Online Appendix to "Narrative Sign Restrictions for SVARs"

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A Robustness of Results for the Oil Market

Consider the following alternative formulation of Narrative Sign Restriction 3.

Alternative Narrative Sign Restriction 3. *For the period corresponding to August 1990 (outbreak of the Persian Gulf War), aggregate demand shocks are the least important contributor to the observed unexpected movements in the real price of oil. In other words, the absolute value of the contribution of aggregate demand shocks is smaller than the absolute value of the contribution of any other structural shock.*

Figure A.1 plots the same IRFs reported in Figure 2, but the darker shaded areas and solid lines now add the Alternative Narrative Sign Restriction 3 to the baseline identification instead of adding the Narrative Sign Restrictions 1-3.[1] As the reader can see, Figures 2 and A.1 are almost identical.[2] Hence using either set of narrative sign restrictions has comparable effects on the IRFs and on other results such as the FEVD and historical decompositions presented above.[3]

Given that the restriction relating to August 1990 appears to be key to our results, it warrants some additional discussion. In particular, we will analyze the robustness of the

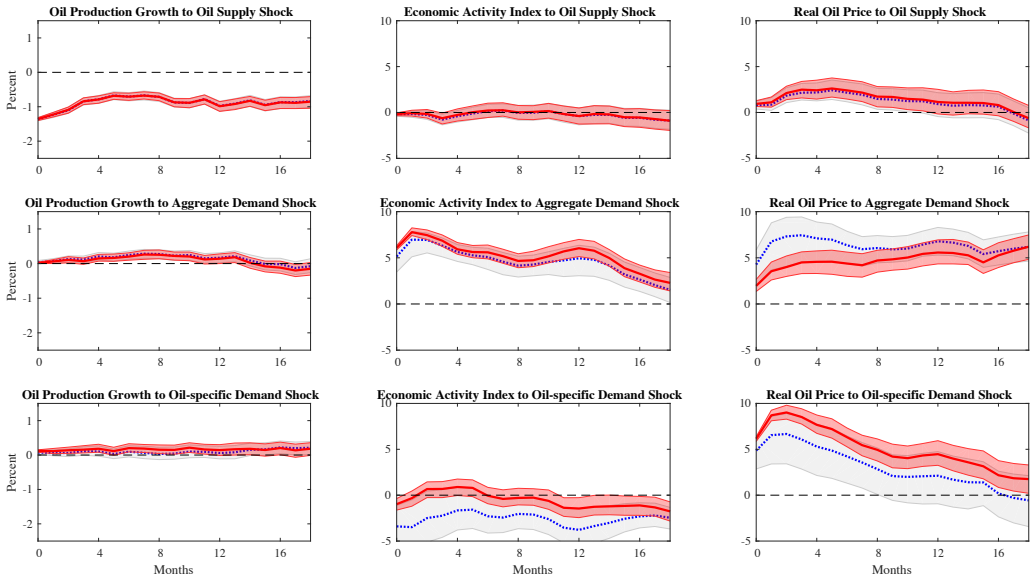
[1] Alternatively, one may also reformulate Narrative Sign Restrictions 1 and 2 so as to include only the August 1990 event, but as can be seen from the third row of Table 2, Narrative Sign Restrictions 1 and 2 are always satisfied by the baseline specification for this particular event. Therefore it is enough to use just Alternative Narrative Sign Restriction 3.

[2] Alternative Narrative Sign Restriction 3 affects in total one time period. Ten thousand draws that satisfy the baseline restrictions are generated. Out of these, 749 satisfy the narrative sign restrictions. We approximate their weight in the importance step by using one thousand draws.

[3] The equivalents to Figures 3 and 4 using Alternative Narrative Sign Restriction 3 are essentially identical to the originals, which use Restrictions 1-3. We do not display them owing to space considerations, but they are available upon request.

Figure A.1: IRFs WITH AND WITHOUT NARRATIVE SIGN RESTRICTIONS

(ALTERNATIVE NARRATIVE SIGN RESTRICTION 3)



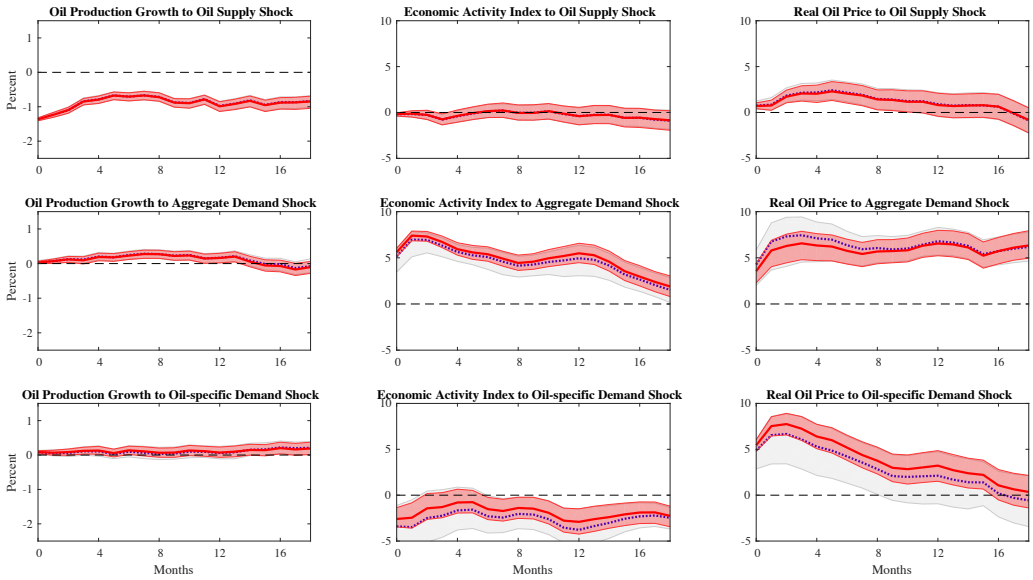
Note: The light shaded area represents the 68% (point-wise) HPD credible sets for the IRFs and the dotted lines are the median IRFs using the baseline identification restrictions. The darker shaded areas and solid lines display the equivalent quantities when Alternative Narrative Sign Restriction 3 is also satisfied. Note that the IRF to oil production has been accumulated to the level.

