Finance and Economics Discussion Series
Divisions of Research & Statistics and Monetary Affairs
Federal Reserve Board, Washington, D.C.

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2020-014

Please cite this paper as:
Bu, Chunya, John Rogers, and Wenbin Wu (2020). "Forward-Looking Monetary Policy and the Transmission of Conventional Monetary Policy Shocks," Finance and Economics Discussion Series 2020-014. Washington: Board of Governors of the Federal Reserve System, https://doi.org/10.17016/FEDS.2020.014.

Forward-Looking Monetary Policy and the Transmission of Conventional Monetary Policy Shocks

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January 2020

Abstract

Standard structural VAR models and estimation using Romer and Romer (2004) monetary policy shocks show that, in samples after the 1980s, a contractionary conventional monetary policy shock generates smaller and sometimes perversely-signed impulse responses compared to earlier samples. Using insights from the central bank information effects literature, we show that the analyses producing these results suffer from an omitted variables problem related to forward-looking information emanating from Federal Reserve forecasts. Transmission of conventional monetary policy shocks takes on the standard signs, and is typically significant, once Fed forward-looking information is taken into account. This reconciliation does not follow from adding private sector forecasts to the estimation frameworks.

1 Introduction

A central question in monetary economics is the transmission of monetary policy shocks (Friedman and Schwartz (1963), Tobin (1970), Sims (1972)). Recent studies use Structural Vector Autoregression (SVAR) models and Romer and Romer (2004, R&R hereafter) shocks to quantify the effects of monetary policy shocks. Traditionally, these two methodologies generated results in line with standard monetary models. Following a contractionary monetary policy shock, output decreases gradually and then goes back to its original level; the price level may increase at first due to the price puzzle (Eichenbaum, 1992), but usually decreases afterward. However, as documented below (and in the literature), standard SVAR models and estimates using R&R shocks both point to a much smaller or even perversely-signed effects of (conventional) monetary policy shocks over the post-1983 sample compared to the pre-1983 sample. Both approaches require the inclusion of the 1970s and early 1980s in order to generate conventional results that a contractionary movement in the policy indicator is followed by a significant decrease in output and prices.

We analyze this instability of monetary policy shock transmission against the backdrop of increasingly forward-looking policy regimes over the last several decades. Figure 1 plots the monetary policy shocks derived from the standard SVAR and the baseline R&R approach during the Great Inflation of 1970s-1980s. Shocks are large and volatile, under a regime leaning against high inflation. Afterwards, when inflation subsides and policymakers begin to pay attention to more than current inflation, monetary policy shocks become smaller. Utilizing insights from the literature on the central bank information effect, we demonstrate that monetary policy shocks generated by these well-known approaches contain information that can be forecasted. The omission of forward-looking information works like a traditional omitted-variables problem, causing upward bias in estimates of a contractionary monetary policy shock. Based on this observation, we propose a solution to resolve the identification problem: include forward-looking information into traditional SVAR models and the R&R regressions. We find that incorporating Greenbook forecasts on output and price level, which have superior information to private forecasts (Romer and Romer (2000), Paul (2019a,b)), into SVAR models helps to reconcile the unstable impulse responses over pre- and post-1983 samples. This reconciliation does *not* follow when we replace Greenbook forecasts with Blue Chip forecasts. Transmission under the R&R approach is also sensitive to inclusion of further ahead Greenbook forecasts, as the upward bias disappears when we extend the forecast horizons of the R&R policy reaction function from one quarter *lag* to four quarters ahead.

Related literature We point out a serious problem in standard SVAR models and the R&R approach, which remain commonly used methods in the vast literature on monetary policy shock identification and transmission.[1] We complement Boivin and Giannoni (2006), Owyang and Wall (2009), Barakchian and Crowe (2013) (BC hereafter), and Ramey (2016), which show that the effects of monetary policy estimated by standard VAR models are unstable over time. However, as noted in Nakamura and Steinsson (2013, 2018), though BC's method of directly incorporating aggregated high frequency measures of monetary policy shocks into VAR models can produce better estimates of the shocks, it has a statistical power problem since these shocks are small. Nakamura and Steinsson (2018) (NS) also point to a problem that the high frequency shocks cannot resolve–the Fed information effect, which refers to the bias caused by the central bank's information advantages over the public (Paul (2019a,b) provides recent further analysis). Our paper differs from BC in that we incorporate forward-looking information and thus propose a unified solution to the puzzling responses of output and prices post 1983. Because the forward-looking information that solves the puzzles is from the Fed and not the private sector, we also address the Fed information effect. Miranda-Agrippino and Ricco (2018) (MAR) also address the inflormation effect. Like MAR, we show that puzzling impulse responses to identified monetary policy shocks can emerge from the signalling effects accompanying policy actions. However, there are important differences in our papers. First, they utilize instrumental variables techniques to identify shocks, while we document, and solve, the puzzling results within *traditional* identification frameworks. Their paper solves the puzzles by using an alternative instrument, while we show that traditional monetary policy shocks produce standard impulse response results as long as they are augmented with forward-looking *Fed* information. This is useful because these traditional monetary policy shocks have been used extensively in the literature. In addition, our sample period is different and longer than that of MAR. We compare the pre-1983 and post-1983 samples and find that the puzzles emerge only in the latter. Lastly, we show that the empirical puzzles are driven by the omission of the Fed's forward-looking information rather than the public forecasting information (e.g., Blue Chip forecasts).

The next section describes data and details about the standard SVAR model and the R&R approach, as well as the puzzling effects of monetary policy on output and price post 1980s. Section 3 provides a solution by introducing Fed forecasts into the analysis, as well as further discussion about why our modifications work. Section 4 considers some robustness checks. Section 5 concludes.

[1] In Bu, Rogers, and Wu (2019), we extend our discussion to the zero lower bound period using a different framework.

2 Unstable Results from Standard Approaches

2.1 Empirical Models

Standard SVAR models and the R&R narrative method are two conventional methodologies used to identify monetary policy shocks and estimate the impulse responses. Standard SVAR models assume that endogenous movements in the federal funds rate can be estimated by current and lagged macroeconomic variables considered in the model, while monetary policy shocks do not affect output and price level in the current period:

$$X_t = A_0 + A_1 X_{t-1} + A_2 X_{t-2} + \ldots + A_q X_{t-q} + B\epsilon_t \tag{1}$$

We initially adopt a 4-variable VAR specification with monthly data with variables ordered: log industrial production (IP); log consumer price index (CPI); log commodity prices (PCOM); and the effective federal funds rate (FFR) as the policy instrument. Based on the recursivity assumption, the first three variables can affect, rather than respond to, contemporaneous monetary policy shocks, an innovation to the federal funds rate. This monthly VAR includes 12 lags.

Another widely-used measure of monetary policy shocks, the R&R narrative method, takes into consideration anticipatory movements of monetary policy. They specify the policy reaction function by regressing the intended change in the federal funds rate during FOMC meetings (Δffr_m) on the federal funds rate before any change made in this FOMC (ffb_m) and the Fed's internal forecasts of real output growth ($\Delta\tilde{y}$), inflation ($\tilde{\pi}$) and unemployment ($\tilde{u}$)):

$$\Delta ffr_m = \alpha + \beta ffb_m + \sum_{i=-1}^{2} \gamma_i \Delta\tilde{y}_{mi} + \sum_{i=-1}^{2} \gamma_i (\Delta\tilde{y}_{mi} - \Delta\tilde{y}_{m-1,i}) + \sum_{i=-1}^{2} \phi_i \tilde{\pi}_{mi} + \sum_{i=-1}^{2} \theta_i (\tilde{\pi}_{mi} - \tilde{\pi}_{m-1,i}) + \rho\tilde{u}_{m0} + \epsilon_m \tag{2}$$

the residuals ϵ_m are identified as exogenous monetary policy shocks, which are independent of forecasting information included in the regression. In this policy reaction function, the forecasting horizons of real output growth and inflation extend from the previous quarter to two quarters ahead. One reason for this choice of horizons is that Greenbooks rarely included forecasts more than two quarters ahead in the late 1960s and early 1970s.

Romer and Romer then estimate the effects of the new shock series via a single dynamic

equation, regressing macroeconomic variables on its own lags and lags of the shock series:

$$\Delta y_t = \alpha + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \sum_{j=1}^{q} \gamma_i \epsilon^m_{t-j} + e_t \tag{3}$$

where ϵ^m is the constructed R&R shock series. Here y represents current and lagged values of macroeconomic variables such as IP and CPI. R&R pick p=24, q=36 for IP and p=24, q=48 for CPI. The estimated coefficients are used to construct impulse responses to the R&R shocks.

