAR results above, and propose an alternative method for identifying monetary policy shocks.

## A new approach: sign restrictions.

For the results to follow, we shall use the new sign restriction methodology of Uhlig (1999): Canova and de Nicolò (2000) or Faust (1998) offer a similar approach. The "conventional view", that contractionary policy shocks lead to a rise in interest rates and declines in nonborrowed reserves, prices and output, is used directly for identifying monetary policy shocks. Put differently, the conventional view is supported "per construction". This is a tool one should use with caution: the approach applied in this way says nothing about whether the conventional wisdom is correct in the first place. In fact, Uhlig (1999) has shown that monetary policy shocks, identified via the effect of raising interest rates, lowering nonborrowed reserves and lowering inflation, have no clear effects on output, see also Sims and Zha (1998). For the purpose here, we feel comfortable with imposing that restriction however: after all, we wish to learn something about monetary policy shocks, taking the conventional view as given.

More precisely, the identifying restrictions are placed on the impulse response functions by requiring that

- i) the response of the Federal Funds Rate does not fall below zero during the first 12 months (i.e. month 0 to 11) following the shock,
- ii) the response of CPI inflation, nonborrowed reserves and real GDP does not rise above zero during the first 12 months following the shock.

When adding the log of the stock market, the same identification restrictions have been used, i.e., the impulse response of the stock market has not been restricted.

It has become common in many structural VARs to impose that prices or inflation rates do not react within the period to monetary policy shocks. Imposing this restriction here poses no technical difficulty. But whereas zero restrictions of this type are of essence in structural VARs, they should only be imposed here if they are truly part of the conventional wisdom: this clearly is a matter of judgement. We have chosen not to impose it, in light of the evidence, that many prices are changed at very high frequency, such as weekend sales prices in supermarkets or prices for airline tickets. I.e., we cannot be sure that prices do not react instantaneously, and leave it up to the data to inform us.

A Bayesian vector autoregression with 6 lags and a constant has been fitted to the data, using a Normal-Wishart prior, described in Uhlig (1999): suffice it to say that it is a very weak prior and permits stationary, unit and explosive roots. Bayesian methods for VARs and their policy applications are developed in greater detail in Sims and Zha (1998), and their more sophisticated approach can be combined with the approach here. We have elected to proceed with the Normal-Wishart prior because of its simplicity.

The estimation proceeds by taking many draws from the posterior for the VAR coefficients  $B(L)$  (eliminating those with roots above 1.01) as well as many draws on the space of possible impulse vectors. Keeping only those joint draws, in which the sign restrictions for the impulse responses are satisfied, error bands etc. can be calculated. Shown are always the 16% and 84% (point-by-point) quantiles. More details are in Uhlig (1999).

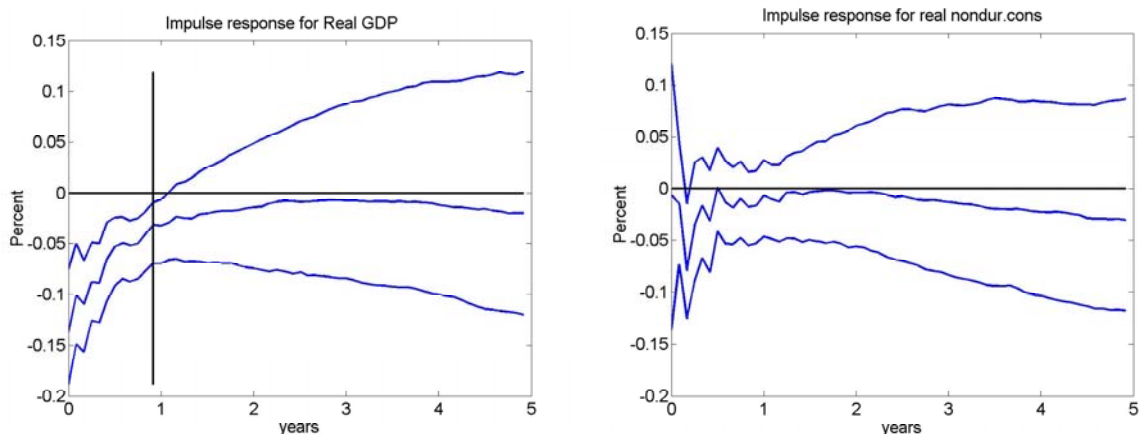
# Impulse Response Functions

Before looking for the monetary policy shocks in the data, we argue that these shocks are the ones we should indeed be looking for, as they have the "desired" conventional consequences.