results to using the Type B variant of Alternative Narrative Sign Restriction 3, instead of the Type A variant we have been using so far. Recall from Section 3.3 that for this case the Type A restriction specifies that the contribution of the aggregate demand shock to the spike in the real price of oil is "less important than any other," whereas the Type B restriction would specify that the contribution is "less important than the sum of all others." Clearly, in this case Type A is a stronger version than Type B, since being less important than any other contribution automatically implies being less important than the (absolute) sum of all others (see the discussion in Section 3.4.2). Figure A.2 plots the same IRFs reported in Figure A.1 when adding the Alternative Narrative Sign Restriction 3 to the baseline identification, but in its milder Type B variant.[4] As the reader can see, the main conclusions are maintained.

[4]Alternative Narrative Sign Restriction 3 (Type B) affects in total two structural shocks. Ten thousand

Figure A.2: IRFs WITH AND WITHOUT SIGN NARRATIVE RESTRICTIONS

(ALTERNATIVE NARRATIVE SIGN RESTRICTION 3 – TYPE B)



Note: The light shaded area represents the 68% (point-wise) HPD credible sets for the IRFs and the dotted lines are the median IRFs using the baseline identification restrictions. The darker shaded areas and solid lines display the equivalent quantities when the Alternative Narrative Sign Restriction 3 (Type B) is also satisfied. Note that the IRF to oil production has been accumulated to the level.

In any case, since it seems accepted that aggregate demand shocks are the least important contributor to the observed unexpected movements in the real price of oil in August 1990, we support the view that the more restrictive Type A variant is adequate. However, changing from Type A and Type B can be a useful way of expressing different degrees of confidence in the narrative information itself.

B Robustness of Results for Monetary Policy Shocks

Note that the Narrative Sign Restriction 5 in the main text is of Type B. It postulates that the absolute value of the contribution of the monetary policy shock is "larger than the sum of the

draws that satisfy the baseline restrictions are generated. Out of these, 4, 500 satisfy the narrative sign restriction. We approximate their weight in the importance step by using one thousand draws.

absolute value of the contribution of all other structural shocks" to the unexpected movement in the federal funds rate in October 1979. A Type A restriction would postulate that the contribution is "larger than the absolute value of the contribution of any other structural shocks." Clearly, in this case Type B is a stronger version than Type A. In our view, there is overwhelming evidence that the unexpected increase in the federal funds rate observed in October 1979 was the outcome of a monetary policy shock; hence, a Type B restriction is justified. Nevertheless, we will check the robustness of our results to specifying a milder Type A version of this restriction. To do this we will consider Alternative Narrative Sign Restriction 5.[5]

Alternative Narrative Sign Restriction 5. *For the observation corresponding to October 1979, a monetary policy shock is the most important driver of the unexpected movement in the federal funds rate. In other words, the absolute value of the contribution of monetary policy shocks to the unexpected movement in the federal funds rate is larger than the absolute value of the contribution of any other structural shock.*

Alternative Narrative Sign Restriction 5 does not meaningfully change the implications for the period around October 1979 relative to Narrative Sign Restriction 5. Figure B.1 replicates the panels displayed in Figure 5 and Figure B.2 replicates the IRFs displayed in Figure 6, but this time using Alternative Narrative Sign Restriction 5 instead of Narrative Sign Restriction 5. As the reader can see, the results are almost identical. Since Alternative Narrative Sign Restriction 5 is weaker than Narrative Sign Restriction 5, the contribution of the monetary policy shock is now slightly smaller and it is only responsible for between 50 and 115 basis points of the 225-basis-point unexpected increase in the federal funds rate observed in October of 1979.