Another hybrid approach to measure the effects of the new shock series is to incorporate the R&R shocks into the baseline 4-variable VAR model with monthly data. This hybrid VAR includes four variables: the cumulative R&R shocks, log industrial production, log consumer price index and log commodity prices. Since the R&R shocks are constructed as exogenous to contemporaneous and forecasted macroeconomic variables, it is reasonable to place the cumulative R&R shocks first in the order, according to the recursivity assumption. This hybrid VAR also includes 12 lags.

2.2 Data

To compute the impulse responses, we collect macroeconomic data from the Fed's official database over 1959m1-2007m12, and extract forecasting information from Greenbooks issued at the FOMC meetings over 1969m1-2007m12. For the baseline SVAR model, our data include IP, CPI, a commodity price index, the effective federal funds rate. Robustness checks require measures of M1, non-borrowed reserves and total reserves. For the R&R approach, we use the same data as originally used in Romer and Romer (2004), including the intended changes in the federal funds, the previous federal funds rate and Greenbook forecasts for real output growth, inflation and unemployment rate.

2.3 Unstable Results

Figure 2 shows impulse responses to a contractionary monetary shock pre-and post-1983 for the baseline SVAR model. One standard error confidence intervals are produced by bootstrap. The pre-1983 estimation yields the standard results that a positive innovation in the fed funds rate is associated with an immediate decrease in IP and a gradual decrease in the CPI about 10 months after the shock (Figure 2A). A slight increase in the CPI at the beginning is typically documented as the price puzzle. However, results change significantly when estimated over the post-1983 sample (Figure 2B). A contractionary monetary shock leads to much muted and even opposite-signed effects on both

output and price. An initial increase in output, "the output puzzle", is statistically significant for the first 5 months. Though output drops afterwards, it remains insignificantly different from zero. The price puzzle is again significant for almost 2 years. These anomalous effects are typical of the unstable impulse responses generated from traditional SVAR models in the 1980s.

Figure 3 presents similar impulse responses of IP and CPI with R&R shocks. Over the sample 1969 to 1983, a contractionary shock has significantly large effects (Figure 3A). Industrial production decreases for 30 and 15 months in the baseline R&R approach and the hybrid VAR approach, respectively. The CPI is roughly flat in the first 20 months and gradually decreases through the later periods in both approaches. However, the R&R shocks also generate anomalous results after 1983 (Figure 3B). That is, IP gradually increases after a contractionary policy shock in both the baseline R&R and the hybrid VAR approach. The CPI response differs in the two approaches. In the baseline R&R approach, the CPI is ragged and stays insignificantly different from zero. In the hybrid VAR model with cumulative R&R shocks, the CPI gradually decreases, as was the case before 1983, but its confidence interval becomes wider, such that the decrease is statistically insignificant.

3 A Solution based on Forward-Looking (Fed) Information

We begin with a discussion of the role of forward-looking information in policymaking and how this could be incorporated into estimation of monetary policy shocks. Next we show that this succeeds in reconciling the unstable impulse responses discussed above. Lastly, we show further evidence that forecasting information became increasingly important for monetary policy shock identification due to changes in policy regimes in the late 1970s-early '80s.

3.1 Role of forward-looking information

Forward-looking information plays a key role in monetary policy. The Federal Reserve has invested substantial resources in creating Greenbook forecasts since late 1965. Targets for the federal funds rate or non-borrowed reserves are often adjusted in response to these forecasts. However, the baseline SVAR model doesn't include any future information. It is thus very much likely to contain anticipatory movements of the target series, which may obscure the causal relationship between monetary policy and its observable effects. For example, if the Federal Reserve adopts an expansionary monetary policy based on its forecasts of a recession, the stimulative effect may only partly dampen but not reverse the downard trend. Expansionary policy thus may be followed by a

decrease in output and inflation, just as in the impulse responses above.

A simple regression of the monetary policy shock series measured by the baseline SVAR model on standard forecasting variables sheds light on the importance of forward-looking information. In the first step, we construct a shock series as the residuals of regressing the federal funds rate on other variables in the baseline SVAR model. The forecasting variables are extracted from Greenbook forecasts for GDP and CPI, the two forecasting macroeconomic variables that are central to policymakers' decisions. We gradually include the output and price forecasts with horizons of 1 to 3 quarters ahead. Panel a of Table 1 reports the regression results. The original shock series is very responsive to combinations of GDP and CPI forecasts up to 3 quarters ahead. Most of the estimated coefficients are statistically significant at 1%. These results strongly suggest that there is important forward-looking information omitted in the baseline VAR.

In their novel addressing of the anticipatory problem, Romer and Romer (2004) develop a narrative approach to identify monetary policy shocks from a reaction function that includes the Fed's internal forecasts. The horizons of the forecasting variables extend from the last quarter to two quarters ahead. Although Romer and Romer argue that the forecasts of two quarters ahead are enough to capture the likely forecasted path of economy at longer horizons, policymakers became increasingly forward-looking over time. From 1969 to 1977, the Greenbooks provide forecasts for only two quarters ahead. But since January 1978, the forecasting set expands to five quarters ahead and then seven quarters ahead. This reflects the improvement of Federal Reserve's forecasting ability as well as its increasing concern about the distant future. In light of this, the baseline R&R reaction function may fail to take important forecasting information into consideration. Our hypothesis is that omission of longer term forecasts causes upward-bias in the estimation of a contractionary monetary shock, leading to the puzzling impulse responses of output and prices post 1980.

Now consider the same regressions using R&R shocks on the longer-term forecasting variables. The dependent variable is residuals derived from the R&R policy reaction function. The independent variables include 3- and 4-quarter-ahead Greenbook forecasts for real GDP, GDP deflator, the growth of real GDP and the growth of GDP deflator. Panel b of Table 1 shows the results of this regression, with standard error in the brackets. The first row includes only forecasts for GDP deflator; coefficients are significant at the 5% level. The second row includes forecasts for real GDP and coefficients are both statistically significant at 1%. The third row includes forecasts for both real GDP and GDP deflator. All coefficients are still statistically significant and those of GDP forecasts are of higher significance level. The last two rows gradually include more forecasts for the growth

of real GDP and growth of GDP deflator. The coefficients on real GDP forecasts and GDP deflator forecasts remain as statistically significant. These results further suggest that the R&R measure of monetary policy shock omits important information about the distant future.

3.2 Empirical results using structural VARs

To reconcile the unstable impulse responses after 1983, we incorporate forecasts into the baseline SVAR model[2]. The Greenbooks provide forecasts for quarterly GDP growth, CPI inflation and unemployment rate. We apply those growth rate forecasts to the previous month's realized production and inflation. In light of the importance of future information about output and inflation as shown in Table 1, we introduce level forecasts for 1- and 2-quarter-ahead GDP and CPI into the baseline 4-variable model. In this forecasts-augmented SVAR model, the forecasting variables are placed just before the policy instrument, allowing those forecasts to respond to rather than affect the current macroeconomic environment, and to affect rather than respond to monetary policy.

The effects of a 100 basis point innovation to the federal funds rate on output and price, based on monthly data from 1983m1 to 2007m12, are shown in Panel a of Figure 4, all with one standard deviation. In general, the output and price puzzles are eliminated by augmenting the baseline VAR with forecasting variables. A contractionary monetary policy shock almost immediately decreases industrial production with a slight "output puzzle" in the first month. The decreasing output troughs after 15 months. The price response is also immediate and settles at a new lower level after about 20 months. The output and price responses follow a decreasing trend compared to the unstable results for the baseline SVAR over the post-1983 sample. These results corroborate our hypothesis that incorporating forecasts into the empirical SVAR model may eliminate the output and price puzzles. In Figure A.4 of Appendix A, we assess the effects of incorporating even longer forecasting horizons. The impulse responses of combining 1-, 2- and 3-quarter-ahead GDP and CPI forecasts into the baseline SVAR produces similar results as Panel a of Figure 4.

3.3 Empirical results for the R&R approaches

As previously discussed, the baseline R&R regression may be too conservative about including forecast horizons when policymakers are increasingly concerned about the distant future. This leads to an overestimate of the effects of a contractionary monetary policy shock or an underestimate of

[2]Barth and Ramey (2002) use a similar augmented SVAR approach, but they failed to resolve the price puzzle. Our focus here is instead the output puzzle, and we show that the augmented approach does help.

an expansionary one, resulting in the puzzling impulse responses post-1983. We introduce 3- and 4- quarter-ahead forecasts of real GDP and GDP deflator into Equation (2) and derive a new R&R monetary policy shock that is independent of longer-term forecasts. Panel b of Figure 4 presents the impulse responses to a 100 basis point innovation of the new shock. There is no evidence of puzzling results for output and price. The left two plots show the impulse responses generated from regressing macroeconomic variables on the lags of itself and lags of the new R&R shock series, similar to the baseline R&R approach. Both IP and CPI gradually decrease after a contractionary shock. The right two plots show the impulse responses generated from incorporating cumulative new R&R shocks into a standard 4-variable VAR. The contractionary shock immediately decreases industrial production and reaches its peak impact after 25 months, while the CPI is roughly flat throughout. Hence, our new R&R shock series yields standard impulse responses of output and price, free of the contractionary results over pre and post 1983 samples.