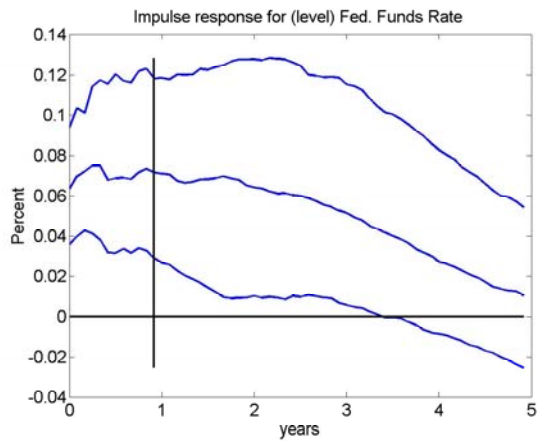
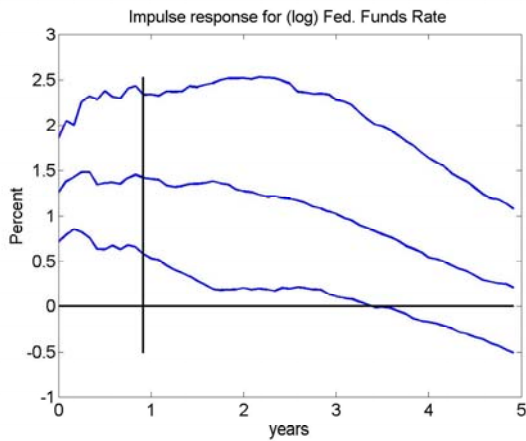
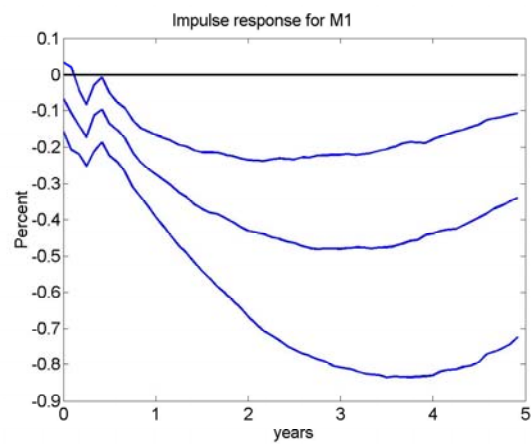
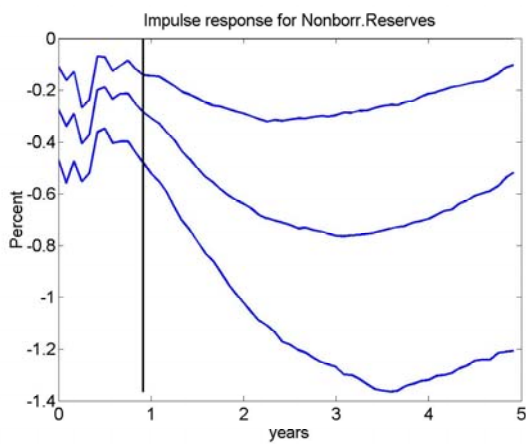
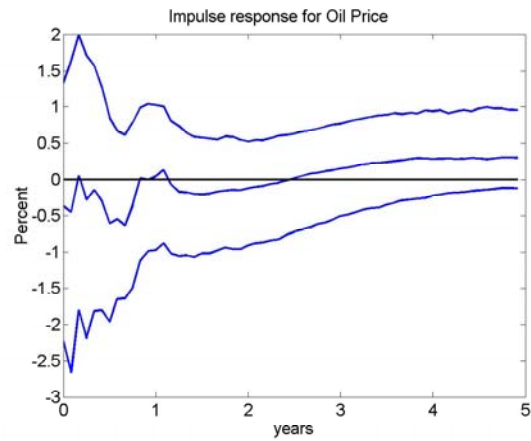
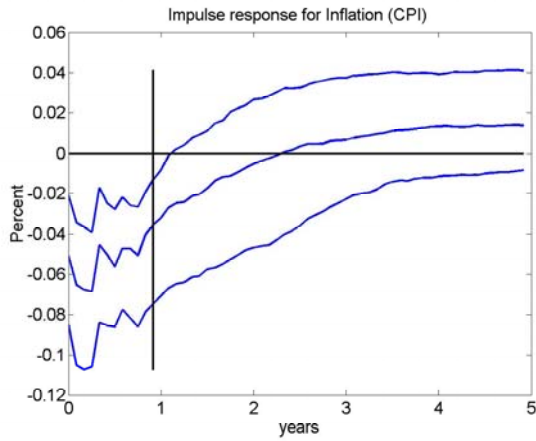
The following graphs show the impulse response for the monetary policy shock only as it is the only shock we have identified. The VAR has been estimated on the basis of data from January 1986 to (and including) November 2000. The vertical lines in the graphs for the Federal Funds Rate, nonborrowed reserves, CPI inflation and real GDP show until which point the impulse responses have been restricted to be of the appropriate sign. While the log of the Federal Funds Rate has been used for estimating the VAR, the impulse response shown here is twice: first, as percentage of its current level or the level deviation of its logarithm (log-FFR) and second, as the more commonly used level response in percent interest (level-FFR): to convert the former into the latter, we have assumed a "base" level for the Federal Funds Rate of 5 percent.

They all look fairly reasonable. Obviously, where the sign restrictions have been imposed, the impulse responses are "forced" to look reasonable: in particular, the price puzzle is avoided by construction. Note that it is hard to find a negative effect on consumption, despite the fact that the reaction of output has been restricted to be negative. This could be consistent with an interpretation, that monetary policy shocks generate offsetting wealth- and substitution effects. Note also, that inflation appears to react within the period to a monetary policy shock with this identification.

Also note the scale. A one-standard-deviation monetary policy shock adds about 4 to 10 basis points to a Federal Funds Rate of 5%: this clearly is not much. This already shows that monetary policy shocks have been only at most a minor explanation of the movements of the Federal Funds Rate during the Greenspan years. Consequently, also the reaction of real output and inflation is small and comparable in size to the movement in the Federal Funds Rate. The reaction of real GDP actually looks a bit large, given the small movement in the Federal Funds Rate. We have imposed here the conventional view, that real GDP reacts negatively to a monetary policy surprise: either the reaction is strong, because these types of surprises are rare, or, alternatively, the reaction of real GDP shown here and in the graphs below should be considered an "upper bound" of what might be reasonable.







## Eliminating the surprises and on-the-equilibrium-path projections

Having identified the monetary policy surprises, we can now eliminate them from the data. More precisely, we compare two scenarios. In the first, we are using the actual data until (and including) September 2001, and projections beyond that, taking draws for future interest rate changes and changes in other variables based on the estimated VAR data generating process. The second scenario differs from the first in that we "subtract" the monetary policy surprises in December 2000 until September 2001 from the data, during which interest rates fell from 6.5% to 3%. We start the simulations in December 2000 rather than January 2001, because

we are using the FEDFUNDS series from the Federal Reserve Bank of St. Louis: that series is an average of daily figures rather than the Federal Funds target rates prominently announced in newspapers. It takes the maximal value of 6.51 in November 2000 compared to the slightly lower value of 6.40 in December 2000. The cleanest exercise therefore is to do the counterfactual simulations starting in the first months of the turnaround in interest rates, i.e. already in December 2000, rather than taking the data of December as given and risking an extrapolation of an admittedly small, initial decrease.

Subtracting these surprises means to eliminate its effects on all current and future data. I.e., recalculate the data with

$$Y(t) = c + B(L)Y(t - 1) + v(t)$$

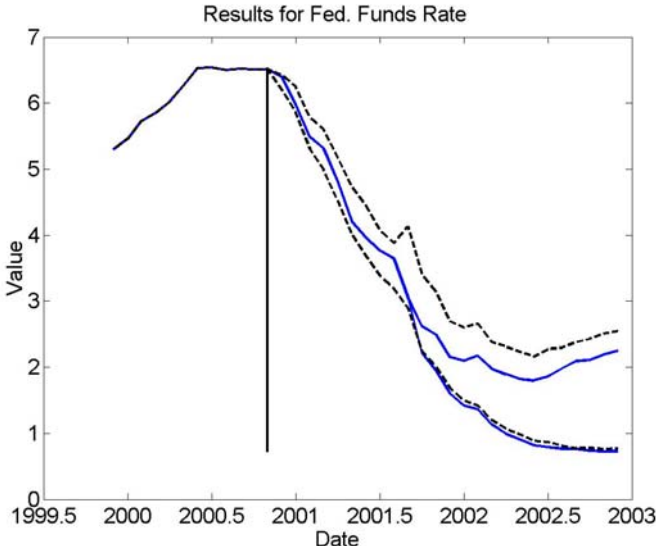
where

$$v(t) = u(t) - a\varepsilon(t)$$

for December 2000 until September 2001 in the second scenario, with  $a$  the estimated monetary policy impulse vector and  $\varepsilon(t)$  the estimated monetary policy shock. Let its variance be  $\sigma_\varepsilon^2$ . From October 2001 onwards,  $v(t)$  is drawn from the Normal distribution  $N(0, \Sigma - aa'\sigma_\varepsilon^2)$  for the second scenario, i.e. without monetary policy shocks, and from  $N(0, \Sigma)$  for the first scenario, i.e. including monetary policy shocks.