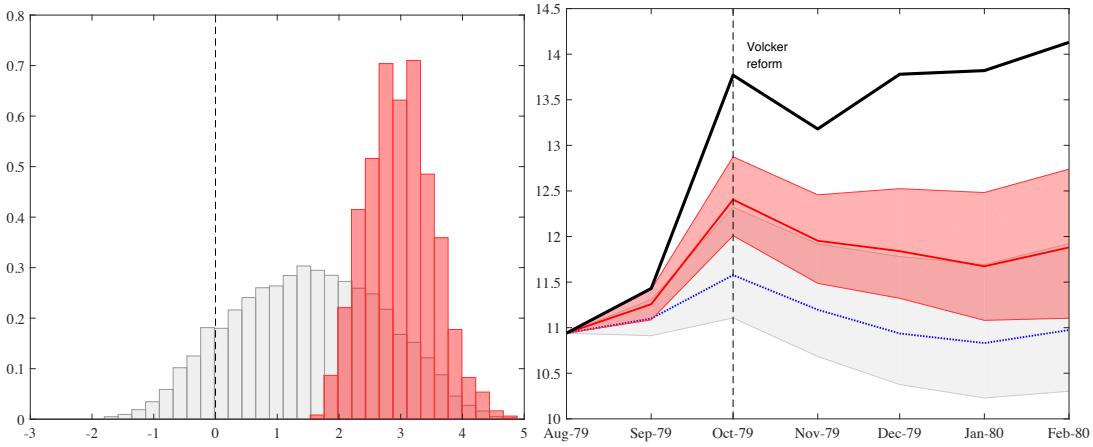
[5]Narrative Sign Restriction 4 and Alternative Narrative Sign Restriction 5 affect in total one structural shock. The 10,116 draws generated in the previous exercise are used as the baseline. Out of these, 2,175 additionally satisfy Narrative Sign Restrictions 4 and Alternative Narrative Sign Restriction 5. We approximate their weights in the importance step by using one thousand draws.

Figure B.1: Results Around October 1979 with Narrative Sign Restrictions

(Narrative Sign Restriction 4 and Alternative Narrative Sign Restriction 5)

(a) Monetary Shock for October 1979

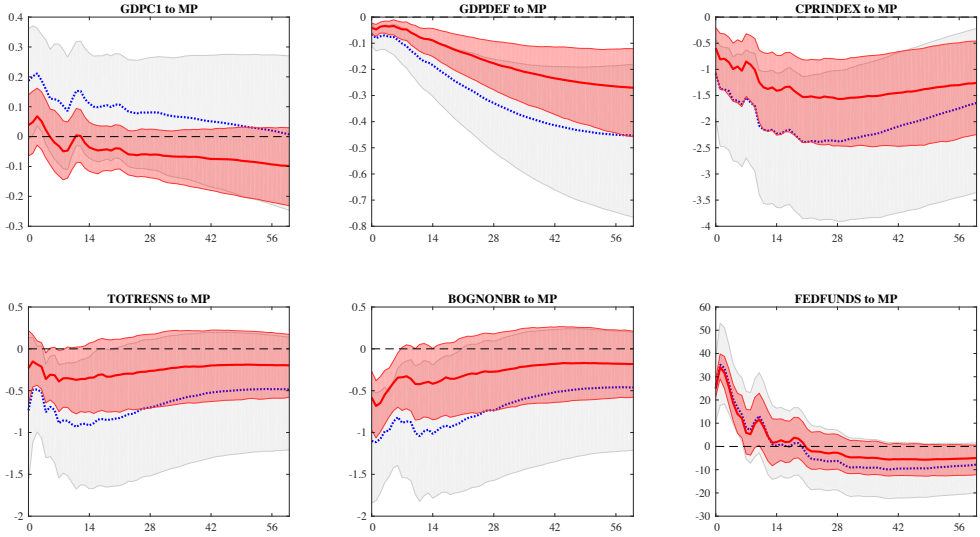
(b) Counterfactual Federal Funds Rate



Note: Panel (a) plots the posterior distribution of the monetary policy shock for October 1979. Panel (b) plots the actual federal funds rate (solid wide) and the median of the counterfactual federal funds rate (solid thin) resulting from excluding all non-monetary structural shocks. The light bands represent 68% (point-wise) HPD credible sets around the median.

Figure B.2: IRFs with and without Narrative Sign Restrictions

(Narrative Sign Restriction 4 and Alternative Narrative Sign Restriction 5)



Note: The light shaded area represents the 68% (point-wise) HPD credible sets for the IRFs and the dotted lines are the median IRFs using the baseline identification restrictions. The darker shaded areas and solid lines display the equivalent quantities for the models that additionally satisfy Restriction Narrative Sign Restriction 4 and Alternative Narrative Sign Restriction 5. The IRFs have been normalized so that the monetary policy shock has an impact of 25 basis points on the federal funds rate.