3.4 Regression of new shock series

We do further regressions to show that the anticipatory movement of the federal funds rate contained in the original shock series are removed in our new shock series. First for the SVAR model, a new shock series is constructed via our forecasts-augmented SVAR model described in Section 3.2. Regressing this new shock series on the same forecasting variables in Table 1, all coefficients in Panel a of Table 2 are statistically insignificant, indicating the removal of forward-looking information. As for the R&R approach, we derive the new shock series from extending the forecasting horizons for real GDP and GDP deflator in Equation (2) up to 4 quarters ahead. Panel b of Table 2 shows the results of regressing this new shock series on all the 3- and 4-quarter-ahead Greenbook forecasts. All coefficients are statistically insignificant.

3.5 Discussion of changing policy regimes

The changing policy regimes of the 1980s coincides with the increasing importance of forecasting information to monetary policy identification. For the baseline SVAR model, we divide the full sample 1959-2008 into three subsamples based on changes in policy regimes. The break points are 1979 and 1983, between which is the Volcker period. Panel a of Table A.1 presents results of regressing the original SVAR shock series on forecasting variables during each subsample. Considering the sample length, we choose as independent variables Greenbook forecasts for real GDP and

CPI 1-quarter ahead. Forecasting information clearly plays a more important role in the post 1983 subsample compared to the previous two periods. Coefficients on the forecasts of next quarter real GDP and CPI are both significant at 1% in the third row, while their corresponding values in the first and second rows are essentially zero. In addition, the R-squared of the recent subsample (0.043) is much larger than that of the pre-1979 subsample (0.006). The forward-looking information plays a more important role in explaining monetary policy shocks in the post 1983 period.

For the R&R policy reaction function, since the pre-1983 subsample is too short to generate reliable results, we follow BC (2013) in reporting F tests of the joint significance to analyze whether the elements of the information set changed over time. The first step is to focus on the sets of forward-looking and backward-looking variables in Equation (2). The forward-looking set contains 8 variables of 1 and 2 quarter-ahead forecasts and the backward-looking set contains 9 variables: -1(previous) and 0 (current) quarter forecasts. Panel b of Table A.1 presents the F test of the two variable sets over pre- and post-1983 subsamples. The p value of both sets reduces significantly after 1983, which indicates the important role of forecasting variables in this period. To keep in line with our new method to include 3- and 4-quarter-ahead information in the R&R policy reaction function, we do further F tests on two sets of longer-term forward-looking variables in Panel c. The first set includes all 16 forecasts extending from 1 to 4 quarters ahead and the second set focuses on the 8 longer-term forecasts of 3 and 4 quarters ahead. In this test, we choose the subsample 1979-2007 rather than the post 1983 period because a larger sample size helps to offset the possible collinearity of regressors in the R&R policy equation. Panel d of Table A.1 of the Appendix shows the significance of 3- and 4-quarter ahead forecasts after 1983, when some regressors are dropped in R&R policy reaction function to avoid collinearity. Over the subsample 1979-2007, both forward-looking sets are clearly important in policymaking. This corroborates our argument that the forecasting horizon of the R&R policy equations is too short as the market becomes more forward-looking, leading to puzzling impulse responses of output and price after 1983.

3.6 Is it the Fed's forecasts or any forward-looking information?

Greenbook forecasts have proven to be more informative than private-sector forecasts, as emphasized in the large literature on central bank private information effects (see Romer and Romer (2000)). In this subsection, we substitute the Greenbook forecasts with the widely-used Blue Chip survey expectations and test whether or not the results mimic those above. For the SVAR baseline results, we analogously use the same 1- and 2-quarter ahead Blue Chip forecasts for GDP and

CPI into the augmented SVAR model. Panel a of Figure 5 plots the impulse responses. In this experiment, monetary policy shocks still generate significant "output and price puzzle" after 1983, even if they are allowed to react to private sector forecasts. Similarly, extending the R&R approach to 3- and 4-quarter ahead Blue Chip forecasts, there are "output puzzle" and muted effects on dampening inflation in Panel b of Figure 5. Overall, the private-sector forecasts are not helpful for reconciling the puzzling monetary policy shock effects after 1983.

4 Robustness: forecast augmentation in other models

CEE(1996) Specification We follow Christiano, Eichenbaum, and Evans (1996) and estimate a 7-variable VAR with monthly data that includes monetary aggregates. Variable ordering is: log IP, log CPI, log commodity prices (PCOM), effective federal funds rate (FFR) to proxy the policy instrument, total reserves (TR), M1, and non-borrowed reserves (NBRD). Based on the recursivity assumption, the first three variables (IP, CPI, PCOM) in SVAR may affect, rather than respond to, contemporaneous monetary policy. The last three monetary aggregate measures (TR, M1 and NBRD) are exogenous to contemporaneous monetary policy. An innovation to the federal funds rate is identified as the monetary policy shock. This monthly VAR includes 12 lags. Figure A.1a,b show impulse responses to a contractionary monetary shock pre- and post-1983. Estimation before 1983 yields conventional results, while after, responses are muted and insignificantly different from zero. Incorporating forecasting information by including Greenbook forecasts for 1-, 2- and 3-quarter ahead GDP and CPI as determinants of monetary policy, we see in Figure A.1c that output and prices both take a ragged but steady downward path after a contractionary shock. The unstable impulse responses in the CEE specification is thus also resolved by incorporating Fed forecasts.

Wu-Xia Index In the second robustness check, we substitute the effective federal funds rate with the Wu-Xia index taken from Wu and Xia (2015) as the policy instrument in the baseline SVAR model. Figure A.2a,b show impulse responses to a contractionary monetary shock pre- and post-1983 for the Wu-Xia model. The pre-1983 responses are similar to those of the baseline FFR model: standard decreasing responses of output and prices, together with an evident price puzzle. For the recent sample of 1983-2007, the Wu-Xia model generates very muted contractionary effects. Figure A.2c includes forecasts for 1- and 2-quarter ahead GDP and CPI into the model. The forecasts-augmented version of this model once again produces impulse responses consistent with the standard effects of monetary policy shocks on macroeconomic variables.

R&R with Quarterly GDP Data Finally, we incorporate quarterly data into the R&R approach. To do so, we accumulate the R&R shock series generated from Equation (2) within each quarter and use quarterly macro data to estimate impulse responses. For the baseline R&R dynamic regression (3), we substitute monthly values of the original R&R shock series, IP, and CPI with quarterly values of the quarterly shock series, real GDP, and GDP deflator. We use p=8, q=12 for real GDP, and p=8, q=16 for the GDP deflator. For the hybrid VAR approach, the variables are ordered: cumulative R&R shock series, log real GDP, log GDP deflator and log CRB index with 4 lags. Figure A.3a and A.3b present the unstable impulse responses of output and prices in both R&R approaches over both the pre- and post-1983 samples. The price puzzle emerges in all four responses of the GDP deflator. Real GDP decreases immediately over the pre-1983 period but remains roughly flat over the post-1983 sample. However, when we control for 3-4 quarters ahead forecasts in the R&R policy reaction function, these puzzling responses again disappear, as shown in Figure A.3c. These results are similar to what we found in our benchmark investigation with monthly data.

5 Conclusion

In this paper, we reproduce the unstable transmission results from shocks to monetary policy over different sample periods and provide a new explanation of those "puzzling" results. Our workhorse frameworks are a standard SVAR model and the Romer & Romer approach, but we demonstrate that both the puzzle and our solution also materialize in other frameworks. In the pre-1983 sample, a contractionary monetary policy shock leads to a significant decrease in output and price level, but in the post-1983 sample, there are much smaller or even opposite-signed effects. We then provide evidence that these puzzling results emerge because the conventional methods fail to take into consideration the Fed's forecasts for the future, or the forecasting horizons adopted were too short, in an era of increasingly forward-looking policy and markets. In this spirit, we construct new shock series via incorporating important forecasting information extracted from Greenbooks into SVAR models and the Romer & Romer approach. Our new shock series generates stable impulse responses of output and price, with conventional signs, over different sample periods.

