

# **Macroeconomic Shocks and Their Propagation**

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### 3. Monetary Policy Shocks

This section reviews the main issues and results from the empirical literature seeking to identify and estimate the effects of monetary policy shocks. I begin by with a brief overview of the research before and after Christiano, Eichenbaum, and Evan's (1999) *Handbook of Macroeconomics* chapter on the subject. I then focus on two leading externally identified monetary policy shocks, Romer and Romer's (2004) narrative/Greenbook shock and Gertler and Karadi's (2015) shock identified using fed funds futures. I focus on these two shocks in part because they both imply very similar effects of monetary policy on output, despite using different identification methods and different samples. In an empirical exploration of the effects of those shocks in systems that impose fewer restrictions, though, I discovered that relaxing some key over-identifying assumptions yields estimated responses of output and prices that are very different from the standard story.

Before beginning, it is important to clarify why we are interested in monetary policy shocks. Because monetary policy is typically guided by a rule, most movements in monetary policy instruments are due to the *systematic* component of monetary policy rather than to deviations from that rule. Why, then, do we care about identifying shocks? We care about identifying shocks for a variety of reasons, the most important of which is to be able to estimate *causal* effects of money on macroeconomic variables. As Sims (1998) argued in his discussion of Rudebusch's (1998) critique of standard VAR methods, because we are trying to identify structural parameters, we need instruments that shift key relationships. Analogous to the supply and demand framework where we need demand shift instruments to identify the parameters of the supply curve, in the monetary policy context we require monetary rule shift instruments to identify the response of the economy to monetary policy.

It should be kept in mind, though, that a finding that monetary shocks themselves contribute little to a standard forecast error variance decomposition does not imply that monetary policy is unimportant for macroeconomic outcomes. Rather, such a finding would be consistent with the notion that the monetary authority pursues systematic policy in an effort to *stabilize* the economy and is rarely itself a source of macroeconomic volatility.

### **3.1 A Brief History through 1999**

The effect of monetary policy on the economy is one of the most studied empirical questions in all of macroeconomics. The most important early evidence was Friedman and Schwartz's path-breaking 1963 contribution in the form of historical case studies and analysis of historical data. The rational expectations revolution of the late 1960s and 1970s highlighted the importance of distinguishing the part of policy that was part of a rule versus shocks to that rule, as well as anticipated versus unanticipated parts of the change in the policy variable. Sims (1972, 1980a, 1980b) developed modern time series methods that allowed for that distinction while investigating the effects of monetary policy. During the 1970s and much of the 1980s, shocks to monetary policy were measured as shocks to the stock of money (e.g. Sims (1972), Barro (1977, 1978)). This early work offered evidence that (i) money was (Granger-) causal for income; and (ii) that fluctuations in the stock of money could explain an important fraction of output fluctuations. Later, however, Sims (1980b) and Litterman and Weis (1985) discovered that the inclusion of interest rates in the VAR significantly reduced the importance of shocks to the money stock for explaining output, and many concluded that monetary policy was not important for understanding economic fluctuations.<sup>1</sup>

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<sup>1</sup> Of course, this view was significantly strengthened by Kydland and Prescott's (1982) seminal demonstration that business cycles could be explained with technology shocks.

There were two important rebuttals to the notion that monetary policy was not important for understanding fluctuations. The first rebuttal was by Romer and Romer (1989), who developed a narrative series on monetary policy shocks in the spirit of Friedman and Schwarz's (1963) work. Combing through FOMC minutes, they identified dates at which the Federal Reserve "attempted to exert a contractionary influence on the economy in order to reduce inflation" (p. 134). They found that industrial production decreased significantly after one of these "Romer Dates." The Romers' series rapidly gained acceptance as an indicator of monetary policy shocks.<sup>2</sup> A few years later, though, Shapiro (1994) and Leeper (1997) showed that the Romers' dummy variable was, in fact, predictable from lagged values of output (or unemployment) and inflation. Both argued that the narrative method used by the Romers did not adequately separate *exogenous* shocks to monetary policy, necessary for establishing the strength of the causal channel, from the *endogenous* response of monetary policy to the economy.

The second rebuttal to the Sims and Litterman and Weiss argument was by Bernanke and Blinder (1992). Building on an earlier idea by McCallum (1983), Bernanke and Blinder turned the money supply vs. interest rate evidence on its head by arguing that interest rates, and in particular the federal funds rate, were *the* key indicators of monetary policy.<sup>3</sup> They showed that both in Granger-causality tests and in variance decompositions of forecast errors, the federal

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<sup>2</sup> Boschen and Mills (1995) also extended the Romers' dummy variables to a more continuous indicator.

<sup>3</sup> Younger readers not familiar with monetary history might be surprised that anyone would think that monetary policy was conducted by targeting the money stock rather than the interest rate. To understand the thinking of that time, one must remember that Milton Friedman had argued in his 1968 Presidential Address that the central bank could not peg interest rates, and prescribed targeting the growth rate of the money stock instead. In fact, the evidence suggests that the Fed has almost always targeted interest rates. The only possible exception was from late 1979 through 1982, when the Fed said it was targeting nonborrowed reserves. Interest rates spiked up twice during that period, and it was convenient to suggest that those movements were beyond the Fed's control. Subsequent research has shown that in fact most of the movements in the Federal funds rate even during that period were directly guided by the Fed (e.g. Cook (1989), Goodfriend (1991)). The Fed's claim that they were targeting the money supply not interest rates gave them political cover for undertaking the necessary rise in interest rates to fight inflation.

funds rate outperformed both M1 and M2, as well as the three-month Treasury bill and the 10-month Treasury bond for most variables.

The 1990s saw numerous papers that devoted attention to the issue of the correct specification of the monetary policy function. These papers used prior information on the monetary authority's operating procedures to specify the policy function in order to identify correctly the shocks to policy. For example, Christiano and Eichenbaum (1992) used nonborrowed reserves, Strongin (1995) suggested the part of nonborrowed reserves orthogonal to total reserves, and Bernanke and Mihov (1998) generalized these ideas by allowing for regime shifts in monetary policy rules.<sup>4</sup> Another issue that arose during this period was the "Price Puzzle," a term coined by Eichenbaum (1992) to describe the common result that a contractionary shock to monetary policy appeared to raise the price level in the short-run. Sims (1992) conjectured that the Federal Reserve used more information about future movements in inflation than was commonly included in the VAR. He showed that the price puzzle was substantially reduced if commodity prices, often a harbinger of future inflation, were included in the VAR.

Christiano, Eichenbaum, and Evans' 1999 *Handbook of Macroeconomics* chapter "Monetary Policy Shocks: What Have We Learned and To What End?" summarized and explored the implications of many of the 1990 innovations in studying monetary policy shocks. Perhaps the most important message of the chapter was the robustness of the finding that monetary policy shocks, however measured, had significant effects on output. On the other hand, the pesky price puzzle continued to pop up in many specifications.

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<sup>4</sup> An important part of this literature was addressed to the "liquidity puzzle," that is, the failure of some measures of money supply shocks to produce a negative short-run correlation between the supply of money and interest rates.

## **3.2 A Brief Overview of Findings Since 2000**

In this section, I will begin by briefly overviewing two important departures from the time-invariant linear modeling that constitutes the bulk of the research. I will then summarize the findings of the most current results from the literature in terms of the effect on output.