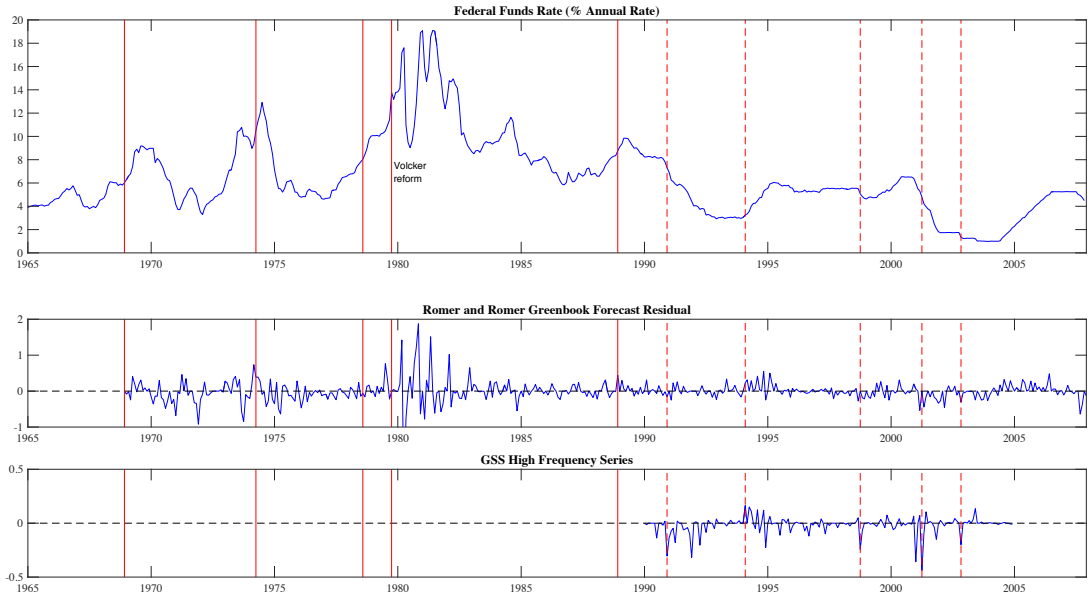
C A New Chronology of Monetary Policy Shocks

In Section 6 we showed that using narrative information on a single event – October 1979 – is enough to obtain the result that the effects of contractionary monetary policy shocks on output are negative with very high posterior probability. That event is in our view the clearest and most uncontroversial, but there is a long literature that uses narrative and historical sources to isolate monetary policy shocks. This section first checks whether additional uncontroversial narrative information is available and second whether imposing it sharpens the results.

Following the pioneering work of Friedman and Schwartz (1963), Romer and Romer (1989) (henceforth, RR-89) combed through the minutes of the FOMC to create a dummy series of events that they argued represented exogenous tightenings of monetary policy. Focusing exclusively on contractionary shocks, they singled out a handful of episodes in the postwar period "in which the Federal Reserve attempted to exert a contractionary influence on the economy in order to reduce inflation" (RR-89, p. 134). These are December 1968, April 1974, August 1978 and October 1979. Romer and Romer (1994) later added December 1988 to the list. The Romer and Romer (1989, 1994) monetary policy narrative became very influential, but has been criticized by Leeper (1997), who pointed out that their dates are predictable from past macroeconomic data. As a consequence, in recent years alternative methods have been developed to construct time series of monetary policy shocks that are by design exogenous to the information set available at the time of the policy decision. The first prominent example is Romer and Romer (2004) (henceforth, RR-04), who regressed changes in the intended federal funds rate between FOMC meetings on changes in the Fed's Greenbook forecasts of output and inflation. By construction, the residuals from this regression are orthogonal to all the information contained in the Greenbook forecasts, and can plausibly be taken to be a measure of exogenous monetary policy shocks. A second approach looks at high-frequency financial data. Gürkaynak et al. (2005) look at movements in federal funds

futures contracts during a short window around the time of policy announcements to isolate the monetary policy shocks.

Figure C.1: Chronology of Monetary Policy Shocks



Note: The upper panel displays the average monthly level of the effective federal funds rate, in percent annual terms. The middle panel displays the Romer and Romer (2004) Greenbook forecast residual series, extended to 2007, while the lower panel displays the Gürkaynak et al. (2005) federal funds surprise series. The solid vertical lines represent the original dates singled out as monetary policy shocks by Romer and Romer, (1989, 1994), whereas the dashed vertical lines represent the additional episodes identified in the chronology below.

The solid vertical lines in Figure C.1 represent the Romer and Romer (1989, 1994) dates. The middle panel plots the RR-04 residuals, extended backward one month to cover the December 1968 meeting and forward to the end of 2007, whereas the lower panel plots the Gürkaynak et al. (2005) measure of monetary policy shocks. During the subsamples in which the series overlap, they disagree a great deal. For this reason, we will draw on the three approaches to select the dates for which the evidence of an exogenous monetary policy shock appears to be most compelling. For the period 1965-1991, which overlaps with the analysis conducted by Romer and Romer (1989, 1994), we start with their dates as candidate shocks

and review the evidence in light of the RR-04 analysis. Of the five Romer and Romer (1989, 1994) dates we keep three. The reasons for the choice are as follows.

- *December 1968.* After remaining stable around 6% for much of 1968, the federal funds rate began increasing gradually after the December meeting, a tightening that accelerated in the spring of 1969. It is unclear, however, that this event qualifies as a monetary policy shock. RR-89 (p. 140, footnote 13) recognize that "the tightening that occurred in December was in part a response to evidence of stronger growth," and the updated Greenbook residual series shows no shock for that meeting, suggesting that the roughly 25-basis-point increase in the federal funds rate registered that month can be fully explained by stronger output and inflation forecasts. We therefore exclude this event from our chronology.

- *April 1974.* Facing weak economic activity and accelerating inflation after the 1973 Arab oil embargo, the Fed chose to tighten policy, allowing the federal funds rate to rise to about 12% before loosening again with the objective of countering inflation expectations. The analysis of the Greenbook forecast reveals an outsized response of the Fed to the prevailing macroeconomic conditions. Indeed, the RR-04 series displays large positive residuals around this event, making it a good candidate for a monetary policy shock.