These are on-the-equilibrium-path projections: what is assumed is that the systematic way the central bank reacts to past news remains unchanged, i.e. that policy is unchanged (except at most for reducing the variance of the policy shocks to zero). Note that unchanged policy implies changes in interest rates.

In the next graph, we show our results. The solid line is the first scenario, using actual data, whereas the second scenario is shown with black dashed lines. There is uncertainty in the estimates of the VAR coefficients and the monetary policy impulse vector for the second scenario in December 2000 through September 2001, and there is additional uncertainty regarding  $v(t)$  after that point: for that reason, we show the 16% and 86% quantile.

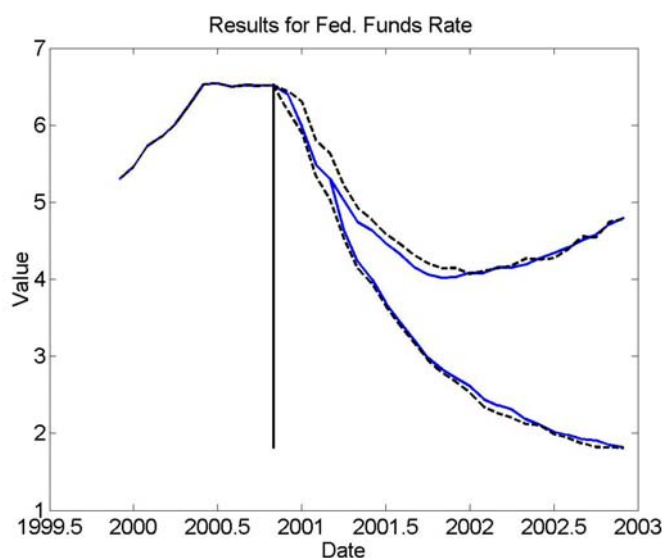


We only show the graph for the Federal Funds Rate as it already tells the entire story: the differences between these two scenarios is surprisingly small. Extrapolating past behaviour leads to predicting a sequence of interest rate cuts almost just as much as the ones that have taken place already, at most at a slightly slower speed. In sum, the sequence of dramatic cuts we have seen, actually turn out to be unsurprising, given shocks elsewhere in the economy not due to monetary policy.

This is the key message of this paper: the cuts seen throughout 2001 are cuts that should be viewed as the usual, systematic reaction of the Greenspan monetary policy to past and present developments in the economy.

The confidence band for interest rates under both scenarios includes very low interest rates around 1 percent starting somewhere towards the beginning of 2002. We do not want to imply that Japanese conditions will take hold in the US (but we also do not want to rule them out either): we merely note that extrapolating the past behaviour of this system of variables, and simulating forward, using historical measures of uncertainty, and based on the currently low and falling interest rates in the US, the calculations will tell us that extremely low interest rates may be a serious possibility in the near future.

For comparison, we present the same exercise, but where we have used data only up to March 2001, during which interest rates were decreased from 6.5% to 5.3%. This exercise predicts a level somewhere between 2.5% and 4% in October 2001, including the actual level of 2.5% at the lower bound of the central  $(84\%-16\%)=68\%$  probability band without appealing the special circumstances of September 11th. Thus, the cut in interest rates were not only unsurprising and systematic responses to developments elsewhere in the economy: they were even predictable as of March 2001.

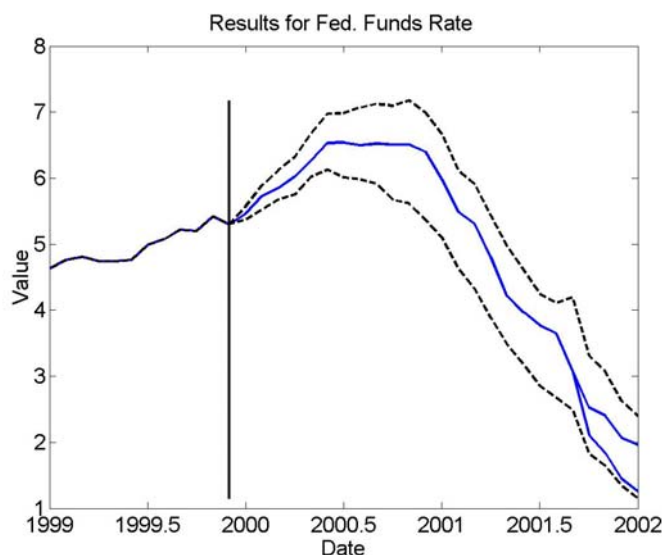


## What about the rise in interest rates in 2000?

If the cuts in 2001 were not surprising, perhaps, the rising rates in 2000 were. We have therefore redone the exercise above, starting the simulations in January 2000. To do this, the VAR and thus the reaction function for the Federal Reserve has been estimated on the basis of

data until December 1999 alone: so if there was a change in policy, it would show up in these graphs.

The next figure shows, that the no-surprise path is rather similar to the actual data path. Again, we conclude that the actions of the Federal Reserve Bank have been far less surprising than they occasionally have been claimed to be in the popular press, and instead are systematic reactions to developments taking place elsewhere in the economy.



## The components of the rise in interest rates in 2000 and the fall in 2001

The projections above track the actual developments of the Federal Funds Rate pretty well, explaining it as the systematic reaction of the Federal Reserve Bank to past data. So, what, exactly, did the Federal Reserve Rate react to? Why first the rise and then the fall in interest rates in 2000 and 2001? A more detailed look provides the answer.

More precisely, in order to decompose the movements in the Federal Funds Rate (FFR) into its responses to other variables plus the monetary policy shock, begin by writing the VAR equation for the log Federal Funds Rate (IFFR) as

$$IFFR(t) = c_{IFFR} + B_{IFFR}(L)Y(t-1) + \beta v(t) + \varepsilon(t)$$

where  $c_{IFFR}$  is the constant in the equation for  $IFFR(t)$  in the VAR,  $B_{IFFR}(L)$  is the row vector in  $B(L)$  for the IFFR equation,  $\varepsilon(t)$  is the monetary policy shock and  $v(t)$  is that part of  $u(t)$  not explained by the monetary policy shock (see above) with  $\beta$  its coefficient vector in the IFFR equation. I.e., the one-step ahead prediction error  $u_{IFFR}(t)$  for the Federal Funds Rate has been decomposed into

$$u_{IFFR}(t) = \beta v(t) + \varepsilon(t)$$

The decomposition is now done as follows. Suppose one wants to know the "influence" of present and past GDP on the present IFFR: call that IFFR:GDP(t). To that end, find the coefficients in  $B_{IFFR}(L)$  on the lags of the log of GDP - call that  $B_{IFFR:GDP}(L)$  - and likewise, take the entry in  $\beta$  and  $v(t)$  due to GDP,