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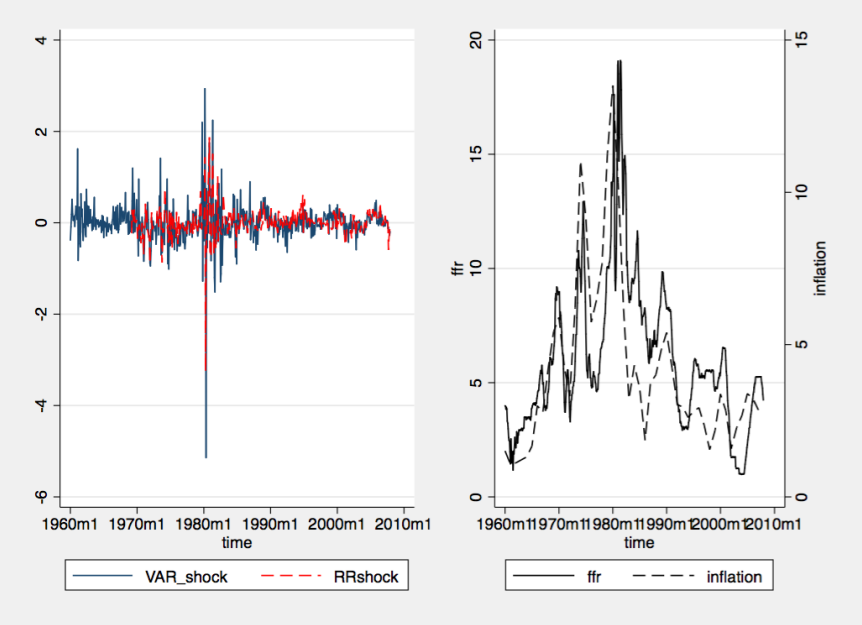
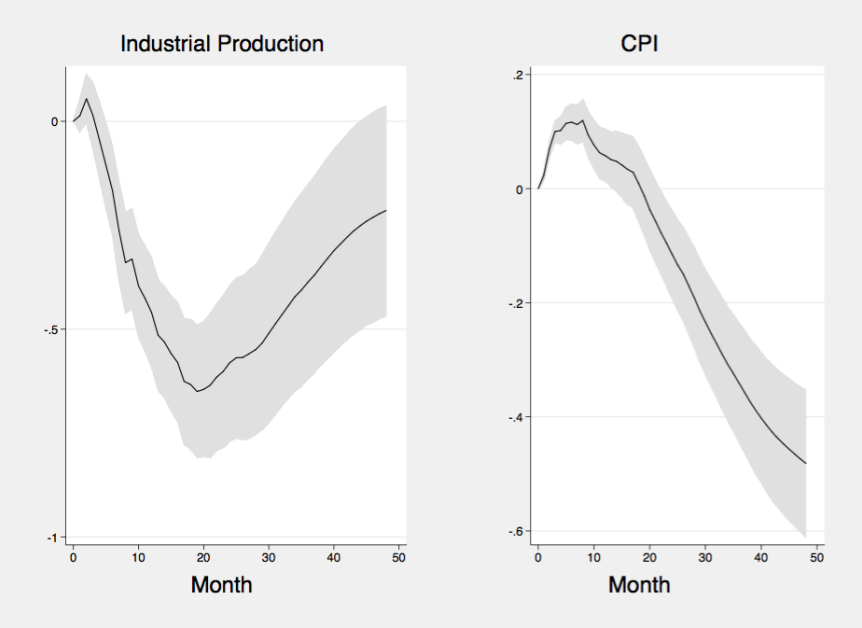
Figure 1: **Monetary Policy Shocks and Inflation**



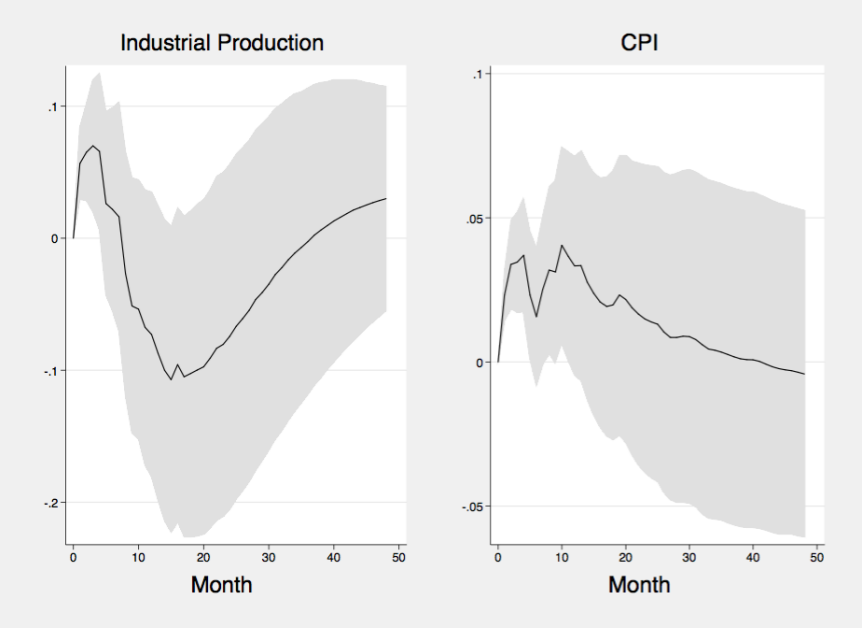
Note: *VAR Shocks* refers to the monetary policy shocks derived from the baseline SVAR with monthly data, 4 endogenous variables and 12 lags. *RR Shocks* refers to the monetary policy shocks derived from the baseline R&R approach. FFR refer the Federal Funds Rate.

Figure 2: **Baseline SVAR Impulse Responses**

a. 1959m1-1982m12



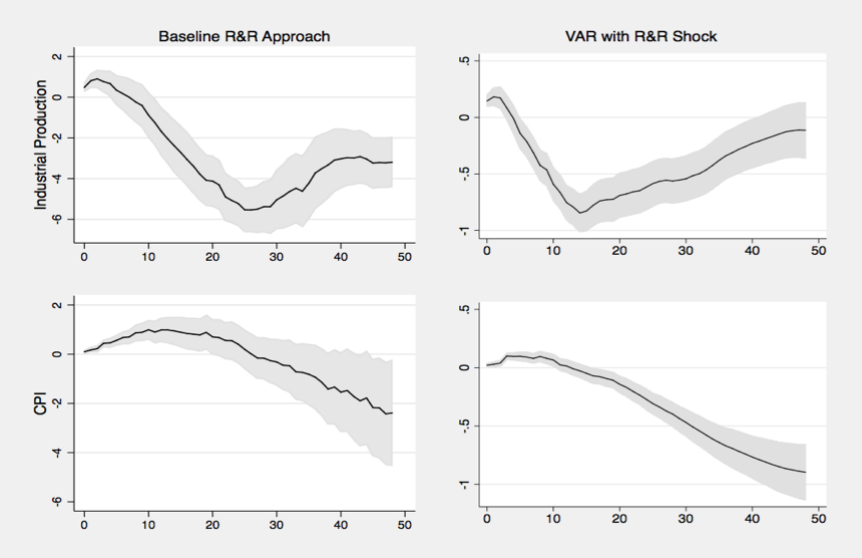
b. 1983m1-2007m12



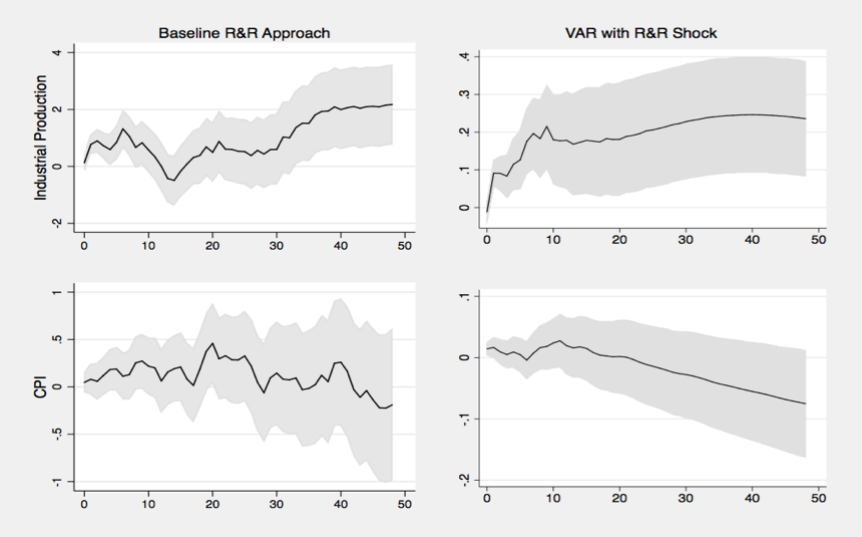
Note: Structural VAR with monthly data, 4 endogenous variables and 12 lags. Variables are ordered as follows: industrial production, consumer price index, commodity prices, the effective federal funds rate. The first three variables are in logs and seasonally adjusted. Graphs show impulse response of industrial production and the consumer price index to a 100 basis point increase in the federal funds rate. 68 percent confidence intervals produced by bootstrapping 300 replications.