- *August 1978.* While RR-89 point to this event as an exogenous monetary policy tightening, an analysis of the Greenbook forecasts suggests that in fact much of this tightening can be explained by the Fed's systematic response to output and inflation. Indeed, the inflation outlook had deteriorated consistently in the spring and early summer of 1978, and the RR-04 series suggests that policy was broadly neutral, if not slightly loose, in August 1978 and subsequent months. We therefore exclude this event from our chronology.

- *October 1979.* The monetary policy decisions of October 6, 1979, enacted shortly after Paul Volcker became chairman of the Fed, are described by RR-89 as "a major anti-inflationary shock to monetary policy," and represent in our view the clearest case in the postwar period of an exogenous policy shock. Lindsey et al. (2013) provide a detailed narrative account of the events leading to the decision to abandon targeting the federal funds rate in favor of targeting non-borrowed reserves as the operating procedure for controlling the money supply. While macroeconomic conditions and, in particular, the deterioration of the inflation outlook and the increase in oil prices that followed the Iranian Revolution of 1978-79 played a large role in causing the shift, the forcefulness of the action, the surprise character of the action, and the dramatic break with established practice in the conduct of policy strongly suggest the occurrence of a monetary policy shock.[6]

- *December 1988.* Romer and Romer (1994) extended the original RR-89 chronology to include the sequence of interest rate increases that started in late 1988. As in previous events, their examination of the records of policy points to a shift toward tighter policy in order to "permit progress towards reducing inflation over time." This is confirmed by the Greenbook series, which shows that inflation forecasts did not worsen during that period, and real growth forecasts were revised upwards only moderately. Indeed the RR-04 series displays a positive value of 44 basis points in December 1988 and additional positive values for the subsequent four months. Therefore, the evidence appears to favor the occurrence of a monetary policy shock during this period.

We now turn to the 1990-2007 period, which was not covered by the Romers' original chronology. This period poses additional challenges given that, as argued by Ramey (2016),

[6]Note that because the RR-04 measure by construction includes only decisions that were made at regularly scheduled FOMC meetings, and the October 1979 reform was announced on a Saturday and outside of the regular FOMC cycle, the observation corresponding to this period is not available in the RR-04 series.

monetary policy has been conducted in a more systematic way, so true monetary policy shocks are now rare and therefore harder to identify. It is difficult to find instances that match the Romers' criterion of an event in which the Fed attempted to engineer a recession in order to bring down inflation, since inflation has been low and stable since the early 1990s. There are, however, a number of instances in which the Fed deviated from its usual behavior, responding more aggressively than normal in order to offset perceived risks to its inflation and employment goals. By construction, both the RR-04 measure and the high-frequency measure of Gürkaynak et al. (2005) (henceforth, GSS), which are available for this period, are likely to capture this type of event well. We single out as events December 1990, February 1994, October 1998, January 2001 and November 2002. These are represented by the dashed vertical lines in Figure C.1. With the exception of the 1994 event, they all represent circumstances in which the Fed eased aggressively, citing "risk management" considerations in response to unusual risks to economic growth. Here we explain why we choose each of these five events.

- *December 1990.* During the fall of 1990 the FOMC had started to ease monetary policy in response to the Gulf War and the associated spike in oil prices, which was expected to cause an economic contraction. By the time of the FOMC meeting of December 18, hopes of a quick resolution of the war emerged and oil prices had reversed almost half of their increase. The Greenbook forecasts presented by the staff foresaw a more robust recovery during the subsequent spring, and the forecast for the level of output was revised upward for both the December and the February meetings. The FOMC, however, decided to ease policy further on both occasions, contrary to expectations (as seen by the presence of negative shocks in the GSS series) and to its usual reaction function (as seen in the RR-04 series), citing the need to "insure" the economy from the risk of a deeper recession or further shocks.[7] We will therefore keep this event in

[7]The main justification for the surprisingly dovish stance appears to be an unwillingness to sacrifice output in

the chronology.

- *February 1994.* Starting in February 1994, the FOMC began a series of tightening moves that over the subsequent 12 months increased the fed funds rate by 300 basis points. The start of the tightening campaign certainly was a complete surprise to financial market participants, leading to a major adjustment in longer-term interest rates.[8] The speed of subsequent hikes was also a surprise, as can be seen from the GSS series. Moreover, the sequence of interest rate increases appears aggressive relative to usual procedures. Indeed, the RR-04 series displays a positive shock for the observation corresponding to every single meeting up to November 1994, and an examination of the staff projections and forecasts prepared for the Feburary meeting reveals that the tightening between February and November was more aggressive than both the baseline policy proposal prepared by the staff, and a tighter policy alternative. There is evidence, however, that the 1994 event could be an example of superior information, or "policy foresight," rather than a true monetary policy shock. Indeed, an examination of the minutes of the February 1994 FOMC meeting reveals that policy makers had confidential access to the employment data to be released publicly later that day, and which had not been available for the preparation of the Greenbook forecast, indicating that at least part of the tightening was a response to news on improving economic activity. Nevertheless, the minutes of the FOMC meetings in the early part of 1994 do reveal an outsized response to the risk of inflation accelerating.