### **3.2.1 Regime Switching Models**

In addition to the switch between interest rate targeting and nonborrowed reserve targeting (discussed by Bernanke and Mihov (1998)), several papers have estimated regime switching models of monetary policy. The idea in these models is that monetary policy is driven not just by shocks but also by changes in the policy parameters. In an early contribution to this literature, Owyang and Ramey (2004) estimate a regime switching model in which the Fed's preference parameters can switch between "hawk" and "dove" regimes. They find that the onset of a dove regime leads to a steady increase in prices, followed by decline in output after approximately a year. Primiceri (2005) investigates the roles of changes in systematic monetary policy versus shocks to policy in the outcomes in the last 40 years. While he finds evidence for changes in systematic monetary policy, he concludes that they are not an important part of the explanation of fluctuations in inflation and output. Sims and Zha (2006) also consider regime switching models and find evidence of regime switches that correspond closely to changes in the Fed chairmanship. Nevertheless, they also conclude that changes in monetary policy regimes do not explain much of economic fluctuations.

### **3.2.2 Time-Varying Effects of Monetary Policy**

In their excellent summary of the monetary policy literature in their chapter in the *Handbook of Monetary Economics*, Boivin, Kiley, and Mishkin (2010) focus on time variation in the effects of monetary policy. I refer the reader to their excellent survey for more detail. I will highlight two sets of results that emerge from their estimation of a factor-augmented VAR (FAVAR), using the standard Cholesky identification method. First, they confirm some earlier finds that the responses of real GDP were greater in the pre-1979Q3 period than in the post-1984Q1 period. For example, they find that for the earlier period, a 100 basis point increase in the federal funds rate leads to a decline of industrial production of 1.6 percent troughing at 8 months. In the later period, the same increase in the funds rate leads to a -0.7 percent decline troughing at 24 months. The second set of results concerns the price puzzle. They find that in a standard VAR the results for prices are very sensitive to the specification. Inclusion of a commodity price index does not resolve the price puzzle, but inclusion of a measure of expected inflation does resolve it in the post-1984:1 period. In contrast, there is no price puzzle in the results from their FAVAR estimation. This time-variation in the strength of the effect of monetary shocks across periods had also been noted previously, such as by Faust (1998) and Barth and Ramey (2001).

Barakchian and Crowe (2013) estimate many of the standard models, such as Bernanke and Mihov (1998), CEE (1999), Romer and Romer (2004), and Sims and Zha (2006b), splitting the estimation sample in the 1980s and showing that the impulse response functions change dramatically. In particular, most of the specifications estimated from 1988 – 2008 show that a positive shock to the federal funds rate *raises* output and prices in most cases.

Another source of time variation is state-dependent or sign-dependent effects of monetary shocks on the economy. Cover (1992) was one of the first to present evidence that negative



monetary policy shocks had bigger effects (in absolute value) than positive monetary shocks. Follow-up papers such as by Thoma (1994) and Weisse (1999) found similar results. Recent work by Angrist, Jordà, and Kuersteiner (2013) finds related evidence that monetary policy is more effective in slowing economic activity than it is in stimulating economic activity. Tenreiro and Thwaites (2014) also find that monetary shocks seem to be less powerful during recessions.

### **3.2.3 Summary of Recent Estimates**

Table 3.1 summarizes some of the main results from the literature in terms of the impact of the identified monetary shock on output, the contribution of monetary shocks to output fluctuations, and whether the price puzzle is present. Rather than trying to be encyclopedic in listing all results, I have chosen leading examples obtained with the various identifying assumptions.

As the table shows, the some key results from research that uses linear models and the identification methods described in section 2.1. As the table shows, the standard CEE (1999) SVAR, the Faust, Swanson, Wright (2004) high frequency identification, Uhlig's (2005) sign restrictions, Smets and Wouters' (2007) estimated DSGE model, and Bernanke, Boivin and Elias's (2005) FAVAR all produce rather small effects of monetary policy shocks. Also, most are plagued by the price puzzle to greater or lesser degree. On the other hand, Romer and Romer (2004), Coibion (2012), and Gertler-Karadi (2015) all find larger impacts of a given shock on output. The Romers' estimates are particularly large.

I will also summarize the effects on other variables from some of the leading analyses. A particularly comprehensive examination for many variables is conducted by Boivin, Kiley, and Mishkin's (2010) with their FAVAR. Recall that they obtained different results for the pre-

versus post-1980 period. For the period from 1984m1 – 2008m12, they found that a positive shock to the federal funds rate leads to declines in a number of variables, including employment, consumption expenditures, investment, housing starts, and capacity utilization.

### **3.3 A Discussion of Two Leading External Instruments**

#### **3.3.1 Romer and Romer’s Narrative/Greenbook Method**

In a 2000 paper, Romer and Romer presented evidence suggesting that the Fed had superior information when constructing inflation forecasts compared to the private sector. Romer and Romer (2004) builds on this result and introduces a new measure of monetary policy shocks that seeks to correct some of the limitations of their earlier monetary policy measure. They construct their new measure as follows. First, they derive a series of *intended* federal funds rate changes around FOMC meetings using narrative methods. Second, in order to separate the endogenous response of policy to the economy from the exogenous shock, they regress the intended funds rate change on the current rate and on the Greenbook forecasts of output growth and inflation over the next two quarters. They then use the estimated residuals in dynamic regressions for output and other variables. They find very large effects of these shocks on output.

John Cochrane’s (2004) NBER EFG discussion of the Romer and Romer paper highlights how their method can not only overcome the identification problem but can also provide us a coherent notion of what a shock to monetary policy really is. In a number of papers, Cochrane has questioned even the existence of a “shock” to monetary policy. He notes that the Fed never “rolls the dice;” every Fed action is a response to *something*. How then can one identify movements in monetary policy instruments that are exogenous to the error term of the model?

As Cochrane (2004) argues, the Romers' method might provide an answer. If the Greenbook forecast of future GDP growth contains all of the information that the FOMC uses to make its decisions, then that forecast is a "sufficient statistic." Any movements in the target funds rate that are not predicted by the Greenbook forecast of *GDP growth* can be used as an instrument to identify the causal effect of monetary policy on *output*. Analogously, any movements in the target funds rate that are not predicted by the Greenbook forecast of *inflation* can be used as an instrument to identify the causal effect of monetary policy on *inflation*. The idea is that if the Fed responds to a shock for reasons other than its effect on future output or future inflation, that response can be used as an instrument for output or inflation. Cochrane states the following proposition in his discussion:

Proposition 1: To measure the effects of monetary policy on output it is enough that the shock is orthogonal to output forecasts. The shock does not have to be orthogonal to price, exchange rate, or other forecasts. It may be predictable from time  $t$  information; it does not have to be a shock to the agent's or the Fed's entire information set. (Cochrane (2004)).

This conceptualization of the issue of interpreting and identifying shocks developed by the Romers and Cochrane is an important step forward. In addition to giving us a way to construct exogenous shocks, it offers an interpretation of monetary policy shocks as a rational response of the Fed rather than as an arbitrary roll of the dice.

I have one practical concern about the implementation of the idea, though. Because of the data limitations and the preference not to limit their sample too much, Romer and Romer

(2004) use forecasts of GDP and inflation only as far as two quarters ahead. This means that the Greenbook forecasts are only a Cochrane “sufficient statistic” for establishing the causal effect for the next two quarters. It seems plausible (as outlined in the news section of this chapter) that the Romer-Romer shocks could include the endogenous response to *news* about changes in inflation and GDP at longer horizons. In fact, the impulse responses from their shocks have no significant negative effect on output and inflation for the first several quarters and then begin to have effects later (often with the wrong sign on inflation). This result is consistent with the traditional "long and variable lags" causal story, but it is also consistent with the following alternative. Suppose that there are no real effects of monetary policy shocks on the real economy. Instead, monetary policy reacts now to news about inflation and output at longer horizons and the effects we are seeing on both the funds rate and the economy is the news rather than a causal effect. This alternative story would also answer the question as to how a very temporary shock to the federal funds could have such persistent effects on output. Perhaps we can only be confident of estimates of the effects of a monetary policy shock on output at horizon  $h$  if we have controlled for forecasts of output at horizon  $h$  when constructing the shocks. I will investigate this issue more below.

