Additional Results for Interest Rates, Money, and Fed Monetary Policy in a Markov-Switching Bayesian VAR*

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THIS APPENDIX IS NOT INTENDED FOR PUBLICATION.

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Appendix R.1.

Additional Model Fit Results

This appendix presents additional model fit results.

R.1.1. Adding a Third Monetary Regime

The best-fit MS-BVAR of the paper assumes two regimes in the impact and lag coefficient regimes of the monetary policy and money demand regression. In this section, I examine whether the data prefer MS-BVARs with three regimes. To answer this question, I estimate 10 additional MS-BVARs.

Table R1 presents the MS-BVARs with three regimes. Models 36 to 40 (labeled "3MPc2v") impose three regimes solely to the monetary policy equation. Models 41 to 45 (labeled "3MPBc2v") allow for three synchronized monetary policy and money demand regimes.[1]

Table R1: List of MS-BVARs with Three Regimes

Model	**Model Specification**	**Identifying Restrictions on $A_0(s_t)$**
Model 36	3MPc2v	Recursive Identification: Interest Rate Rule
Model 37	3MPc2v	Recursive Identification: Money Supply Rule
Model 38	3MPc2v	Non-Recursive Identification: Interest Rate Rule
Model 39	3MPc2v	Non-Recursive Identification: Money Supply Rule
Model 40	3MPc2v	Non-Recursive Identification: Interest Rate/Money Supply Rule
Model 41	3MPBc2v	Recursive Identification: Interest Rate Rule
Model 42	3MPBc2v	Recursive Identification: Money Supply Rule
Model 43	3MPBc2v	Non-Recursive Identification: Interest Rate Rule
Model 44	3MPBc2v	Non-Recursive Identification: Money Supply Rule
Model 45	3MPBc2v	Non-Recursive Identification: Interest Rate/Money Supply Rule

Notes: The label #c indicates the number of states in the impact and lag coefficients, while #v specifies the number of SV regimes. In addition, the label #MPc indicates only the monetary policy rule regression has MS impact and lag coefficients. The label #MPBc indicates only the monetary policy block regressions (FFR and MB) have MS impact and lag coefficients. The label #MPc#MDc indicates the impact and lag coefficients of the money supply and money demand regressions follow independent MS chains.

[1] I also estimated MS-BVARs with three independent monetary policy regimes and two/three independent money demand regimes (labeled "3MPc2MDc2v"/"3MPc3MDc2v"). However, estimation of these MS-BVARs failed to converge. Thus, I do not report these MDD results.

Table R2 reports the model fit results of these additional MS-BVARs along with their two-regime counterparts. Three observations stand out. First, it appears the addition of a three regime does not substantially improve model fit. Second, the data still prefer synchronized money supply and money demand regime changes over restricting MS to the monetary policy regression alone. Third, the preexisting best-fit MS-BVAR (model 28) remains the model with the lowest MDD. However, models 43 and 44 are close competitors. The MDD differences between models 43 and 44 and model 28 indicate the data are indifferent between these models.