- *October 1998.* In late September of 1998, the FOMC responded to the deterioration in

order to reduce inflation. "While substantial additional easing might not be needed under prevailing conditions, a limited further move would provide some added insurance in cushioning the economy against the possibility of a deepening recession and an inadequate rebound in the economy without imposing an unwarranted risk of stimulating inflation later."

[8]See "The great bond massacre" (Fortune, 1994) for a representative contemporary account, which associated the heavy losses experienced by financial companies, hedge funds, and bond mutual funds on their holdings of long-term bonds with the surprise tightening by the Fed.

the global economic outlook stemming from the Russian debt crisis of 1998 and the failure of the hedge fund Long Term Capital Management (LTCM) by lowering the federal funds rate by 25 basis points "to cushion the effects on prospective economic growth in the United States of increasing weakness in foreign economies and of less accommodative financial conditions domestically."[9] On October 15 the FOMC decided to cut by an additional 25 basis points. As can be seen from the GSS series, the move came as a surprise to financial markets. An examination of the transcript of the conference call reveals that there had not been material changes to economic data in the prior two weeks, and that the FOMC was deliberating on "a matter of uncertainties at this point [rather] than clear-cut changes in the outlook," on the basis of turbulence in financial markets. A participant in the meeting pointed out that there was "no basis there for a material change in policy," but "a higher degree of uncertainty [which] reinforces the sense of downside risks."[10] This episode in which the FOMC was seen to respond to financial turbulence alone led to the expression "Greenspan 'put'," which referred to the perceived insurance the Fed was providing to financial market participants against stock market crashes. We will therefore keep this event in the chronology.

- *April 2001.* In response to the weakening in the economy that had begun in the fall of 2000, the Federal Reserve began lowering the federal funds rate with a 50-basis-point cut on January 3, 2001. While the timing of the move was a surprise (it took place during an intermeeting conference call shortly after taking no action at the December meeting just a few weeks earlier), it is unclear whether the January cut can be classified as a monetary policy shock. All participants in the meeting explicitly mentioned a deteriorating outlook for the economy as the reason for lowering interest rates.

[9] See *Statement*, Federal Open Market Committee, September 29, 1998.
[10] See *Transcript*, Federal Open Market Committee, October 15, 1998.

Moreover, in the transcript of the conference call, Chairman Greenspan explicitly mentions having received classified data on unemployment claims pointing to further weakness. A stronger case can be built for the April 18, 2001 meeting, another instance of the FOMC lowering the federal funds rate in a surprise move in between scheduled meetings. In his opening statement, Chairman Greenspan made clear that "in reviewing the economic outlook over the last week, it is fairly apparent that very little of significance has changed." It appears that during this period, as in the 1998 episode, the FOMC was placing a substantial weight on asset price volatility, particularly after the bursting of the dot-com stock price bubble the previous year. We will therefore keep this event in the chronology.

- *November 2002.* In November of 2002 the FOMC lowered the federal funds rate by 50 basis points. This move was both larger than what the market expected, and what, according to the updated RR-04 Greenbook series, was warranted by the available economic data. Moreover, incoming data received after the completion of the Greenbook "were very close to our expectations and require little change to [the] near-term forecast." Particularly in light of developments in Japan, which had been experiencing persistent deflation since the late 1990s, it appears that concerns about deflation loomed large.[11] Geopolitical risks – preparations for the 2003 Iraq war were already under way – were also a concern.[12] Once again, risk management considerations motivated a larger-than-usual cut that would provide 'insurance against downside risks." As Chairman Greenspan argued, "If we move significantly today –and my suggestion would be to lower the funds rate 50 basis points – it is possible that

[11]One participant expressed concern that "a negative demand shock could cause the disinflation trends we've had lately to morph into deflation," and staff simulations placed a 25-30% probability that the economy would experience a deflation. Chairman Greenspan remarked that "if we were to fail to move and the economy began to deteriorate [...] we were looking into a deep deflationary hole." See *Transcript*, Federal Open Market Committee, November 6, 2002.

[12]See *Statement*, Federal Open Market Committee, November 6, 2002.

such a move may be a mistake. But it's a mistake that does not have very significant consequences. On the other hand, if we fail to move and we are wrong, meaning that we needed to, the cost could be quite high."[13] We will therefore keep this event in the chronology.

To summarize, by cross-checking the updated Greenbook residual series from RR-04, the high-frequency series from GSS, and the transcripts from the meetings of the FOMC, we have singled out eight events for which there appears to be a good case that a monetary policy shock occurred. Of these, four were contractionary, or tightening, shocks (positive in terms of their impact on the federal funds rate) and four were expansionary, or easing, shocks (negative shocks). We will therefore consider the Narrative Sign Restrictions 6 and 7 stated in Section 6, reproduced below for convenience:

Narrative Sign Restriction 6. *The monetary policy shock must be positive for the observations corresponding to April 1974, October 1979, December 1988, and February 1994, and negative for December 1990, October 1998, April 2001, and November 2002.*