Separately, Coibion (2012) has explored puzzle concerning the Romers’ estimates. He notes that the Romers’ main estimates produce much larger effects than the shocks identified in a standard VAR, i.e. one in which the monetary policy shock is identified as the residual to the equation for the effective federal funds rate (ordered last). This distinction is important because it implies a very different accounting of the role of monetary policy in historical business cycles. Coibion explores many possible reasons for the differences and provides very satisfactory and revealing answers. In particular, he finds that the Romers’ main results, based on measuring the

effect of their identified shock using a single dynamic equation, is very sensitive to the inclusion of the period of nonborrowed reserves targeting, 1979 – 1982 and the number of lags (the estimated impact on output is monotonically increasing in the number of lags included in the specification). In addition, their large effects on output are linked to the more persistent effects of their shock on the funds rate. In contrast, the Romers’ hybrid VAR specification, in which they substituted their (cumulative) shocks for the federal funds rate (ordered last) in a standard VAR, produces results implying that monetary policy shocks have “medium” effects. Coibion (2012) goes on to show that the hybrid model results are consistent with numerous other specifications, such as GARCH estimates of Taylor Rules (as suggested by Hamilton (2010) and Sims-Zha (2006a)) and time-varying parameter models as in Boivin (2006) and Coibion and Gorodnichenko (2011). Thus, he concludes that monetary policy shocks have “medium” effects. In particular, a 100 basis point rise in the federal funds rate leads industrial production to fall 2 – 3 percent at its trough at around 18 months.

### **3.3.2 Gertler and Karadi’s HFI/Proxy SVAR Method**

A recent paper by Gertler and Karadi (2014) combines high frequency identification methods (HFI) with traditional VAR methods. They have two motivations for using these methods. First, they seek to study the effect of monetary policy on variables measuring financial frictions, such as interest rate spreads. The usual Cholesky ordering with the federal funds rate ordered last imposes the restriction that no variables ordered earlier respond to the funds rate shocks within the period. This is clearly an untenable assumption for financial market rates. Second, they want to capture the fact that over time the Fed has increasingly relied on

communication to influence market beliefs about the future path of interest rates (“forward guidance”).

A key additional methodological feature of Gertler and Karadi’s work is the use of the “external instrument” or “proxy SVAR” methods discussed in section 2. The advantage of this method is that one does not need to resort to Cholesky orderings, as long as the external instrument satisfies the key relevance and exogeneity properties. Following Mertens and Ravn (2013), Gertler and Karadi estimate the reduced form residuals from their VARS and then use their HFI series to identify the structural shocks from the reduced form residuals. These shocks are used to calculate the usual VAR impulse responses.

In the implementation, Gertler and Karadi estimate the residuals using monthly data from 1979 to 2012, but then execute the proxy SVAR from 1991-2012 since the instruments are only available for that sample. Their baseline results imply that a monetary policy shock that leads to a 100 basis point increase in the federal funds rate results in a decline of industrial production of -2.2 percent at its trough 18 months later and a small but statistically insignificant decline in the consumer price index.<sup>5</sup>

### **3.4 New Results Based on Linking Some Recent Innovations**

I now explore the effects of monetary policy in more detail using the two leading external instruments – the Romers’ shocks and Gertler and Karadi’s shocks - and I will also discuss links between them.<sup>6</sup>

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<sup>5</sup> The authors’ baseline results are for a shock that results in a 25 basis point increase in the one-year bond. I combined the information in Figure 1 and 3 to construct the estimates given in the text to facilitate comparison with other studies.

<sup>6</sup> Smets and Wouter’s (2007) monetary shock estimate is another leading candidate for an external instrument. I did not include their shock only because I am working with monthly data, and their shock is estimated on a

### 3.4.1 Explorations with Romer and Romer's Shock

I begin by extending Coibion's (2012) analysis of the Romer and Romer (2004) shocks and consider the effects of employing an instrumental variables approach. There are two reasons that an instrumental variables approach is better than the hybrid VAR. First, Romer and Romer's hybrid VAR embeds a cumulative measure of their shocks in a VAR, ordered last in a Cholesky decomposition and thereby imposes a zero restriction on the contemporaneous effects. While it is useful "exogeneity insurance" to purge the Romer's measure from any predictive power based on lagged variables, there is no reason to impose the additional contemporaneous zero restriction. Second, one would expect all external instruments to be noisy measures of the underlying shock, as Stock and Watson (2012) and Mertens and Ravn (2013) have argued. For these two reasons the instrumental variables approach is preferred.

In the first extension, I use Mertens and Ravn (2013) proxy SVAR method. In the second version, I use Ramey and Zubairy's (2014) external instrument – Jordà (2005) local projection method.

Coibion estimated his systems from 1969 to 1996, whereas I extend the sample through 2007. To determine whether the extended sample changes the results of Romer and Romer's hybrid VAR I first re-estimate Coibion's small hybrid VAR system with the log of industrial production, unemployment, the log of a commodity price index, the log of CPI, and the cumulative Romer shock in a VAR with 12 monthly lags included. The data are monthly

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quarterly frequency. I will use their other shocks in later sections when I examine shocks that are usually estimated on a quarterly basis.

updated from 1969m1 through 2007m12.<sup>7</sup> Following their procedure, I order the cumulative shock last in the VAR and use the Cholesky decomposition.

Figure 3.1A shows the estimated impulse responses, with the shaded areas are 90 percent confidence bands. The results are very similar to those reported by Romer and Romer (2004) and Coibion (2012). After a positive shock to the funds rate, industrial production shows no response for several months and then begins to fall. The point estimates imply that a shock that leads to a peak response of the funds rate of 100 basis points leads to a decline in industrial production of -1 percent at its trough. This response is somewhat smaller in magnitude than those found by Coibion for the shorter sample, where the fall was -1.6 percent. The overshooting of production after three years does not appear in Romer and Romer's estimates, but does appear in Coibion's estimates. The unemployment rate does nothing for ten months after the shock and then finally rises. Prices do not move for 10 months and then begin to fall. Thus, the responses are roughly similar even in the updated data through 2007. The estimates are less precise, though.

As I discussed in Section 3.3, there is substantial evidence that there might have been a structural break in the 1980s, both in the way that monetary policy was conducted and the impact of monetary policy shocks on the economy. Therefore, I explore the results from estimating the system on a sample that begins in 1983. I use Wieland and Yang's (2015) updated Romer and Romer Greenbook data and re-estimate the Romers' policy rule for 1983 to 2007 to create a new series of shocks. I then re-estimate the model for this shortened period.

Figure 3.1B shows the impulses responses from the hybrid VAR estimated over the post-1983 period. The signs of most of the results change. Interest rates rise, of course, but industrial

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<sup>7</sup> I am grateful to Johannes Wieland for sharing his update of the Romer-Romer shocks and the underlying data used in Wieland and Yang (2015).



production also rises persistently, unemployment falls, and the price index falls. The estimates are not very precise, but are nonetheless worrying.