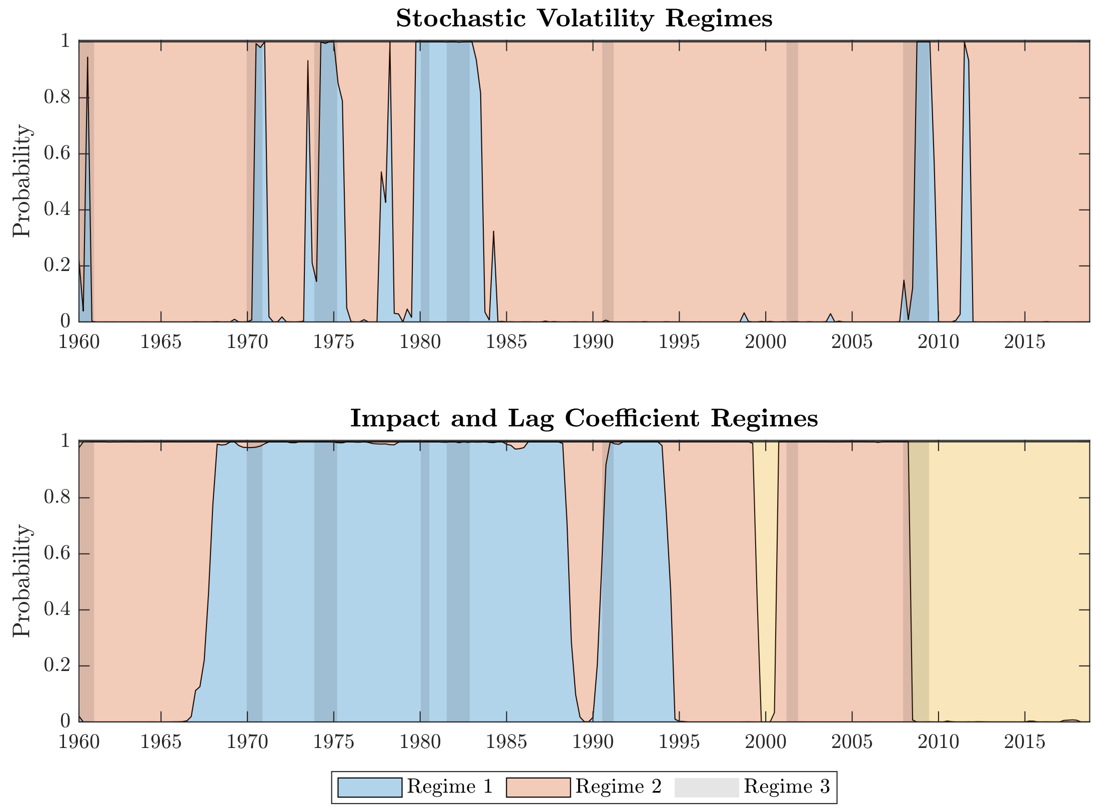
Table R2: Log Marginal Data Densities

	Model Specification			
Identifying Restrictions on $A_0(s_t)$	2MPc2v	2MPBc2v	3MPc2v	3MPBc2v
Recursive Identification: Interest Rate Rule	Model 21 -2560.34	Model 26 -2384.34	Model 36 -2590.25	Model 41 -2386.73
Recursive Identification: Money Supply Rule	Model 22 -2563.16	Model 27 -2389.06	Model 37 -2539.01	Model 42 -2393.94
Non-Recursive Identification: Interest Rate Rule	Model 23 -2413.09	**Model 28** **-2370.43**	Model 38 -2407.89	Model 43 -2370.58
Non-Recursive Identification: Money Supply Rule	Model 24 -2491.21	Model 29 -2375.36	Model 39 -2392.80	Model 44 -2370.90
Non-Recursive Identification: Interest Rate/Money Supply Rule	Model 25 -2454.35	Model 30 -2373.96	Model 40 *	Model 45 *

Notes: Marginal data densities (MDDs) of the MS-BVARs are computed using the truncated modified harmonic mean (MHM) estimator of Sims, Waggoner, and Zha (2008). The results shown are expressed in logarithms and are based on 10 million MCMC draws and the full data sample from 1960Q1 to 2018Q4. An asterisk (*) indicates the chains of the Metropolis-within-Gibbs MCMC sampler did not converge for the relevant model. In this case, the model being estimated lacks a well-approximated MDD. The model number and log MDD corresponding to the best-fit MS-BVAR are highlighted in bold.

Figure R1 plots the regime probabilities of the second best-fit MS-BVAR, model 43. Similar to model 28, one SV regime coincides with NBER dated recessions. With the addition of a third regime, we can see that money policy and money demand entered a new regime during the Great Inflation and the early 1990s. This result is similar to the one produced by Sims and Zha (2006)'s best-fit MS-BVAR with MS coefficients. However, there still appears to be a regime switch in Fed monetary policy and banks' outside money demand behaviors around the dot-com bust of 2000 and from 2007 to the end of the sample.

Figure R1: Smoothed Conditional Regime Probabilities of Model 43, 1960Q1 to 2018Q4



Notes: This figure plots the smoothed conditional SV and impact and lag coefficient regime probabilities of the "Non-Recursive Identification: Interest Rate Rule" 3MPBc2v MS-BVAR. The results shown are based on 10 million MCMC draws and the full data sample from 1960Q1 to 2018Q4. The shaded bars correspond to the NBER recession dates.