Narrative Sign Restriction 7. *For the periods specified by Restriction 6, monetary policy shocks are the most important contributor to the observed unexpected movements in the federal funds rate. In other words, the absolute value of the contribution of monetary policy shocks is larger than the absolute value of the contribution of any other structural shock.*

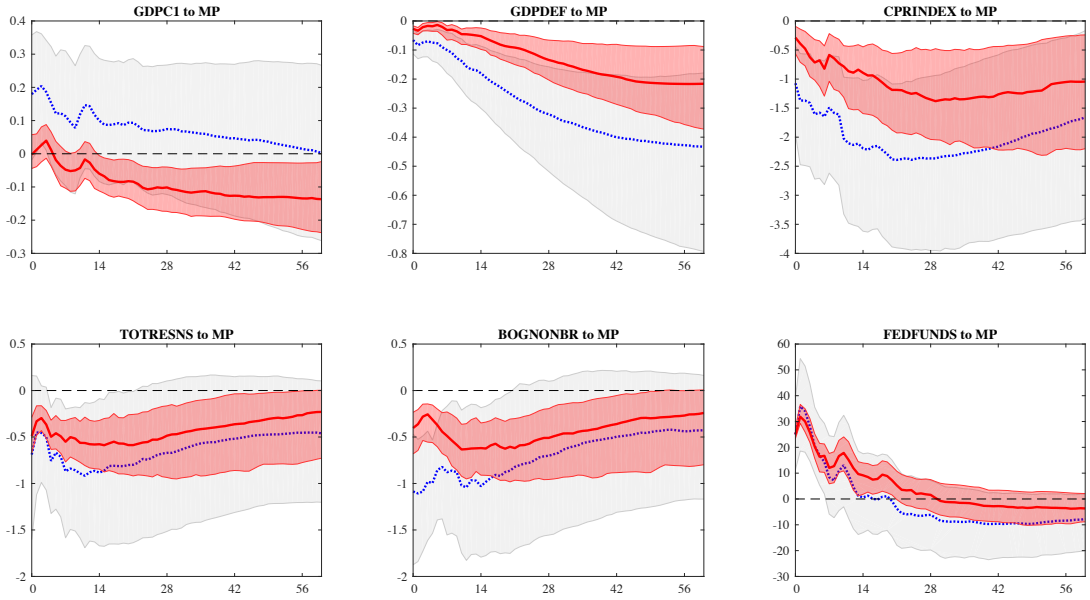
In terms of the definitions of Section 3, Narrative Sign Restriction 6 is a restriction on the sign of the structural shocks, whereas Narrative Sign Restriction 7 is a Type A restriction on the historical decomposition.

Figure C.2 presents the IRFs to a monetary policy shock, with and without narrative information. The light shaded area represents the 68% (point-wise) HPD credible sets for the

[13] See *Transcript*, Federal Open Market Committee, November 6, 2002.

Figure C.2: IRFs with and without Narrative Sign Restrictions

(Narrative Sign Restrictions 6 and 7)



Note: The light shaded area represents the 68% (point-wise) HPD credible sets for the IRFs and the dotted lines are the median IRFs using the baseline identification restrictions. The darker shaded areas and solid lines display the equivalent quantities for the models that additionally satisfy Narrative Sign Restrictions 6-7.

IRFs and the dotted lines are the median IRFs using the baseline identification. These results replicate the IRFs depicted in Figure 6 of Uhlig (2005). The darker shaded areas and solid lines display the equivalent quantities when Narrative Sign Restrictions 6-7 are also used. The results are very similar to those using only the Volcker episode, reported in Figure 6 in the main text.

C.1 Results for the 1994 event only

As mentioned in the main tex it is worth highlighting that the February 1994 event stands out because the narrative record identifies a major contractionary monetary policy shock, which was followed in the data by a subsequent boom in output. Therefore, the historical account arguably cannot be considered to be distorted by the presence of a recession shortly after the

monetary policy action. We can specify the following narrative sign restrictions:

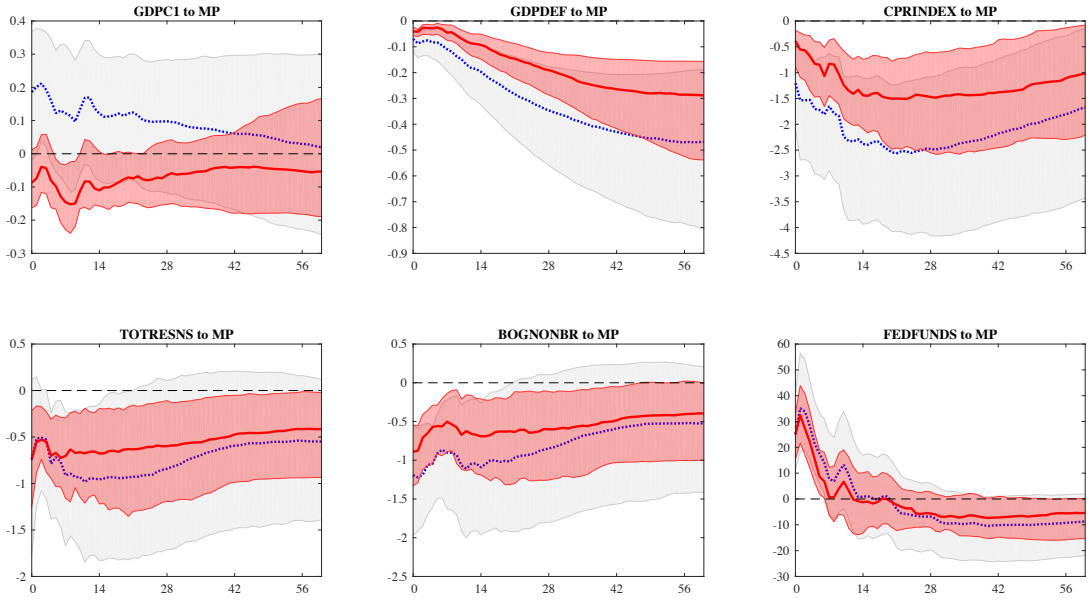
Narrative Sign Restriction 8. *The monetary policy shock must be positive for the observation corresponding to February 1994.*