I next estimate a proxy SVAR. In particular, I estimate the reduced form of Coibion's system with the federal funds rate instead of the cumulative Romer shock and instead use Romer and Romer's monetary policy shock as an external instrument following Mertens and Ravn's (2013) proxy SVAR method (see Section 2 for a description).

Figure 3.2A shows the results for the sample from 1969 through 2007. The shaded areas are 90% confidence bands using Mertens and Ravn's wild bootstrap. A shock to monetary policy raises the federal funds rate, which peaks at 1.4 percent by the month after the shock and falls slowly to 0 thereafter. As Coibion has noted, this drawn-out federal funds rate response is a feature of the Romer-Romer shocks. The response of industrial production is different from the one obtained using the hybrid VAR. In particular, industrial production now rises significantly for about 10 months, then begins falling, hitting a trough at about 29 months. Normalizing the funds rate peak, the results imply that a shock that raises the funds rate to a peak of 100 basis points, first raises industrial production by 0.5 percent at its peak a few months after the shock and then lowers it by -0.9 percent by 29 months. The unemployment rate exhibits the same pattern in reverse. After a contractionary monetary policy shock, it falls by 0.2 percentage points in the first year, then begins rising, hitting a peak of about 0.25 percentage points at month 30. The behavior of the CPI shows a pronounced, statistically significant price puzzle.

Thus, relaxing the zero restriction imposed by Romer and Romer's hybrid VAR leads to very different results. A contractionary monetary policy shock is now expansionary in its first year and the price puzzle is very pronounced.

In fact, Romer and Romer's zero restriction is rejected by their instrument. A regression of industrial production on the current change in the federal funds rate, instrumented by the Romers' shock, including 12 lags of industrial production, unemployment, CPI, commodity prices and the funds rate, yields a coefficient on the change in the federal funds rate of 0.4 with a robust standard error of 0.2. Similarly, the same regression for unemployment yields a coefficient on the change in the federal funds rate of -0.12 with a robust standard error of 0.06. Thus, Romer and Romer's hybrid VAR imposes a restriction that is rejected by their own instrument.

I re-estimated their hybrid VAR, but this time placing their cumulative shock *first* in the ordering. This is the more natural way to run a Cholesky decomposition if one believes that their shock is exogenous. When I do this, I find results (not shown) similar to the proxy SVAR results. In particular, the shock has an expansionary effect on industrial production and unemployment in the first 10 months. There is virtually no price puzzle, though.

The impulse responses for the proxy SVAR estimated for the post-1983 sample are shown in Figure 3.2B. Curiously, the results become more consistent with the standard monetary shock results. For example, the response of the federal funds rate is less persistent. Output starts to fall after only three months, and troughs after 18 months. However, the pointwise estimates are not statistically different from zero.<sup>8</sup> Normalizing for a 100 basis point increase in the funds rate, the decrease in output is -1 percent at the trough. The unemployment rate also behaves more consistently with standard results, doing little for the first 10 months, and then rising during the second year. Some of the pointwise unemployment estimates are

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<sup>8</sup> Since we care more about the statistical significance of the general pattern, we should test the integral of the response for statistical significance rather than each point. I have not yet had time to work out this extension of Mertens and Ravn's wild bootstrap.

statistically different from zero. Prices rise in this shortened sample, though less so than for the full sample and they are not statistically significant.

A concern I discussed earlier is whether the Romer and Romer shocks control for sufficiently long horizons. Recall the discussion above of Cochrane's proposition about the Greenbook forecasts being a sufficient statistic for creating a shock that could be used to make causal statements about monetary shocks on the economy. I pointed out that since the Romers were able to control for Greenbook forecasts of output and inflation for up to two quarters ahead, one could make causal statements using their shocks *only for the horizon covered by the Greenbook forecasts*. The Romers did not control for longer horizons because those projections were not available in the early part of their sample. For the shortened sample I am now considering, longer horizon projections are available. Thus, as a robustness check, I estimate new Romer shocks, adding controls for the projections for growth of GDP and the GDP deflator at the longest horizon available at the time of the FOMC meeting.<sup>9</sup> The dashed lines in Figure 3.2B, which are barely distinguishable from the solid lines, show the impulse responses using this alternative measure. Thus, this quick robustness check suggests that including longer horizon projections does not change the results. This offers an additional degree of confidence that the Romer shock can be used to make causal statements at horizons of a year or more.

I now investigate using the Romer shocks as an external instrument in a system that estimates the impulses using Jordà's (2005) local projection method. As discussed above, the Jordà method puts fewer restrictions on the impulse responses. As discussed above, rather than estimating impulse responses based on nonlinear functions of the reduced form parameters, the Jordà method estimates regressions of the dependent variable at horizon  $t+h$  on the shock in

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<sup>9</sup> This method is not ideal since the horizon varies over time. Sometimes the longest projection is four quarters ahead, sometimes it is five or six quarters ahead. It would be useful to investigate some fixed longer horizon in further research.

period  $t$  and uses the coefficient on the shock as the impulse response estimate. In my specification, the control variables included are a constant term plus two lags of the Romer shock, the funds rate, log industrial production, log CPI, and the unemployment rate. The point estimates are similar if more lags are included.<sup>10</sup>

Figure 3.3A shows the impulse responses for the full sample.<sup>11</sup> The results show a pattern that is very similar to the one using the proxy SVAR, where the impulse responses are nonlinear functions of the reduced form parameters. It continues to show that industrial production rises significantly for several months before falling. Once we normalize for the peak response of the funds rate, the magnitude the effects are very similar to those from the proxy SVAR: a shock leading to a rise of the funds rate by 100 basis points results in output falling by 1 percent at its trough.

Figure 3.3B shows the results for the sample starting in 1983. Here the results look more like those from the hybrid VAR on the reduced sample. Industrial production now rises significantly at every horizon and the unemployment rate falls at every horizon. Prices change little until the third year, when they begin to fall. The strange results are not due to low instrument relevance, since the first-stage F-statistics are very high. Furthermore, I tried a few specification changes, such as adding more lags or including a deterministic quadratic trend. None of these changed the basic results.

I would not be so concerned about these results if the confidence bands included zero in all cases. Because the Jordà method imposes fewer restrictions, the impulse estimates are often less precise and more erratic. However, the confidence bands shown, which incorporate Newey-

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<sup>10</sup> If I include too many lags, warning messages appear from the STATA `ivreg2` command about the covariance matrix. I think the issue is the correction for serial correlation at longer horizons.

<sup>11</sup> Note that the confidence bands are based on a HAC procedure that is different from the Mertens and Ravn wild bootstrap used for the proxy SVARs, so the confidence bands should not be compared across procedures.

West corrections, often don't include zero and thus suggest that the estimates are statistically different from zero.

This exploration highlights the importance of additional restrictions imposed in standard monetary models, as well as the importance of the sample period. Of the six specifications shown, including the hybrid VAR used by Coibion and Romer and Romer, only three specifications do not suggest an expansionary effect of monetary policy in the first year. Three do not display a significant price puzzle. The new puzzle with respect to real variables, however, is much more concerning.

### **3.4.2 Explorations with Gertler and Karadi's Shock**

I now explore specifications using Gertler and Karadi's (2015) shock based on high frequency identification (HFI). I first consider it in isolation and then examine its relationship to the my late sample version of the Romer's shock.