Figure 3: **Romer & Romer Approach Impulse Responses**

a. 1969m1-1982m12



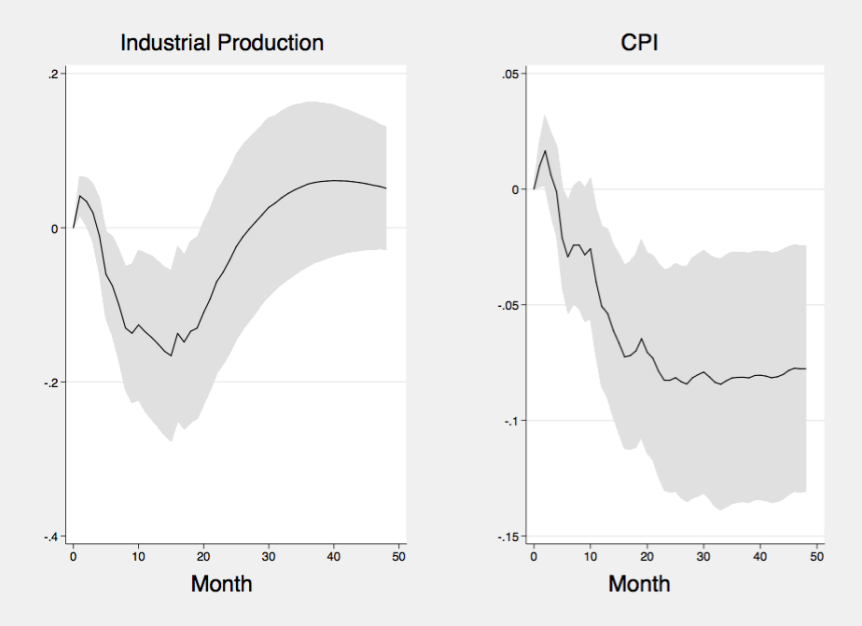
b. 1983m1-2007m12



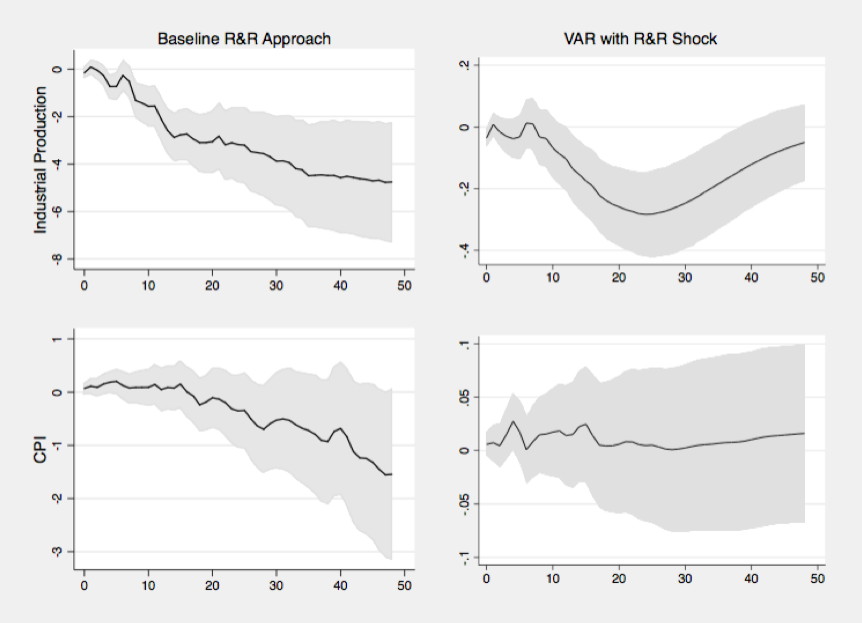
Note: *Baseline R&R Approach* refers to the estimation procedures of Romer & Romer (2004). *VAR with R&R Shock* refers to the 4-variable SVAR with monthly data, using cumulative R&R shocks in substitution of the effective federal funds rate. Variables ordered as: the cumulative R&R shocks, the log industrial production, the log consumer price index, the log commodity prices. Graphs show impulse response of industrial production and the consumer price index to a 100 basis point increase in the R&R shocks with 68 percent confidence intervals.

Figure 4: **Fed Forecasts Augmented Impulse Responses**

a. SVAR



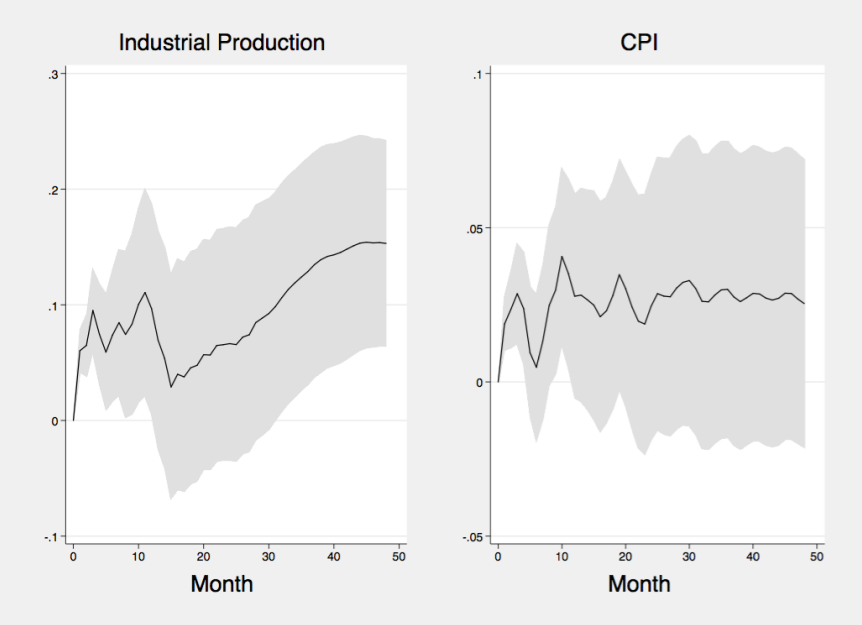
b. R&R



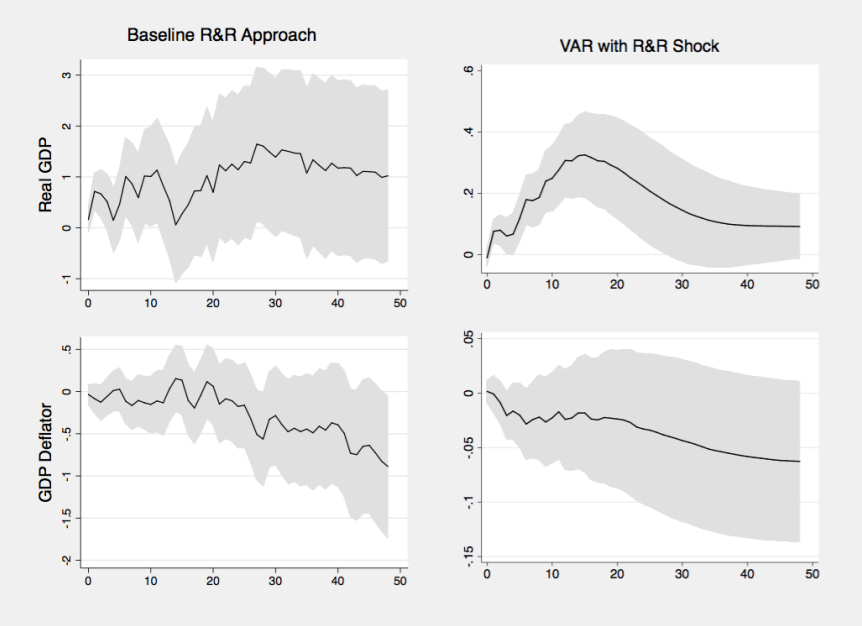
Note: Over sample of 1983m1-2007m12. Greenbook forecasts (1-q and 2-q ahead GDP and CPI) are incorporated in the SVAR model. Confidence intervals are produced by bootstraps. In the R&R estimation, further control for 3-4 quarters ahead forecasts for GDP, GDP deflator in R&R policy reaction function. 68 percent confidence intervals are reported.

Figure 5: **Blue Chip Forecasts Augmented Impulse Responses**

a. SVAR



b. R&R



Note: Over sample of 1983m1-2007m12. Blue Chip forecasts (1-q and 2-q ahead GDP and CPI) are incorporated in the SVAR model. Confidence intervals are produced by bootstraps. In the R&R estimation, further control for 3-4 quarters ahead Blue Chip forecasts for GDP, GDP deflator in R&R policy reaction function. 68 percent confidence intervals are reported.