Narrative Sign Restriction 9. *For the period specified by Restriction 8, the monetary policy shock is the overwhelming contributor to the observed unexpected movements in the federal funds rate. In other words, the absolute value of the contribution of monetary policy shocks is larger than the sum of the absolute value of the contribution of all other structural shocks.*

In terms of the definitions of Section 3, Narrative Sign Restriction 8 is a restriction on the sign of the structural shocks, whereas Narrative Sign Restriction 9 is a Type A restriction on the historical decomposition. Figure C.3 displays the results. As can be seen, the results are qualitatively similar to the ones using the Volcker event. The response of GDP is negative, and significantly so after about a year. Thus, we conclude that it is possible to find an event that did not lead to a recession shortly thereafter – in fact, output growth accelerated in 1994 and 1995 – and yet contains useful information for identification.

Figure C.3: IRFs WITH AND WITHOUT NARRATIVE SIGN RESTRICTIONS

(1994 EVENT ONLY)



Note: The light shaded area represents the 68% (point-wise) HPD credible sets for the IRFs and the dotted lines are the median IRFs using the baseline identification restrictions. The darker shaded areas and solid lines display the equivalent quantities for the models that additionally satisfy Narrative Sign Restrictions 6-7.

D Computational Aspects

In this section we give additional details on the computational properties of our Algorithm 1 for the applications presented in the text. First, recall that Steps 1, 2, and 4 are basically identical to the steps in standard algorithms with traditional sign restrictions; see Rubio-Ramirez et al. (2010) and Arias et al. (forthcoming). The only difference is that now we also need to check whether the narrative sign restrictions hold in addition to checking whether the traditional sign restrictions hold. Second, the main difference with standard algorithms with only traditional sign restrictions is Step 3. After discarding draws that do not satisfy the restrictions, in Step 3 we compute the weights for the accepted draws and in Step 5 we draw with replacement using those weights. Third, Step 1 produces independent draws. This is

very advantageous as the number of draws needed to conduct inference will be much lower than with less efficient algorithms, for instance, those based on Metropolis-Hastings. Fourth, the rejection rate in Step 2 will vary from application to application. We have calibrated the number of draws in Step 1 to obtain around $1,000$ draws that satisfy both the traditional and narrative sign restrictions. This implies that when imposing one or two narrative sign restrictions as in the results presented in Sections 5.4 or 6.3, we only need to produce $10,000$ draws in Step 1. When more narrative sign restrictions are used, as in the results presented in Section 5.3, we might need to obtain more than 10^8 draws in Step 1. Finally, the reader should notice that given that the algorithm is easy to parallelize, obtaining 10^8 draws in Step 1 is not a problem. The computations in this paper were carried out using MATLAB R2016b on an 12-core HP Z420 computer with an Intel Xeon CPU with a 360Ghz processor and 16 Gb of RAM and 10^8 draws were obtained in less than one hour.

Having said this, because we use an importance sampling step, we need to compute the effective sample size to guard against having only a few draws dominate Step 5. If w_i is the weight associated with the i^{th} draw, then the effective sample size is

$$\text{ESS} = \frac{\left(\sum_{i=1}^{N} w_i\right)^2}{\sum_{i=1}^{N} w_i^2}$$

where N is the number of draws that satisfy the restrictions. The effective sample size can be expressed as a percentage by dividing ESS by N and multiplying by 100. For all the applications in the paper we obtained ESS (expressed in percentage) of 85% or above. Hence we do not see any issues with the importance sampling weights, even when considering several narrative sign restrictions as in the case of Section 5.3.

Finally, it is important to mention that the number of draws M necessary to compute weights also depends on the number of narrative sign restrictions considered. In the case of many narrative sign restrictions, as in Section 5.3, we need up to 10^6 draws. In the case of

only one narrative sign restriction as in the results presented in Sections 5.4 or 6.3, $1,000$ draws are enough. Computing the weights using 10^6 draws may be time consuming, but the reader should remember that we only need to compute the weights for the draws that satisfy both the traditional and narrative sign restrictions, i.e., around $1,000$ times. When 10^6 draws were needed to compute the $1,000$ weights, our code needed 3.5 hours to do so. When $1,000$ draws were needed to compute the $1,000$ weights, our code took less than one minute. Once again, since the draws of the algorithm are independent, these times can be massively accelerated using modern parallel computing techniques.