Gertler and Karadi were able to take advantage of the new proxy SVAR method since their paper is very recent. Figure 3.4A replicates the results from the baseline proxy SVAR they run for Figure 1 of their paper.<sup>12</sup> This system uses the three-month ahead fed funds futures (ff4\_tc) as the shock and the one year government bond rate as the policy instrument. The other variables included are log of industrial production, log CPI, and the Gilchrist-Zakrajsek (2012) excess bond premium spread. Note that Gertler and Karadi estimate their reduced form model from 1979:6 through 2012:6, but then use the instruments when they are available starting in the 1990s. The results show that a shock raises the one-year rate, significantly lowers industrial production, does little to the CPI for the first year, and raises the excess bond premium. In order to put the results on the same basis as other results, I also estimated the effect of their shock on

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<sup>12</sup> The only difference is that I used 90% confidence intervals to be consistent with my other graphs.

the funds rate. The results imply that a shock that raises the federal funds rate to a peak of 100 basis points lowers industrial production by about -2 percent.

To explore the robustness of the results, I then use Gertler and Karadi's shocks as instruments in a Jordà local projection framework, as described above for the exercise I conducted using the Romer shocks as instruments. Again, I include two lags of all variables as control variables. Figure 3.4B shows the results. We see the same pattern we saw with the later sample Romer results using this method. The only statistically significant response is the interest rate response, and again, the effects are much more persistent than in the proxy SVAR framework. Output does little for a year and then rises, though not significantly. None of the other responses is statistically significant.

I briefly investigated several alternative specifications to see if the patterns would change. For example, rather than estimating the model only from 1990s on, I estimated it starting in 1979:6 and set the missing instrument values to 0. The results were similar. I also explored the reduced form regressions of variables such as industrial production on the shock itself in the Jordà framework, allowing for 12 lags of variables. Again, if anything, the positive effects on industrial production started becoming more precisely estimated.

The fewer restrictions imposed by the Jordà method result in imprecise estimates. Thus, an obvious next step is to use both the Romer shocks and the Gertler and Karadi shocks as instruments. I first set out to see how they were related in the sample in which both were available, 1990:1 – 2007:12.<sup>13</sup> The correlation between the shocks is 0.26. This suggests that each instrument might contain information not contained by the other, though noise in both instruments is another possibility. I then conducted some further investigations of the Gertler-Karadi shock. Several features emerge. First, the shock is not zero mean. The mean is -0.013

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<sup>13</sup> I use my new version of the Romer shocks estimated from 1983 through 2007.

and is statistically different from zero. Second, it seems to be serially correlated; if I regress it on its lagged value the coefficient is 0.31 with a robust standard error of 0.11. This is surprising since it is supposed to capture only unanticipated movements in interest rates. Third, if I regress it on all of the Greenbook variables that the Romers used to create their shock, I can reject that the coefficients are jointly zero with a p-value of 0.00. Furthermore, the R-squared of the regression is 0.265. Thus, the Gertler-Karadi variable is predicted by Greenbook projections. Gertler and Karadi also worried about this issue, but they performed a robustness check based only on the *difference* between private forecasts and Greenbook forecasts. They found a much lower R-squared (see their Table 4). When they use their purged measure, they find greater falls in industrial production. I have not investigated the effect of using my purged version of their measure.

I then re-estimated the Jordà specification using both the Romer shock and the Gertler-Karadi shock as instruments. I used the variables from Coibion's system (federal funds rate, industrial production, unemployment, CPI, and commodity prices). Two lags of each variable (including the instruments) were included as control variables. The joint instrumentation passed two key diagnostics. First, the first-stage F-statistics were very high, indicating instrument relevance.<sup>14</sup> Second, the Hansen J-statistic test for identifying restrictions were low, with high p-values, suggesting that one cannot reject the overidentifying restrictions.

Figure 3.5 shows the resulting impulse response estimates. The estimates indicate that the federal funds rate stays above normal for all four years. In response, the unemployment rate falls significantly and industrial production rises during the first year, falls slightly in the second year, and then rises again afterward. Moreover, some simple changes to the specification, such

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<sup>14</sup> Olea and Pflueger (2013) show that the thresholds can be higher when the errors are serially correlated, as is the case with the Jordà method. However, even with those adjustments, the tests indicate high levels of instrument relevance.

as adding more lags or including a quadratic trend did not noticeably change these results. The results are quite perplexing from the standpoint of many researchers' priors.

### **3.5 Summary**

The literature exploring the effects of monetary shocks has made substantial progress in the last 15 years. Researchers now take instrument identification and relevance much more seriously when estimating monetary policy shocks. New methods, such as FAVARs and Greenbook forecasts, have improved the conditioning set for estimating monetary policy shocks. Structural VARs, sign restrictions and regime switching models have provided alternatives to the usual Cholesky decomposition. Moreover, new measures of monetary shocks have been developed using rich external data, such as narrative data, Greenbook projections, and high frequency information from financial markets. Recently published work using shocks estimated with external data results in similar conclusions. In particular, Coibion's (2012) reconciliation of the Romer results with the VAR results suggests that a 100 basis point rise in federal funds rate lowers industrial production by about -2 percent at 18 months. Those results are based on data from 1969 through 1996. Gertler and Karadi's (2015) research uses high frequency identification from fed funds futures and Mertens and Ravn's (2013) proxy SVAR method to find very similar results – a fall in industrial production of about -2 percent at 18 months – for the period 1990 through 2012.

This rosy reconciliation picture disappears, however, when the specifications are subjected to some robustness tests. In particular, my new results suggest that the Coibion reconciliation results are dependent on the imposition of the typical Cholesky zero restriction. When I instead use the Romer shocks as external instruments in a proxy SVAR, the results imply



a significant price puzzle and expansionary effects of monetary contractions. When I use Romer and Romer's shock and/or Gertler and Karadi's (2015) HFI shock in a Jordà local projection framework, I again often find expansionary effects of contractionary monetary policy.

As a result, I end this section on the same pessimistic note that Cochrane (1994) ended his explorations. There is still a lot of uncertainty about the effects of monetary policy shocks.

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## **Tables and Figures**

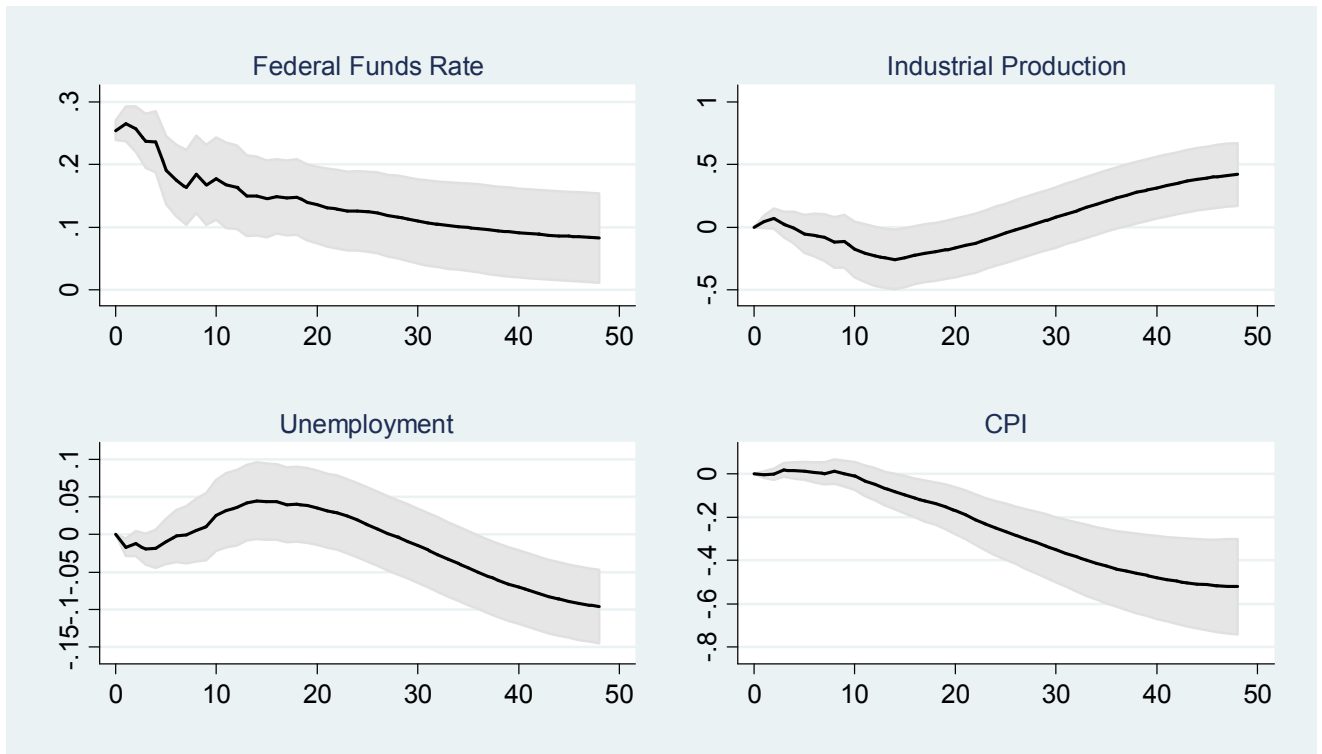
All confidence bands shown on impulse responses are 90% confidence bands.