$$IFFR : GDP(t) = B_{IFFR:GDP}(L)GDP(t-1) + \beta_{GDP}v_{GDP}(t)$$

$v_{GDP}(t)$  is the one-step ahead prediction error in GDP subtracting that part which is due to the monetary policy shock. It does not have a structural interpretation other than "not monetary policy shock". Furthermore, the entries of  $v(t)$  will generally be correlated. One could proceed a step further and attempt a full structural decomposition of  $v(t)$  in e.g. supply and demand shocks etc.: there are a variety of ways in which this could be accomplished. We have not proceeded down this path of structural identification, since our main aim is to summarize the available data with a minimalist set of additional identifying assumptions: none (other than identifying the monetary policy shock) are necessary here. Further below we will examine the fraction of interest rate movements due to e.g.  $v_{GDP}(t)$  as well as the consumption prediction error and interpret this as the movements of interest rate choices due to real variables. This can be viewed either in the narrow sense of a decomposition, or be given a more meaningful economic interpretation: while the origin of these one-step ahead prediction error in GDP and consumption may not be due to structural shocks to the real economy, it may well be that the Federal Reserve is reacting to the effect of that shock on GDP and consumption. With the caveat in mind, that there are several other observationally equivalent interpretations, this benchmark view may nonetheless be useful for reading the graphs shown below.

What is particularly relevant is the revision in this influence since December 1999, i.e.

$$\Delta IFFR : GDP(t) = IFFR : GDP(t) - IFFR : GDP(1999 : 12)$$

Finally, to calculate the influence  $\Delta FFR : GDP(t)$  on the change in the level of the Federal Funds Rate compared to December 1999, calculate

$$\begin{aligned} \Delta FFR : GDP(t) &= FFR : GDP(t) - FFR : GDP(1999 : 12) \\ &= \exp(IFFR(1999 : 12) + \Delta IFFR : GDP(t)) - FFR(1999 : 12) \end{aligned}$$

Note that FFR:GDP(t) and thereby also this revision contains current shocks through  $\beta_{GDP}v_{GDP}(t)$ . One should therefore expect it to be quite erratic. One should also expect serial correlation through the lagged effects  $B_{IFFR:GDP}(L)GDP(t-1)$ .

Uncertainty in the estimation arises from the uncertainty about the lag-coefficients B(L) and the resulting uncertainty about the constructed u(t) as well as uncertainty about the identified monetary impulse vector  $a$  and therefore uncertainty about the decomposition of u(t) into  $a\varepsilon(t)$  and  $v(t)$  as well as the coefficient vector  $\beta$ .

Summing over  $\Delta FFR : X(t)$  for several variables  $X$ , one calculate the influence of a group of variables rather than a single variable on the Federal Funds Rate: this is what is shown in the

graphs below. We have grouped the other variables in three groups. The first group contains price variables, i.e. CPI inflation and oil prices. The second group contains monetary variables, namely M1 and nonborrowed reserves. The third group contains the real variables, i.e. real output and real consumption.

More precisely, in order to calculate e.g. the joint effect of real output and real consumption on the Federal Funds Rate, we calculate

$$\Delta FFR : real(t) = \exp(IFFR(1999 : 12) + \Delta IFFR : GDP(t) + \Delta IFFR : C(t)) - FFR(1999 : 12)$$

For the effect of past FFRs on current values, we have calculated

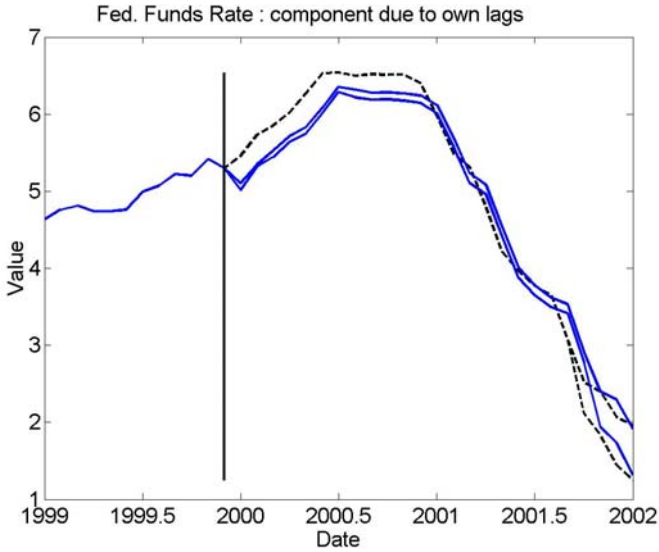
$$IFFR : IFFR(t) = B_{IFFR:IFFR}(L)IFFR(t - 1)$$

and then shown

$$\exp(IFFR(1999 : 12) + IFFR : IFFR(t) - IFFR : IFFR(1999 : 12))$$

so as to start it off from the original level of the data in December 1999.

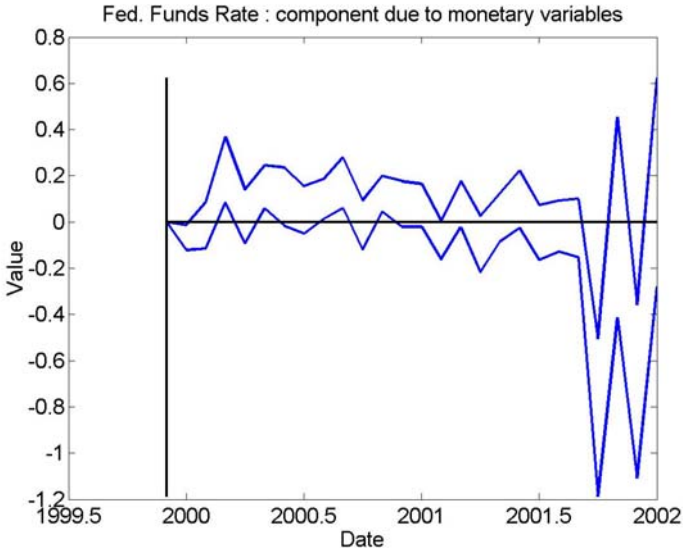
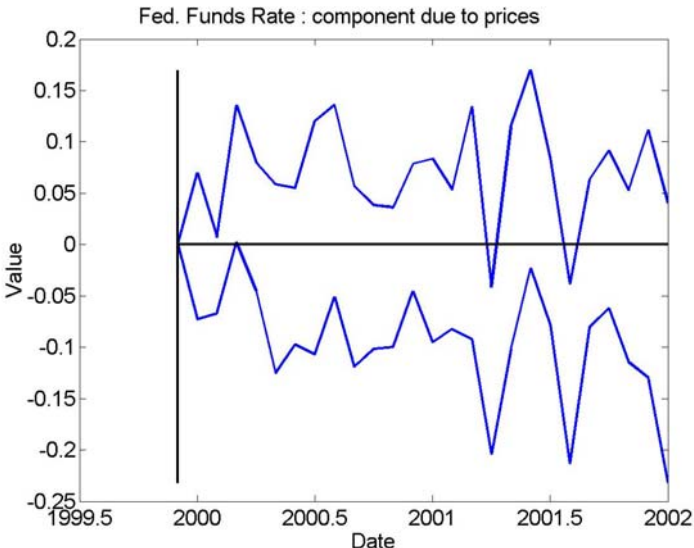
This is what we now examine first. I.e., the first graph compares the benchmark simulations of actual data until September 2001 and simulated data beyond that to that part of the Federal Funds Rate, which can be explained solely by the reaction of that interest rate to its actual own past, given by the benchmark simulations. The benchmark simulations are the black dash-dotted lines, whereas the part that just shows the reaction to its own past is given by the solid lines. There is some coefficient uncertainty as to how that reaction function looks like: the two solid lines show the lower and upper bound. Before September 2001, the degree of uncertainty is apparently pretty small. The uncertainty rises after September 2001 because now, the benchmark projections are no longer a single line of data but a range of possibilities too.