Appendix R.2.

A Baseline Constant Coefficient BVAR

This appendix estimates four constant coefficient BVARs, one for each identification scheme. The goal is to establish a baseline against which to evaluate the estimated MS-BVARs. All constant coefficient and MS-BVARs studied in this paper are estimated with an optimal lag length selected by information-based model selection criteria. The first section of this appendix discusses the lag selection process. Each subsequent section then presents impulse response functions (IRFs) and forecast error variance decompositions (FEVDs) for each of the four estimated constant coefficient BVARs.

R.2.1. Optimal Lag Length

Table R1 reports the information criteria results of a constant coefficient SVAR. An asterisk ($*$) in Table R1 indicates the optimal lag length selected by the criterion listed at the top of the column. The results show that the Sims (1980)'s sequential likelihood ratio (LR) test, the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC), and the Hannan-Quinn Criterion (HQC) are split between six and two lags.

To select between the two suggested lag lengths, I consider the asymptotic properties of each information criteria.[2] For example, the AIC produces inconsistent estimates of the lag length, meaning that the AIC overestimates the true lag length of the SVAR with nonzero probability. In contrast, the BIC and HQC produce consistent estimates, which will almost surely select the correct lag length as the sample size increases. For quarterly data, Ivanov and Kilian (2005) show that the HQC is the most accurate criterion when the sample contains over 120 observations. Ivanov and Kilian (2005) also show that the HQC (as well as the AIC and BIC) dominates the LR test.

[2] Lütkepohl (2005) provides a thorough discussion about the asymptotic properties of various information criteria.

Therefore, I follow the suggestion of the HQC and set the maximum lag length to two.

Table R1: Selection of Optimal Lag Length

Lag	LogLik	LR†	p-Value	AIC	BIC	HQC
1	-2607.1768	—	—	23.6595	25.0131	24.2056
2	-2336.6651	495.9380	0.0000	21.9971	24.5691*	23.0348*
3	-2239.0052	171.3332	0.0000	21.8509	25.6413	23.3802
4	-2149.2897	150.3129	0.0000	21.7744	26.7831	23.7953
5	-2073.8152	120.4944	0.0000	21.8229	28.0500	24.3353
6	-1976.1751	148.1731*	0.0000	21.6770*	29.1223	24.6809
7	-1925.6236	72.7231	0.0647	21.9441	30.6077	25.4396
8	-1862.7422	85.4967	0.0011	22.1030	31.9849	26.0901

† Each sequential LR test was conducted using a 5% significance level.
* An asterisk indicates the optimal lag length selected by the criterion.

R.2.2. Results for the Recursive Identification: Interest Rate Rule BVAR

Figures R1 to R3 present the IRFs for each variable to a one standard deviation shock under the "Recursive Identification: Interest Rate Rule" identification scheme. The median IRFs (solid lines) are plotted over 40 quarters with 68% uncertainty bands (dashed lines). The uncertainty bands are constructed using the 16th and 84th percentiles of 500,000 MCMC draws from the IRF posterior distribution.

The first column of Figure R1 displays the expected *a priori* effects of an aggregate supply shock (i.e., a one standard deviation increase in RGDP). A positive innovation in RGDP causes P to rise and leads to a temporary fall in UR. This finding is consistent with Okun's law. With RGDP and P rising and UR falling, FFR increases. These IRFs are consistent with the view that the Fed systematically raises its policy rate in response to lower output and rising prices and unemployment to prevent higher future inflation.

The next set of IRFs to an aggregate supply shock focuses on the responses in the financial block. As MB falls, R_{CP} rises, which matches a prediction of Brunner and Meltzer (1972). As the Fed alters the composition of inside to outside money, it sets off a chain of relative price changes. Contracting MB puts upward pressure on FFR and shifts the money market curve inward. The reduction of outside money, in turn, causes R_{CP} to rise. The money and credit markets put downward pressure on the real asset price level (i.e., the composite price level of houses, consumer durables, producer's capital, etc.). Thus, the yields on R_{10yr} and R_{Baa} should rise. The results presented here replicate this prediction.