**Table 3.1. Summary of Some Effects of Identified Monetary Shocks**

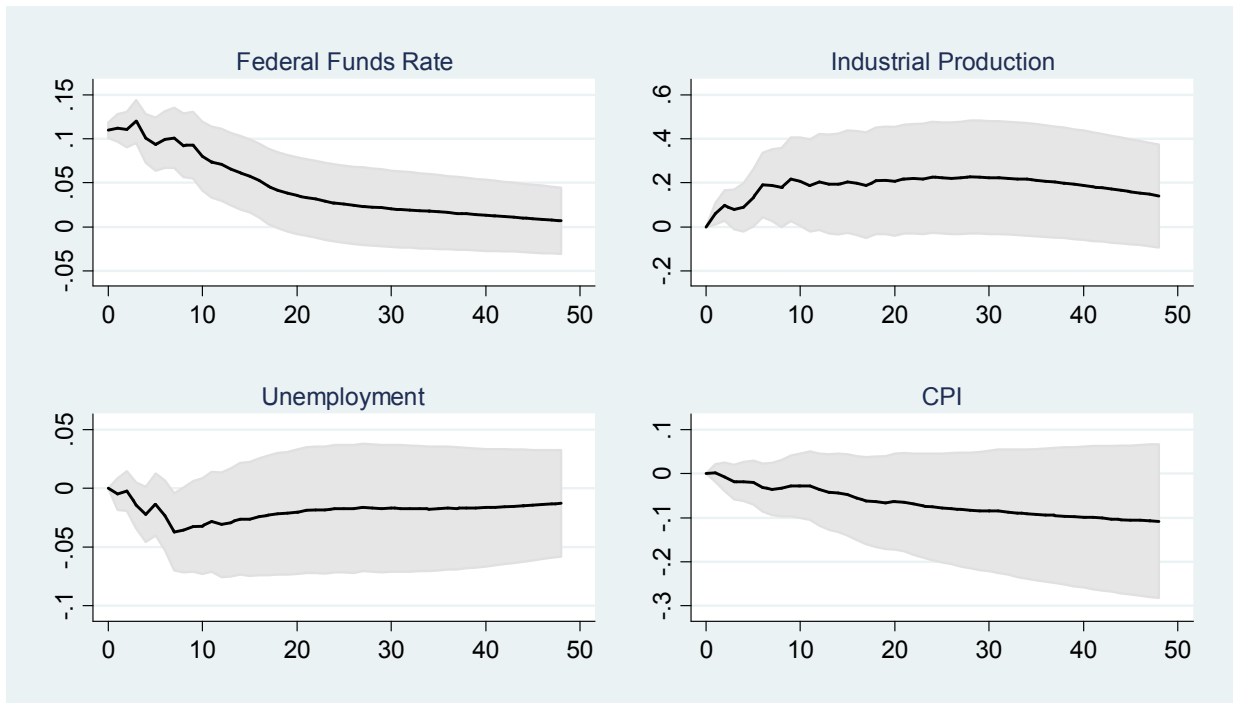
<b>Paper</b>	<b>Method, sample</b>	<b>Impact of 100 basis point increase in funds rate</b>	<b>% of output explained by shock</b>	<b>Price Puzzle?</b>
Christiano, Eichenbaum, Evans (1999) – FFR identification	SVAR, 1965q3 – 1995q3	-0.7% at 8 quarters.	44% at 2 years	Yes, but very small
Faust, Swanson, Wright (2004)	HFI, 1991m2 – 2001m7	-0.6% at 10 months		
Romer and Romer (2004)	Narrative/Greenbook 1970m1 – 1996m12	-4.3% at 24 months	Major part	No, but prices don't change until 22 months
Uhlig (2005)	Sign restrictions, 1965m1 – 1996m12	Positive, but not statistically different from 0	5 – 10% at all horizons.	No (by construction)
Bernanke, Boivin, and Elias (2005)	FAVAR, 1959m1 – 2001m7	-0.6% at 18 months	5% at 5 years	Yes
Smets-Wouters (2007)	Estimated DSGE model 1966Q1 – 2004Q4	-1.8 at 4 quarter trough	10% at 1 year (trough)	No
Boivin, Kiley, Mishkin (2010)	FAVAR, 1962m1-79m9, 1984m1-2008m12	-1.6% at 8 months in early period, -0.7% at 24 months in later period		Only in the early period.
Coibion (2012)	“Robust” Romer-Romer methods, 1970m1 – 1996m12	-2 % at 18 months	“Medium” part	Yes, sometimes
Gertler-Karadi (2015)	HFI-Proxy SVAR, 1979m7 – 2012m6 (1991m1-2012m6 for instruments)	-2.2 % at 18 months	?	No