Table 1: **Original SVAR and R&R Shock Series Regressed on Forecasting Variables**

a. SVAR

	(1)	(2)	(3)
GDP1	0.0131***	-0.197**	-0.435***
	[0.00434]	[0.0881]	[0.131]
CPI1	-0.0129***	-0.348***	-0.684***
	[0.00413]	[0.0920]	[0.221]
GDP2		0.208**	0.852***
		[0.0886]	[0.265]
CPI2		0.342***	1.246**
		[0.0942]	[0.505]
GDP3			-0.404***
			[0.152]
CPI3			-0.572*
			[0.297]
Observations	339	339	339
R-squared	0.028	0.067	0.096

b. R&R

	(1)	(2)	(3)	(4)	(5)
GDPDEFL3	-0.141**		-0.111*	-0.138**	-0.122*
	[0.0609]		[0.0631]	[0.0679]	[0.0674]
GDPDEFL4	0.156**		0.120*	0.148**	0.134*
	[0.0641]		[0.0654]	[0.0700]	[0.0694]
GDP3		0.0966***	0.0821**	0.0669*	0.0757*
		[0.0325]	[0.0341]	[0.0359]	[0.0399]
GDP4		-0.129***	-0.115***	-0.0980**	-0.0878*
		[0.0381]	[0.0391]	[0.0409]	[0.0451]
GDPDEFL_FCD3				-0.0341	-0.0987
				[0.138]	[0.139]
GDPDEFL_FCD4				0.0721	0.0691
				[0.154]	[0.153]
GDP_FCD3					-0.0695
					[0.0823]
GDP_FCD4					-0.123
					[0.0988]
Observations	246	246	246	234	234
R-squared	0.025	0.045	0.058	0.057	0.089
F test	3.07**	5.74***	3.73***	2.30**	2.73***

Note: Constant term not displayed. Standard error in brackets. $*p < 0.10, **p < 0.05, ***p < 0.01$. In Panel a, the dependent variable is the residuals derived from the baseline 4-variable SVAR. GDP1, GDP2 and GDP3 refer to forecasts for real GDP 1-, 2- and 3-quarter ahead. Similarly, CPI1, CPI2 and CPI3 refer to forecasts for CPI 1-, 2- and 3-quarter ahead. In Panel b, the dependent variable is the residuals derived from the R&R regression. GDPDEFL3, GDPDEFL4, GDPD3, and GDPD4 refer to forecasts for inflation and real GDP growth 3- and 4-quarter ahead. GDPDEFL_FCD3, GDPDEFL_FCD4, GDPD_FCD3, and GDPD_FCD4 refer to changes in forecasts for inflation and real GDP growth 3- and 4-quarter ahead. All forecasts are extracted from Greenbooks.

Table 2: **Forecast-augmented Shock Series Regressed on Forecasting Variables**

a. SVAR

	(1)	(2)	(3)
GDP1	-8.93E-11	-3.24E-10	-0.0717
	[0.00234]	[0.0524]	[0.0704]
CPI1	9.45E-11	1.38E-09	0.185
	[0.00233]	[0.0473]	[0.122]
GDP2		2.45E-10	0.183
		[0.0521]	[0.136]
CPI2		-1.32E-09	-0.437
		[0.0484]	[0.284]
GDP3			-0.111
			[0.0779]
CPI3			0.252
			[0.169]
Observations	327	327	327
R-squared	0	0	0.014

b. R&R

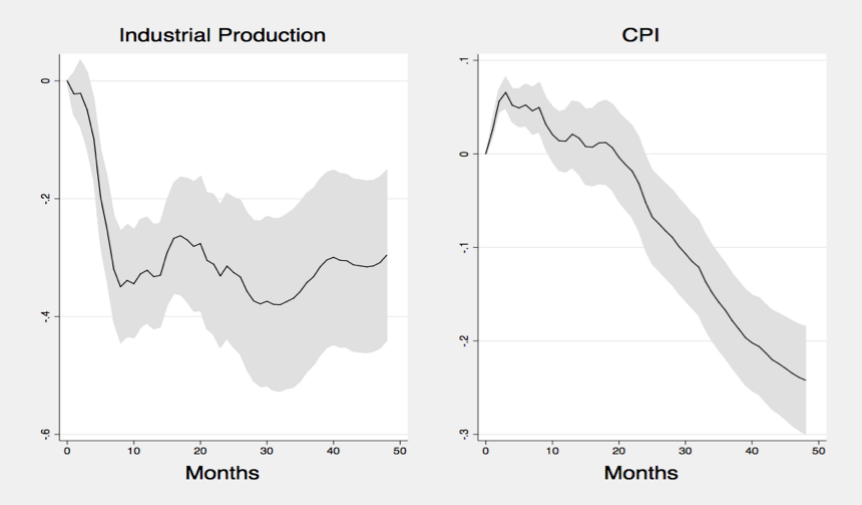
	(1)	(2)	(3)	(4)	(5)
GDPDEFL3	-6.78E-09		-5.09E-09	-5.08E-09	-4.68E-09
	[0.0659]		[0.0697]	[0.0718]	[0.0725]
GDPDEFL4	7.01E-09		5.49E-09	5.57E-09	5.18E-09
	[0.0692]		[0.0720]	[0.0738]	[0.0745]
GDP3		3.76E-09	3.08E-09	3.02E-09	3.78E-09
		[0.0357]	[0.0379]	[0.0381]	[0.0431]
GDP4		-3.42E-09	-2.73E-09	-2.70E-09	-3.19E-09
		[0.0419]	[0.0433]	[0.0435]	[0.0488]
GDPDEFL_FCD3				-2.32E-09	-4.08E-09
				[0.146]	[0.151]
GDPDEFL_FCD4				-3.65E-09	-3.17E-09
				[0.163]	[0.165]
GDP_FCD3					-3.86E-09
					[0.0890]
GDP_FCD4					8.66E-10
					[0.107]
Observations	235	235	235	235	235
R-squared	0	0	0	0	0
F test	0	0	0	0	0

Note: See the notes to Table 1. Here the dependent variable is constructed by orthogonalizing the residuals with respect to additional Greenbook forecast variables.

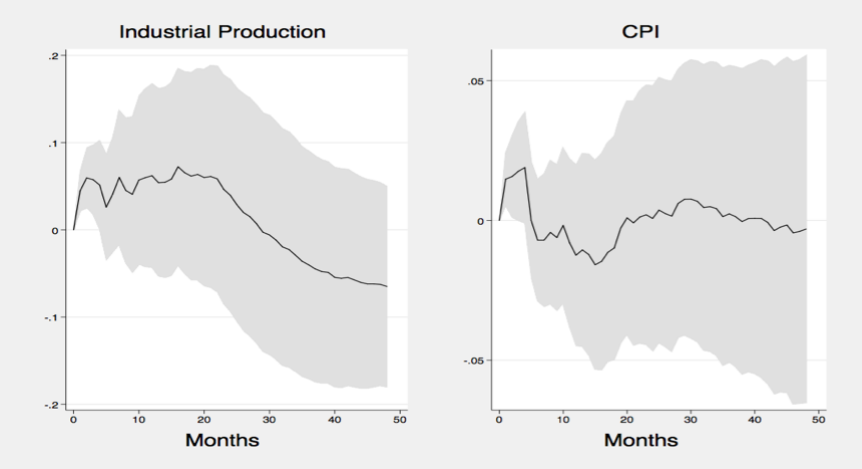
Online Appendix

Figure A.1: **CEE(1996) SVAR Impulse Responses**

a. 1959m1-1982m12

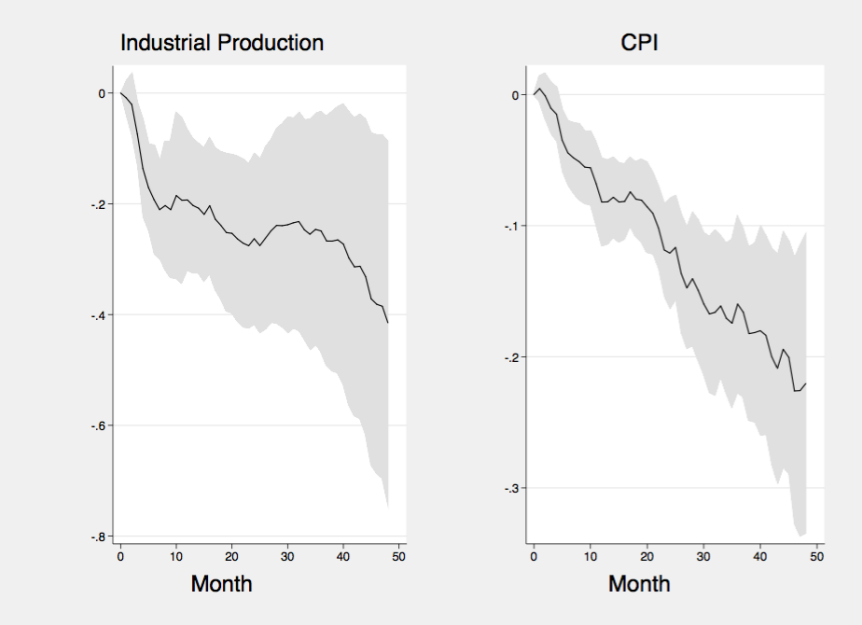


b. 1983m1-2007m12



Note: Structural VAR with monthly data, 7 endogenous variables and 12 lags. Variables are ordered as follows: industrial production, consumer price index, commodity prices, the effective federal funds rate, total reserves, M1, non-borrowed reserves. The first three variables are in logs and seasonally adjusted. Graphs show impulse response of industrial production and the consumer price index to a 100 basis point increase in the federal funds rate. 68 percent confidence intervals produced by bootstrapping 300 replications.