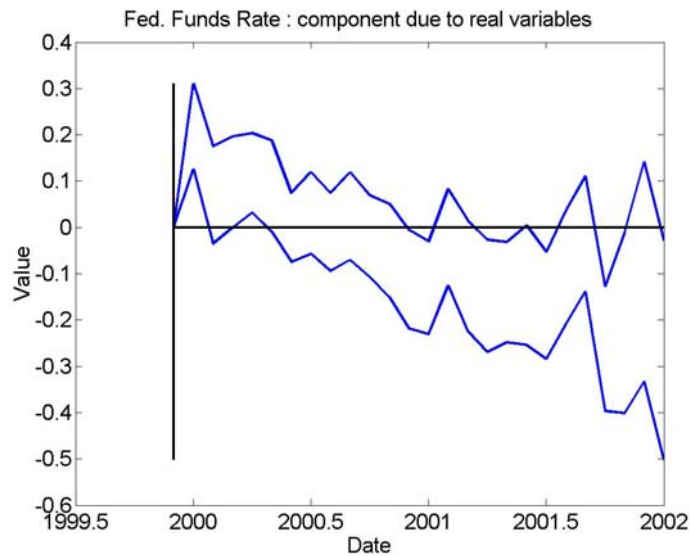
At a first glance, the black and the solid lines coincide pretty well, and one might be tempted to conclude that the interest rates dance to their own music: they go up, because they go up,

and they go down, because they go down. Obviously, that wouldn't be much of an explanation. For a more appropriate analysis, one needs to recognize that interest rates typically do not change radically: last months Federal Funds Rate will typically be a reasonably good predictor for the Federal Funds Rate this month, if nothing else is known. This is what we see in the graphs: it almost looks as if the solid lines have been obtained from the dash-dotted lines by shifting them to the right by one month.

What is more interesting is why the dash-dotted line is different from the solid line, i.e., how it gets pushed around compared to the simple random walk forecast. To that end, we need to look at the dependence of the Federal Funds Rate on the other variables. This is done in the following graphs, which essentially decompose the difference between the solid lines and the black dash-dotted lines in the graph above. What is shown is, how the Federal Funds Rate moves due to lagged and contemporaneous movements of other variables, using the calculations explained previously. Note that for the contemporaneous movements of the other variables, we have included only that part, which is not due to monetary policy surprises, otherwise we would just see the uninteresting echo reaction of the Federal Funds Rate to its own, autonomous movements. The latter isn't particularly large anyhow, as we have already shown above.



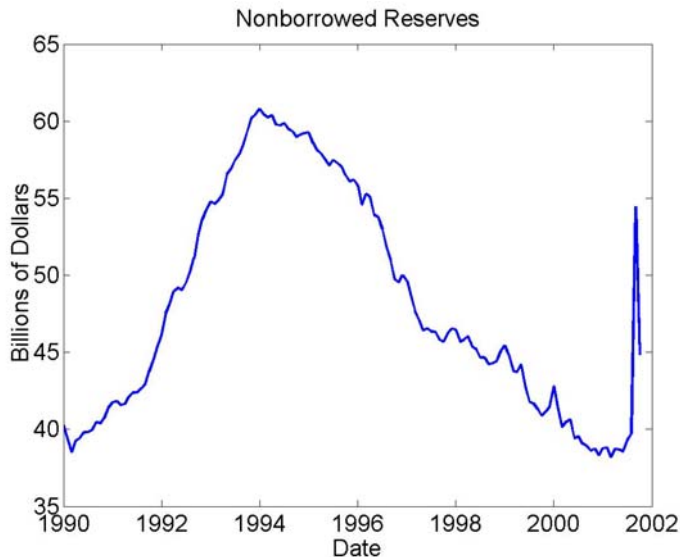




A couple of things are noticeable. First, the degree of uncertainty, i.e. the difference between the solid lines, seems to have risen now. The differences are actually of similar scale to the differences between the solid lines in the own-lags graph above, but they appear to be larger, because we are now seeking to decompose the fairly small difference between the benchmark Federal Funds Rate scenario to the reaction to its own lags in the own-lags graph. Notice that the scale of the figures, i.e., the movements of interest rates explained here, is much smaller than in the graph above. Second, the movements appear to be somewhat erratic. But that is just due to the fact that new information about the economy arrives each month, to which the Federal Reserve reacts in systematic ways.

Now, a story behind the interest rate changes emerges from the data analysis. The price component shows, that the interest rate changes were not driven by inflation surprises directly: there is as much room above the no-change line at zero as there is below. Instead, the second plot shows that there was some additional upward pressure on interest rates of between 10 and 20 basis points in 2000 via monetary variables, turning to a more neutral to negative pressure in 2001. The sudden widening of the bounds for the influence of the monetary policy variables is due to simulating the data from October 2001 onwards and due to the jump upwards in nonborrowed reserves in September 2001, as the following plot reveals.