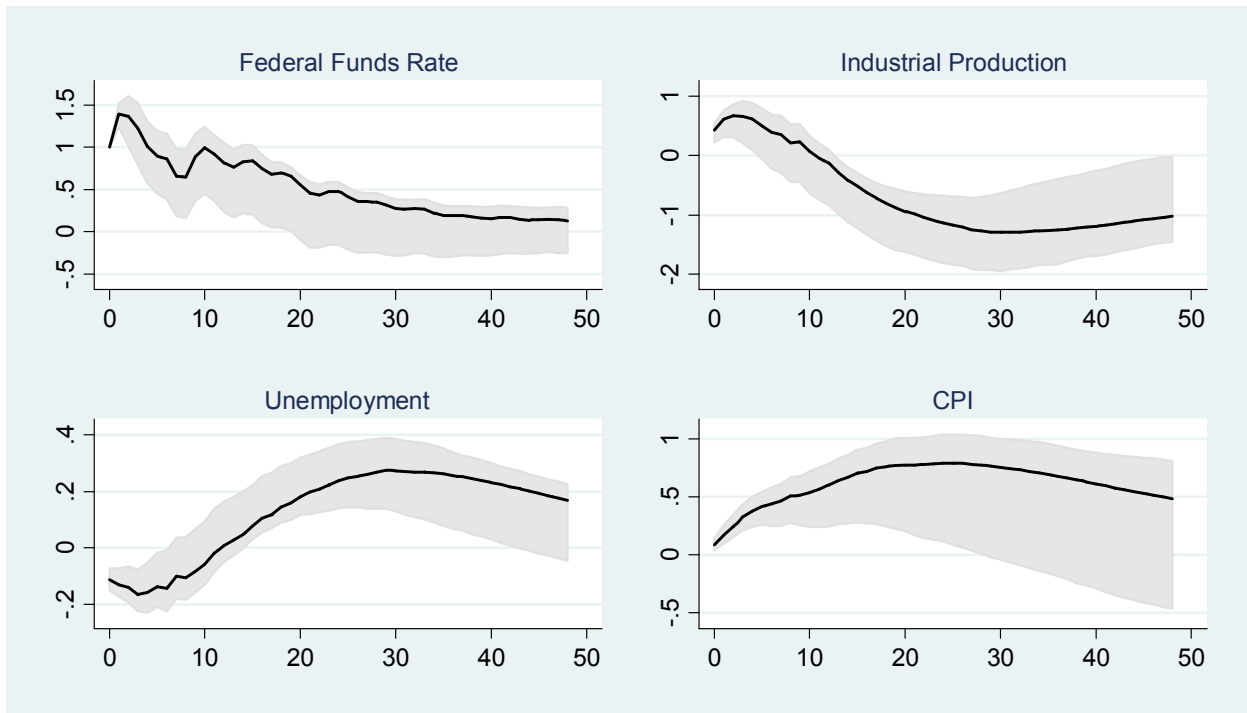
**Figure 3.1A. Romer Hybrid Monetary VAR, 1969m1 – 2007m12 (90% confidence intervals)**



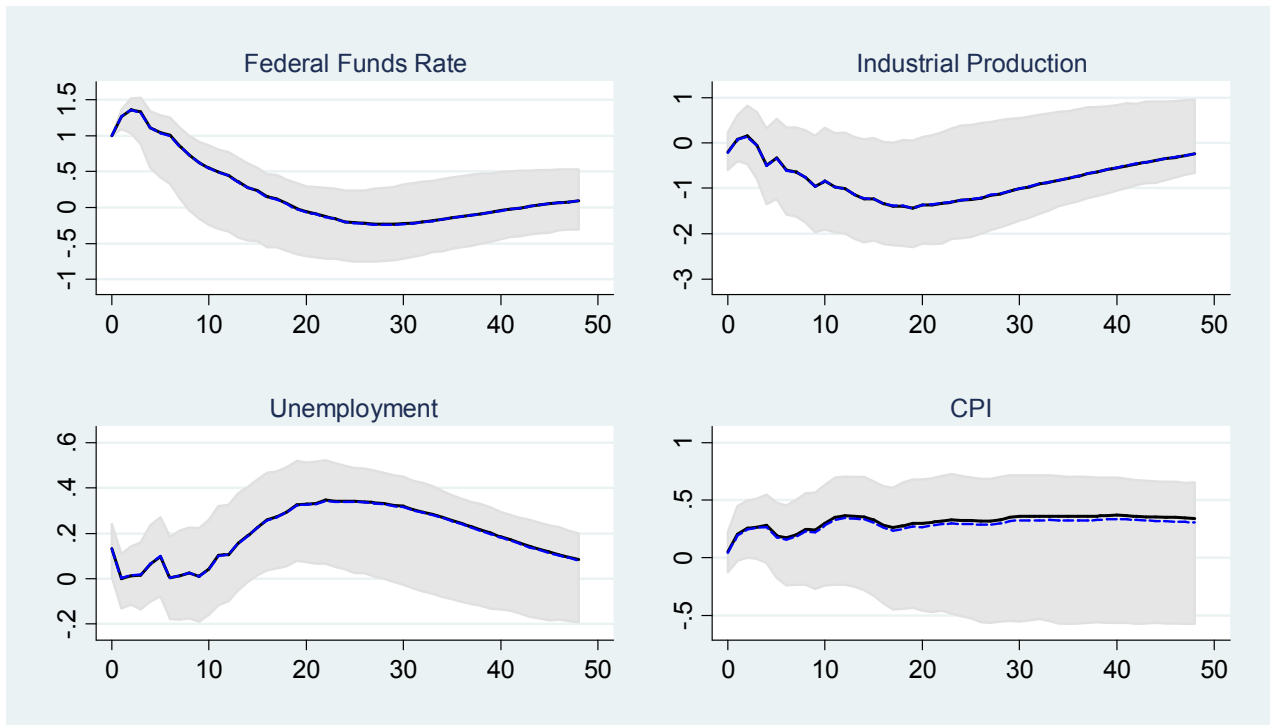
**Figure 3.1B. Romer Hybrid Monetary VAR, 1983m1 – 2007m12 (90% confidence intervals)**



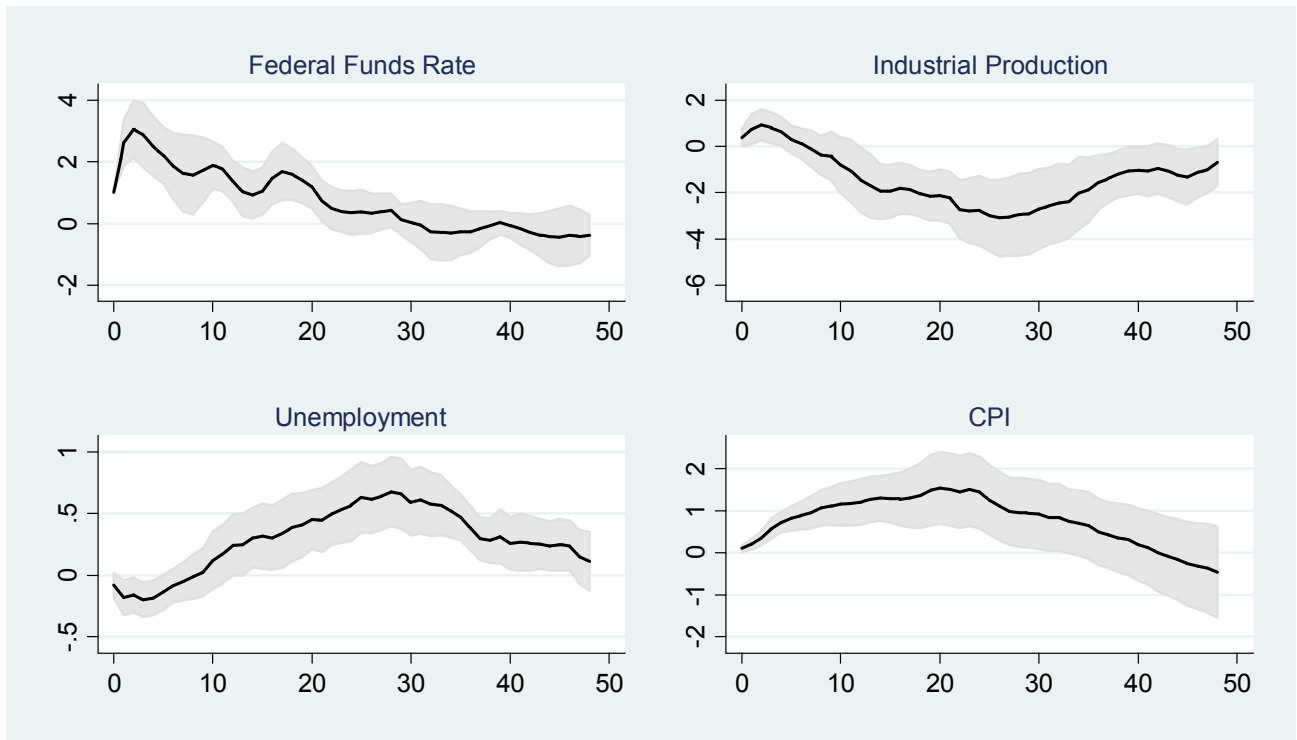
**Figure 3.2A. Proxy Monetary SVAR, Romer, 1969m1 – 2007m12 (90% confidence intervals)**