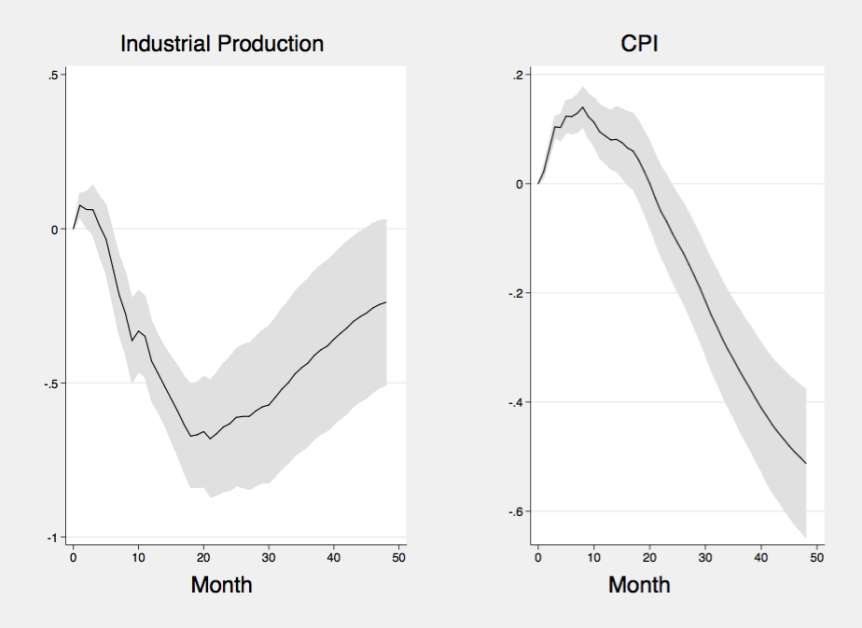
c. Forecasts Augmented 1983m1-2007m12



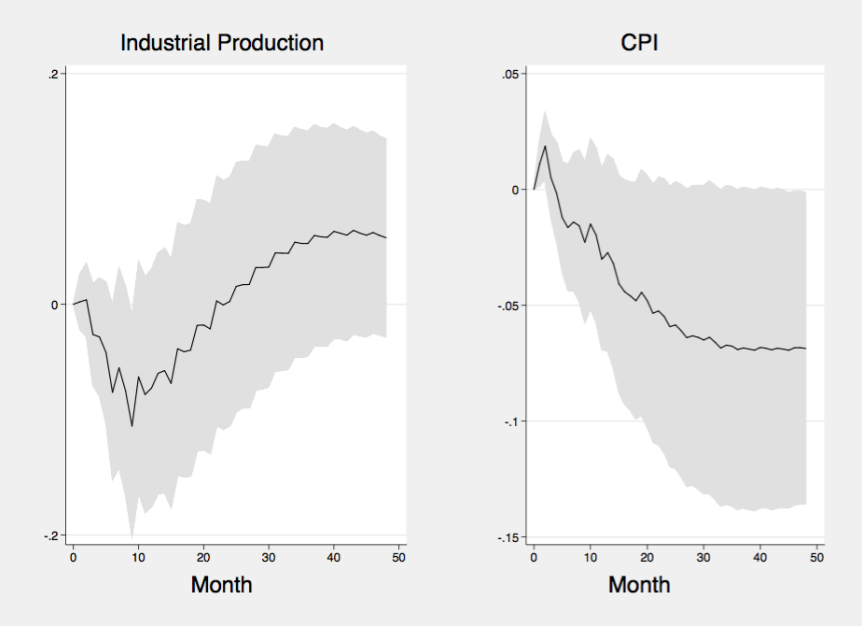
Note: Further include Greenbook forecasts for 1-, 2- and 3-quarter-ahead GDP and CPI as determinants of monetary policy.

Figure A.2: **SVAR with Wu-Xia Index**

a. 1959m1-1982m12

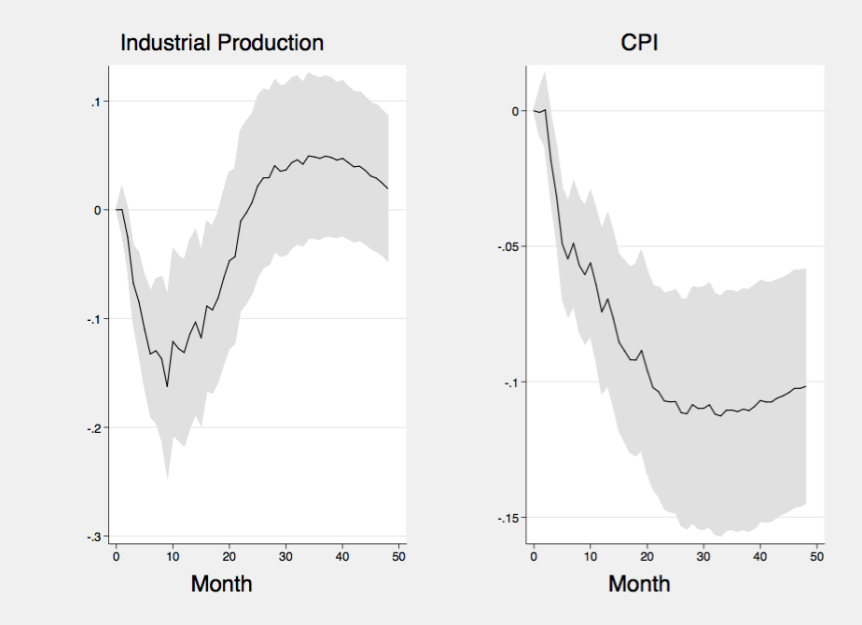


b. 1983m1-2007m12



Note: Structural VAR with monthly data, 4 endogenous variables and 12 lags. Variables are ordered as follows: industrial production, consumer price index, commodity prices, Wu-Xia index. The first three variables are in logs and seasonally adjusted. Graphs show impulse response of industrial production and the consumer price index to a 100 basis point increase in the Wu-Xia index. 68 percent confidence intervals produced by bootstrapping 300 replications.

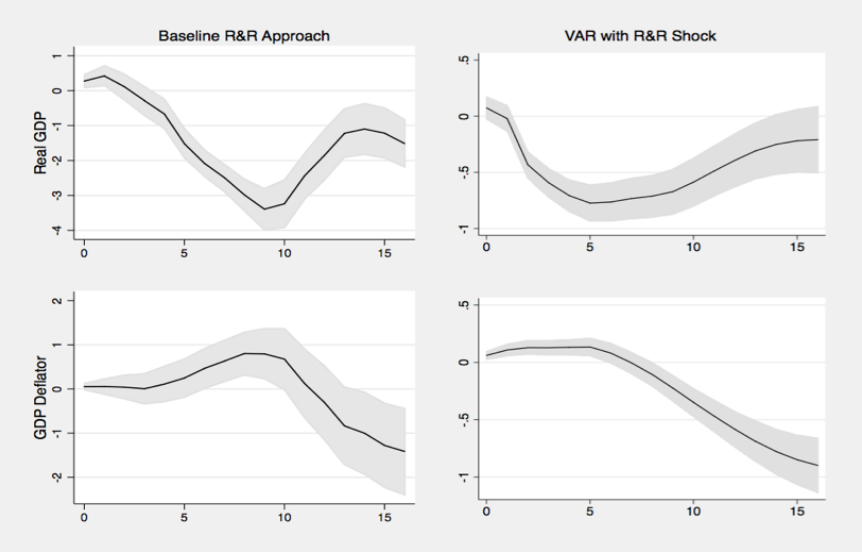
c. Forecasts Augmented 1983m1-2007m12



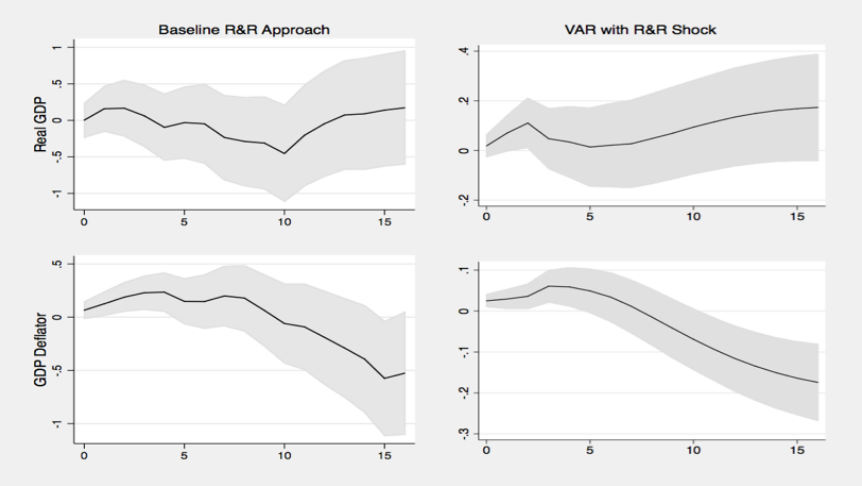
Note: Further include Greenbook forecasts for 1- and 2-quarter-ahead GDP and CPI as determinants of monetary policy.