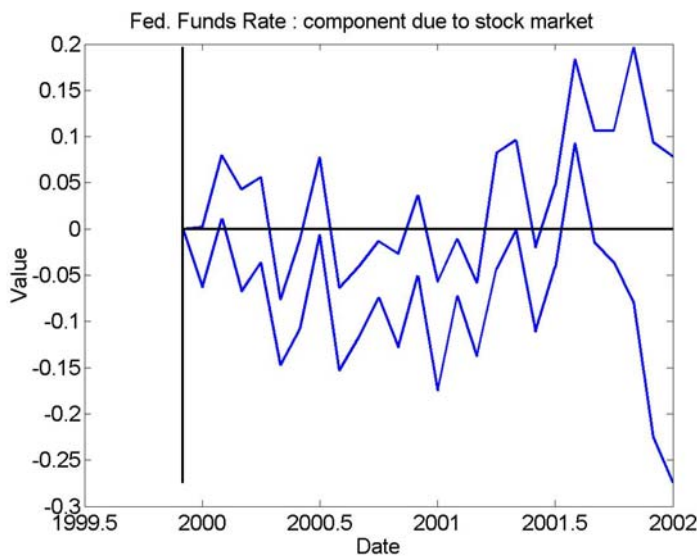
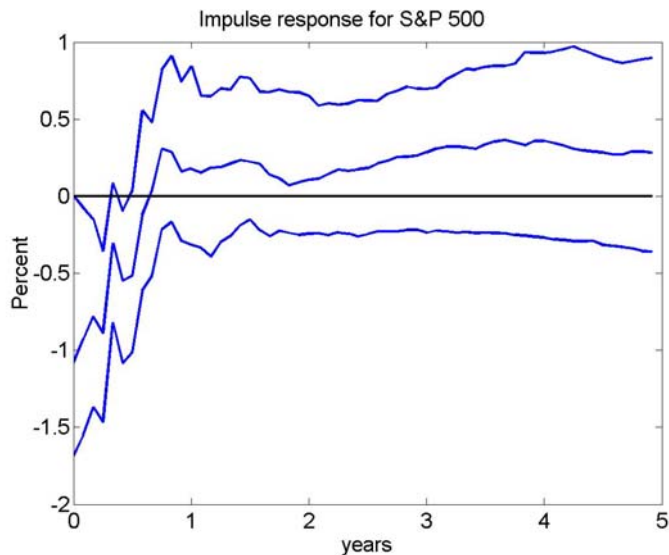




Further, the third plot shows that there was some additional upward pressure on interest rates from real variables at the very beginning in 2001, but mostly downward pressure ever since of somewhere between -10 and -30 basis points. These pressures from monetary and real variables may have inflationary consequences, about which the Fed might have ultimately been concerned about: whether this is so or whether the Fed is reacting for other reasons to these news cannot be deduced from the graphs.

A reaction of 10 to 30 basis points up or down compared to the starting level in 2000 may not seem much. But it actually is: these rather small differences suffice to explain the difference between the benchmark Federal Funds Rate scenario to the reaction to its own lags in the own-lags graph. I.e., combine these small differences with the persistent nature of the Federal Funds Rate, and you get an explanation of the rather large rise in interest rates in 2000 and the rather large fall in 2001.

Does the stock market play a role in all of this? So far, we have left it out of the estimation entirely. One can add a stock market variable - we have chosen cumulated returns based on the SP 500 plus reinvested dividends - and see, how large a component might be explained a reassessment here. This is done in the next two graphs. The first shows the impulse response: it has a reasonable shape. The next shows the component due to the stock market.



According to this plot, the stock market has consistently put downward pressure on the Federal Funds Rate throughout 2000 and 2001, contrary to the perception, that the rise in 2000 was undertaken in order to kill the stock price bubble. It actually started to provide upward pressure towards the second half of 2001, with the very last numbers coming from the simulations. The total influence is e.g. smaller than the influence of the real variables, though.

In sum, the story which this data analysis has to offer, is this. Interest rates rose substantially in 2000 because of the boom conditions at the beginning of 2000 and the pressure from monetary variables such as M1 and nonborrowed reserves. They fell again in 2001, largely because of worsening economic conditions. The Fed reacted to these developments in its usual, systematic way. The stock market played at most a minor role.

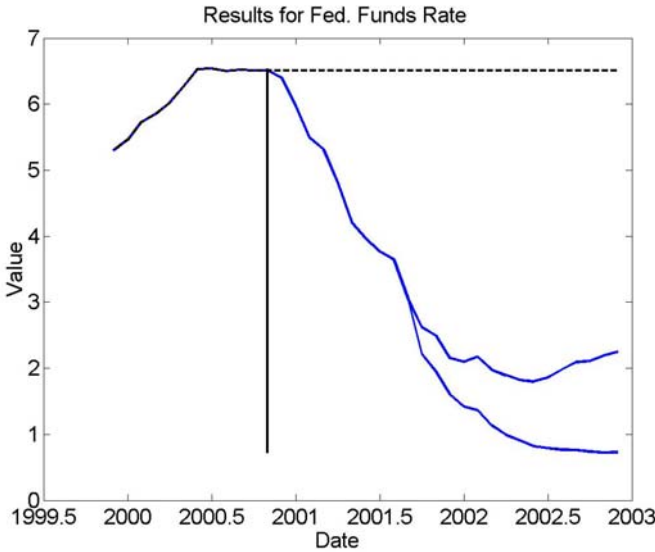
## **A "projection" based on constant interest rates.**

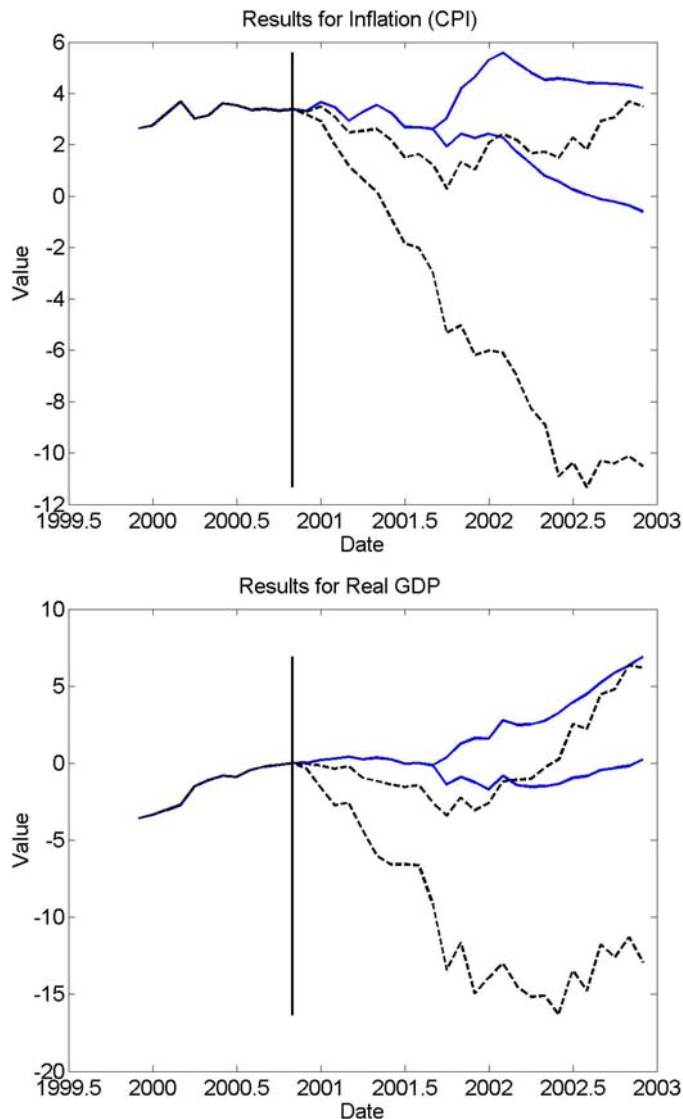
An exercise currently popular at many central bank is to calculate the effects of leaving interest rates unchanged. I.e., one may ask: what would have happened, if Greenspan had not

cut interest rates in a sequence of steps in 2001, but instead, had left the Federal Reserve Rate at its 6.5% December 2000 level? We can answer this question using the same tools as above and again comparing two scenarios. In the first, we are using the actual data until March 2001, and projections beyond that, taking draws for future interest rate changes and changes in other variables based on historical uncertainty. The second scenario differs from the first in that we keep the Federal Reserve Rate constant at 6.5%. More precisely, we have picked a sequence of monetary policy surprises  $\tilde{\varepsilon}(t)$  in such a way as to imply a constant interest rate.