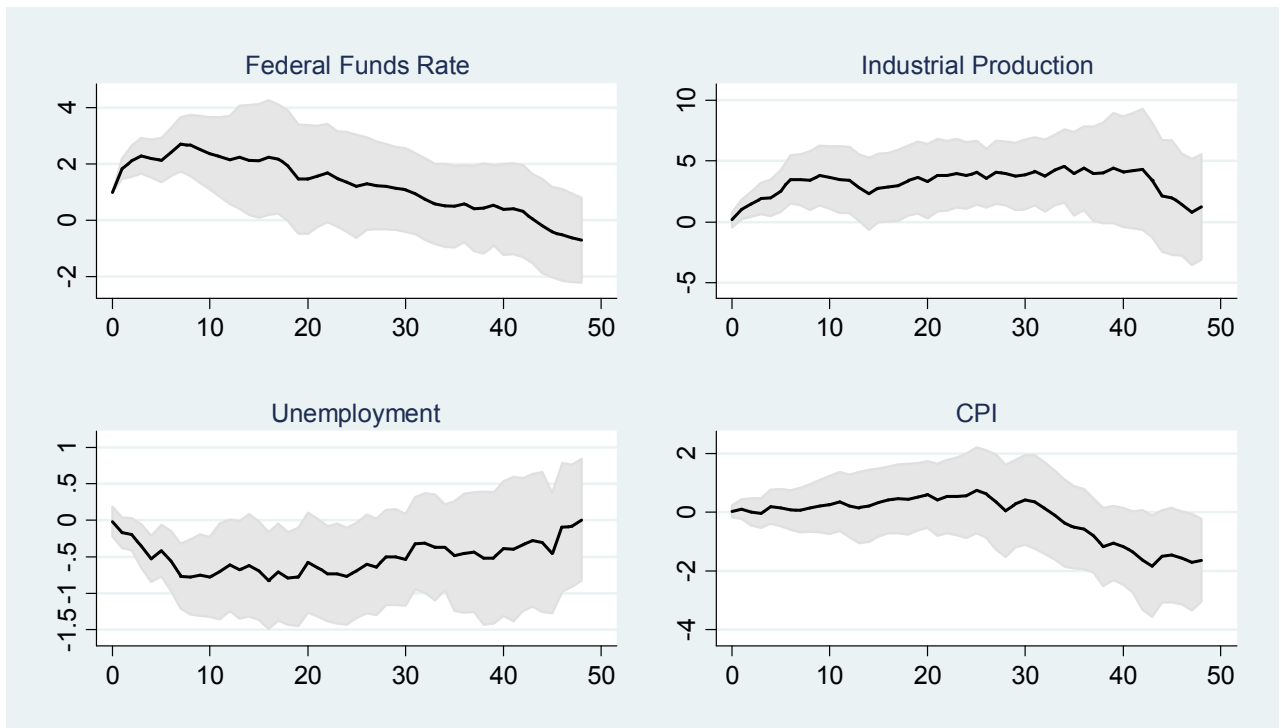
**Figure 3.2B Proxy Monetary SVAR, Romer, 1983m1 – 2007m12 (90% confidence intervals)**



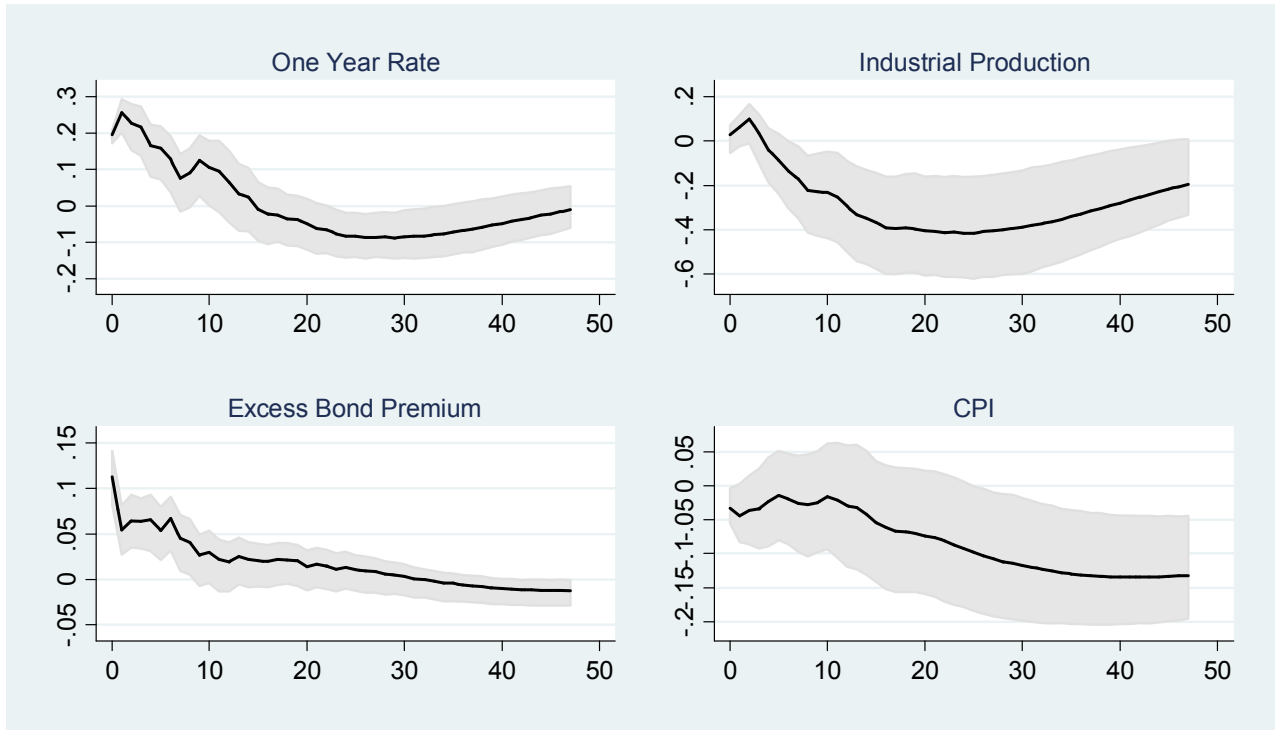
**Figure 3.3A. Monetary Jordà IV, Romer, 1969m1 – 2007m12 (90% confidence intervals)**



**Figure 3.3B. Monetary Jordà IV, Romer, 1983m1 – 2007m12 (90% confidence intervals)**



**Figure 3.4A Monetary Proxy SVAR, Gertler-Karadi, 1990m1 – 2012m6 (90% confidence intervals)**



**Figure 3.4B Monetary Jordà IV, Gertler-Karadi, 1990m1 – 2012m6 (90% confidence intervals)**



**Figure 3.5 Monetary Jordà IV, Romer and Gertler-Karadi Instruments, 1990m1 – 2012m6**  
(90% confidence intervals)