Figure A.3: **Quarterly R&R Approaches**

a. Original R&R 1969Q1-1982Q4

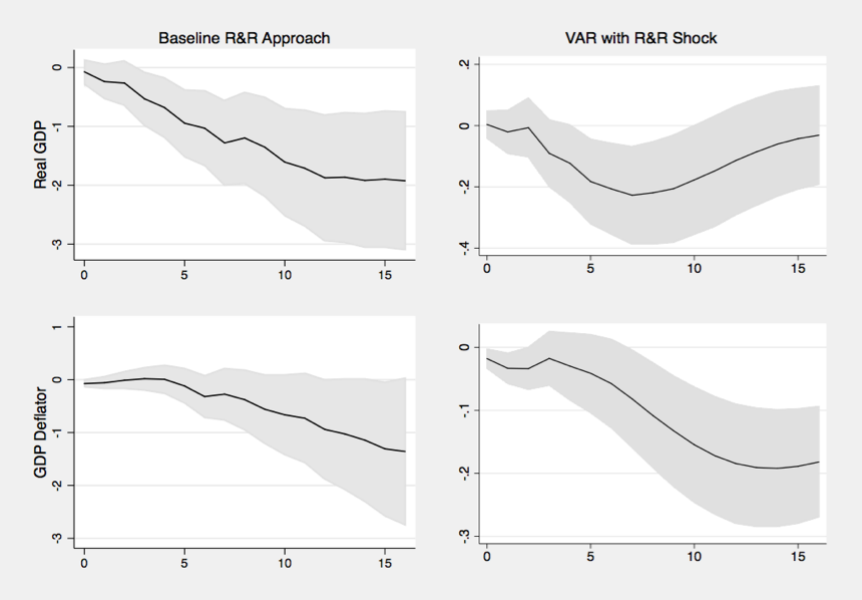


b. Original R&R 1983Q1-2007Q4



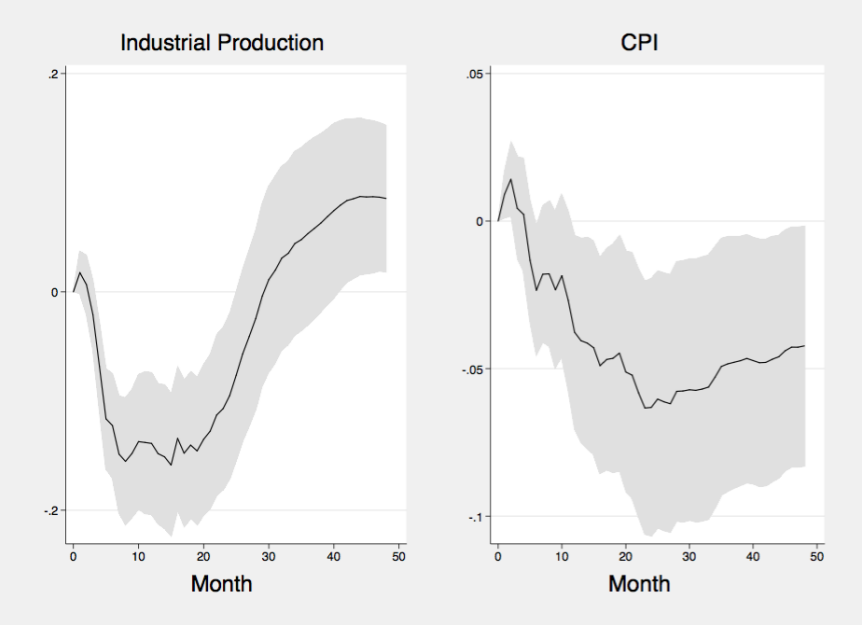
Note: *Baseline R&R Approach* refers to the estimation procedures of Romer & Romer (2004) with quarterly data. Correspondingly substitute monthly variables of monthly R&R shock series, industrial production and CPI index in R&R dynamic regression with quarterly variables of quarterly R&R shock series, real GDP, and GDP deflator. Use p=8, q=12 for real GDP, and p=8, q=16 for GDP deflator. *VAR with R&R Shock* refers to the 4-variable SVAR with quarterly data, using cumulative quarterly R&R shocks in substitution of the effective federal funds rate. Variables ordered as: the cumulative quarterly R&R shocks, the log real GDP, the log GDP deflator, the log commodity prices. Graphs show impulse response of real GDP and GDP deflator to a 100 basis point increase in the R&R shocks with 68 percent confidence intervals.

c. Forecasts Augmented R&R 1983Q1-2007Q4



Note: Further control for 3-4 quarters ahead forecasts for GDP, GDP deflator in R&R policy reaction function to generate new R&R shock series.

Figure A.4: **Incorporating More Forecast Variables in the SVAR**



Note: Over sample of 1983m1-2007m12. Structural VAR with monthly data, 10 endogenous variables and 12 lags. Variables are ordered as follows: industrial production, the consumer price index, commodity prices, Greenbook forecasts for 1-quarter-ahead GDP, Greenbook forecasts for 1-quarter-ahead CPI, Greenbook forecasts for 2-quarter-ahead GDP, Greenbook forecasts for 2-quarter-ahead CPI, Greenbook forecasts for 3-quarter-ahead GDP, Greenbook forecasts for 3-quarter-ahead CPI, the effective federal funds rate. The first 9 variables are in logs and seasonally adjusted. Graphs show impulse response of industrial production and the consumer price index to a 100 basis point increase in the federal funds rate. 68 percent confidence intervals produced by bootstrapping SVAR 300 replications.

Table A.1: **Subsample Test of Changing Policy Regimes**

a. SVAR

	(1) 1959m1-1978m12	(2) 1979m1-1982m12	(3) 1983m1-2007m12
GDP1	-0.00281 [0.00309]	8.94E-02 [0.0855]	0.00886*** [0.00243]
CPI1		-1.65E-02 [0.0315]	-0.00883*** [0.00251]
Observations	141	39	300
R-squared	0.006	0.05	0.043

b. Tests of forward and backward variables in R&R regressions

	Forward-looking		Backward-looking	
	F Test Statistics	P values	F Test Statistics	P values
1969m1-1982m12	0.92	0.4994	3.71	0.0004
1983m1-2007m12	2.25	0.0256	7.97	0

c. Tests of longer-term forward-looking variables

	Quarters 1-4 Forward-looking		Quarters 3-4 Forward-looking	
	F Test Statistics	P values	F Test Statistics	P values
1979m1-2007m12	4.31	0.0000	4.68	0.0000

d. Sub-sample tests of longer-term forward-looking variables post 1983

	3rd-quarter Forward-looking		4th-quarter Forward-looking	
	F Test Statistics	P values	F Test Statistics	P values
1983m1-2007m12	2.09	0.0834	2.15	0.0760

Note: Constant term not displayed. Standard error in brackets. $*p < 0.10, **p < 0.05, ***p < 0.01$. Panel a reports the results of regressions of forecast-augmented shocks on forecasting variables. GDP1 refers to forecasts for 1-quarter ahead real GDP. CPI1 refers to forecasts for 1-quarter ahead CPI. All forecasting growth rate of output and prices are extracted from Greenbooks issued at FOMC and leveled by previous month realized macroeconomic values.
Panel b reports F-tests of joint significance of 8 forward looking variables (quarters q + 1 and q + 2) and 9 backward-looking variables (quarters q - 1 and q) in R&R policy reaction function.
Panel c reports F-tests of joint significance of 16 forward looking variables (quarters q + 1 to q + 4) and 8 forward-looking variables (quarters q + 3 and q + 4) in forecasts augmented R&R policy reaction function. Panel d reports F-tests of joint significance for 3- and 4-quarter ahead forecasts post 1983, respectively.