The results for the Federal Funds Rate, CPI inflation and for the percent change of real GDP compared to December 2000 are in the following graphs. The solid bands are the 16% and 84% confidence bands for the first scenario, whereas the dashed, black lines are the corresponding confidence bands for the second. The vertical line denotes the start of the projections, noting that we additionally used actual data until and including March 2001 for the first scenario: for this exercise, we have used the March 2001 rather than the September 2001 cutoff because it makes it easier to visually compare the uncertainty in the forecast to the deviation from the actual path implied by a constant-interest-rate scenario. Obviously, there is no uncertainty regarding the Federal Funds Rate in the second scenario.

Compare in particular the figure for the Federal Funds Rate to the corresponding figure in the previous "on-the-equilibrium-path" comparison of scenarios for 2001. There the difference between the two was small. That implies, that the surprises which one needs to assume here, are several standard deviations away from zero, i.e. they are dramatically and unrealistically large.



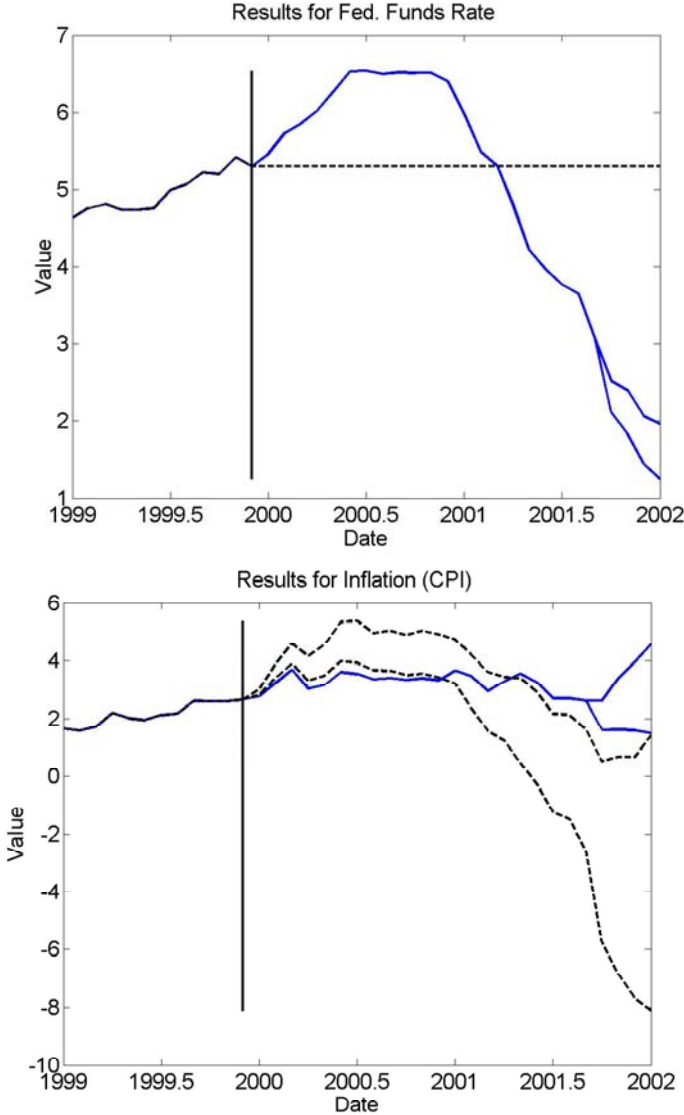


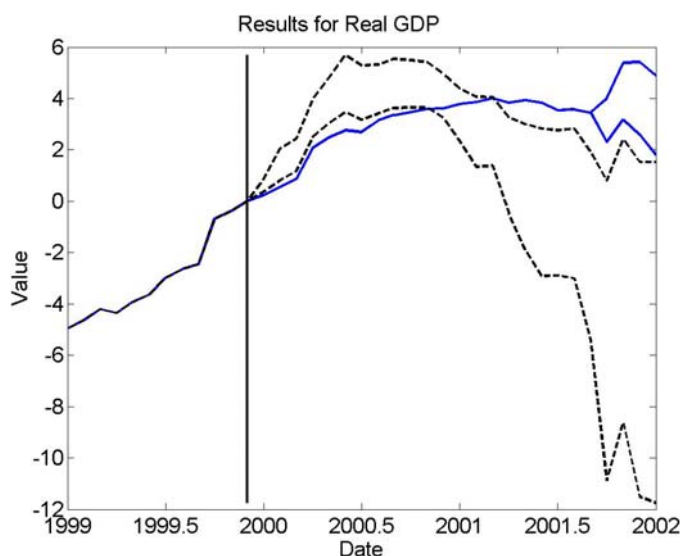
A reading of these results would be as follows. CPI inflation is predicted to fall under both scenarios: in fact, at constant interest rates, inflation would have entered deflationary territory rather quickly. In order to avoid a serious and deep inflation, interest rates need to be cut.

Furthermore, the following observation is important. Assuming, as we have done here, that monetary policy shocks have the ability to influence GDP, continued GDP growth will be much smoother under the given policy than under the alternative of constant interest rates. The confidence bands at the end of 2003 are much tighter, assuming actual policy and simulated policy, using the past as a guide from April 2001 onwards, than with the constant interest rate policy under scenario two. This is all the more interesting as the simulation under the first scenario actually contains more uncertainty as to what interest rates will do. But there is plausible reason for the smoother behaviour of GDP in the first scenario: in essence, as future uncertainty unfolds, the Federal Reserve is allowed to react to changing circumstances in the that scenario, keeping GDP growth on track, while it is prevented from doing so in the second, thus having to rely on luck alone. Whether the Federal Reserve is truly able to influence GDP growth to the extent shown here is a topic of intense debate. One should view the shown differences between the two scenarios as the upper bound on what is possible. In the other extreme, some researchers claim that the Federal Reserve has

practically no effect on real GDP, see in particular Uhlig (1999). In that case, it won't matter much for GDP which scenario we are in. The results for the Federal Reserve rate and CPI inflation should still hold, though.

We have performed a similar counterfactual analysis for the interest hike in 2000, for comparison to the results obtained previously. The first three graphs show the result as to what would have happened, had the Federal Reserve Bank chosen a sequence of monetary policy surprises so as to keep the Federal Funds Rate at its December 1999 level. As one can see, CPI inflation and output growth would have been initially strong, then turning into a steep recession and a steep deflation, compared to actual data.





How useful are these projections? The results show that unchanged interest rates are dramatically far from anything the Federal Reserve might have been considering. One could attempt to show this more formally, using e.g. the two-standard-deviation criterion of Leeper-Zha (2001), but that a constant interest rate scenario would have been extremely unlikely should already be evident enough. The constant-interest-rate projections above can be used for drawing the policy conclusions, that interest rates should not remain at 6.5% for 2001 and 2002 because otherwise the US might experience a deflation of up to minus 10%. This is like saying that when driving a car, one should not follow a straight line for another mile or two, after the road has taken a turn. While that is certainly correct advice, the informational content is obviously limited, although perhaps, some policy makers might find them useful in order to see the dramatic impact that bad monetary policy can have.

Some interpret a no-change-in-interest-rates projection as reflecting a no-change-in-policy scenario. The opposite is true: if there is no change in policy, everybody expects interest rates to be changing. If instead interest rates would not change, agents have two choices: they can either interpret them as a highly unlikely sequence of dramatically large policy shocks. This is the interpretation one needs to keep in mind for interpreting the VAR results above. Alternatively, agents can interpret these deviations as a clear signal that the underlying policy has changed. How agents would react to that is largely unpredictable. This is true, even when using a fully spelled out model: the range of outcomes of subgame perfect equilibria is huge. For an excellent exposition on this topic, see e.g. Sargent (1999) or Ljungqvist-Sargent (2000), chapter 16.

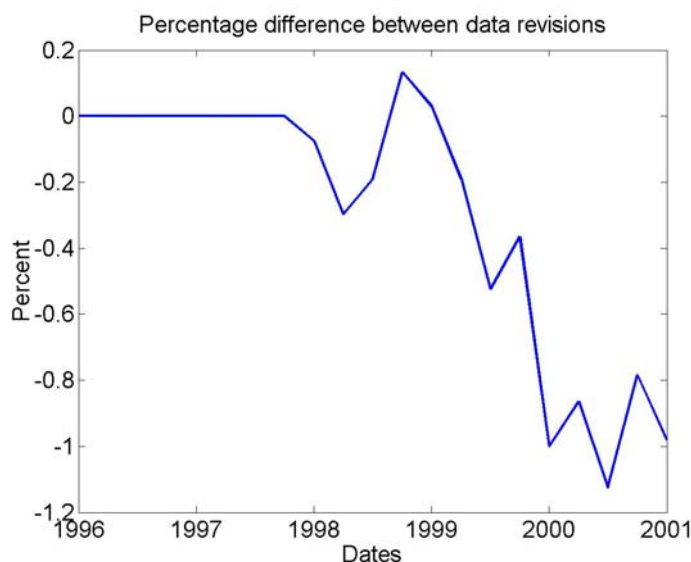
Thus, to interpret the no-change-in-interest-rates projection requires considerable mental discipline and awareness that these projections actually show a dramatic change in policy, interpreted by agents as a highly unlikely sequence of dramatically large policy shocks. Given that these projections are mainly used as communication tools by central banks to a public largely unaware of these caveats, the results can be highly misleading.

The alternative is clear. We have provided an analysis based on a no-shocks-to-policy scenario further above. This is the kind of on-the-equilibrium-path analysis which is internally consistent, easy to communicate to the public. Further, it contains information about the likely future paths of interest rates, which is a far more interesting piece of

information than telling the public to possibly expect -10 % deflation, if interest rates had not been changed after December 1999 for two years.

## Data Revisions.

Finally, we note that GDP figures have been under continuous revision, possibly giving additional reason for the actions by the Federal Reserve. Data revisions have been singled out to be an important explanation for monetary policy in the early 1970s by Orphanides (2001). This may have been a factor in 2001 as well. The following plot compares the data for real GDP (GDP96), taken from the Federal Reserve Bank in St. Louis web site in May 2001 to the data in November 2001: what is shown is the difference between the new and the old data in percent of the new data. As one can see, real GDP is judged to be lower now by one percent compared to the previous figures, with most of the "revisional decline" being attributed to the year 1999. Standard Taylor rule estimates would imply that these revisions have been responsible for an additional 50 basis point cut. Data revisions have not been incorporated in the VAR exercise above.



## Conclusions.

In 2001, the Fed has lowered interest rates in a series of cuts, starting from 6.5 % at the end of 2000 to 2.0 % by early November. This paper asks, whether the Federal Reserve Bank has been surprising the markets. The paper thus uses these events as a showcase and case study for the application of some recent econometric techniques useful for answering the question. In order to concentrate on the Greenspan period, a vector autoregression is fitted to US data, starting in 1986 and ending in March 2001. Monetary policy shocks are identified, using a new sign restriction methodology of Uhlig (1999), imposing the "conventional view" that contractionary policy shocks lead to a rise in interest rates and declines in nonborrowed reserves, prices and output.

We compare two on-the-equilibrium-path projections for the Federal Funds Rate, setting the policy shocks to zero in one scenario and allowing actual or simulated shocks in the second. We find that these scenarios differ very little. This demonstrates that neither the Fed policy

choices in 2001 nor those of 2000 were surprising, but that they can instead be understood as systematic reactions to developments elsewhere in the economy.

We provide a methodology for decomposing these reactions. We have shown that the interest rate changes were not driven by inflation surprises directly. Instead, there was some additional upward pressure on interest rates of between 10 and 20 basis points in 2000 via monetary variables, turning to a more neutral to negative pressure in 2001. Further, there was some additional upward pressure on interest rates from real variables at the very beginning in 2001, but mostly downward pressure ever since of somewhere between -10 and -30 basis points. The pressure from monetary and real variables may have been exerted through their inflationary consequences, about which the Fed might have ultimately been concerned about: whether this is so or whether the Fed is reacting for other reasons to these news cannot be deduced here.

Finally, we argue against the usefulness of constant-interest-rate projections. E.g., the constant-interest-rate projections provided towards the end of this paper say, that interest rates should not have remained at 6.5% for 2001 and 2002 because otherwise the US might experience a deflation of up to minus 10%. This is like saying that when driving a car, one should not follow a straight line for another mile or two, after the road has taken a turn: correct advice, but not particularly useful. Further, to interpret the constant-interest-rates projection requires considerable mental discipline and awareness that these projections actually show a dramatic change in policy, interpreted by agents as a highly unlikely sequence of dramatically large policy shocks. In sum, constant-interest-rate projections are of limited informational value, can be highly misleading and should be replaced by the kind of "on-the-equilibrium" zero-shock-to-monetary-policy projections which have been provided in the first parts of this paper.

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