Finally, the shapes of the IRFs of R_{Baa} and RGDP to an aggregate supply shock reveal an interesting linkage between the financial and real sides of the economy. As R_{Baa} gradually rises, RGDP falls. After R_{Baa} reaches its peak around the 16 quarter horizon and begins to fall, RGDP levels off at its new permanently higher level. This matches the relative price prediction between new production and exist capital by Tobin (1961) and Brunner and Meltzer (1972, 1988).

The second column of Figure R1 plots the IRFs to a one standard deviation increase in P (i.e., an aggregate demand shock). A positive innovation in P leads to a permanently higher price level. Note that the IRF of the FFR to an aggregate demand shock does not increase in line with P for all 40 quarters. Instead, the FFR peaks around six quarters after the initial shock. The FFR begins to fall around the same time RGDP and UR start to significantly deviate from their steady-state levels. Nevertheless, as the FFR rises and subsequently falls, MB does not significantly deviate from zero. This result is the liquidity puzzle discussed in Gordon and Leeper (1994) and Leeper and Roush (2003). Surprisingly, the liquidity puzzle emerges in a model that contains an inside and outside monetary aggregate. The existence of a liquidity puzzle in these results runs counter to the standard convention in the literature of adding a narrow monetary aggregate to mitigate the liquidity puzzle; see, for example, the argument given by Strongin (1995). Lastly, the IRFs of R_{CP}, R_{10yr}, and R_{Baa} display the expected results following a series of open market operations consistent with the movements of the FFR.

The third and final column of Figure R1 plots the IRFs to a one standard deviation increase in UR (i.e., a labor supply shock). Most of the IRFs display qualitatively similar patterns to the IRFs to an aggregate supply shock, but with an opposite sign. In summary, Okun's law and the expected *a priori* predictions of how movements in outside money influence financial and real economic conditions remain intact.

The IRFs to an identified monetary policy and outside money demand shock are reported in Figure R2. Recall that under an interest rate rule, the Fed's policy instrument is the FFR. Therefore, non-systematic variations in the FFR are identified as monetary policy shocks. Innovations in MB are identified as outside money demand shocks.

Following a contractionary monetary policy shock, RGDP gradually falls, hitting its lowest point around the 12 quarter horizon. A puzzling result appears as P is significantly higher for the entire 40 quarter horizon. This result is the price puzzle. In addition to the price puzzle, the liquidity puzzle is also present. However, the hump-shaped IRF of MI suggests a liquidity effect in the credit (inside money) market. Moreover, the relationships between the FFR and R_{CP} and the FFR and MI indicate there is a significant short-term decline in credit market activity. The increase in R_{CP} and the decline in MI support this idea. Finally, the expected *a priori* prediction that a contractionary monetary policy shock leads to a fall in the real asset price level is evident in the IRFs of R_{10yr} and R_{Baa}.

An outside money demand produces several economically interesting IRFs. Starting with the IRF of the FFR, a positive innovation in MB fails to cause any significant variation in the FFR. This IRF verifies that a Fed targeting the FFR can hold it steady in the face of outside money demand shocks. However, as Goodfriend (2005) predicts, holding the FFR steady is not sufficient for insulating the economy from outside money demand shocks. For example, notice that the IRFs of RGDP, UR, and R_{Baa} are significantly different from zero in the short run. These IRFs support the argument that monetary shocks that move the real asset price level also generate business cycle fluctuations.

The IRFs to shocks originating from the financial block appear in Figure R3. Starting with the credit (inside money) supply shock, a positive innovation in R_{CP} significantly lowers MI in the first several quarters. The IRFs of the FFR, MI R_{10yr}, R_{Baa}, and RGDP are interpreted as follows. Since the Fed operates under an interest rate rule, the Fed conducts open market operations to prevent the FFR from falling. These operations drain outside money from the banking system. In summary, the policy rate remains constant, the real asset price level unambiguously falls, and output temporarily contracts as expected. The IRF of MB to a credit supply shock exhibits a liquidity puzzle.

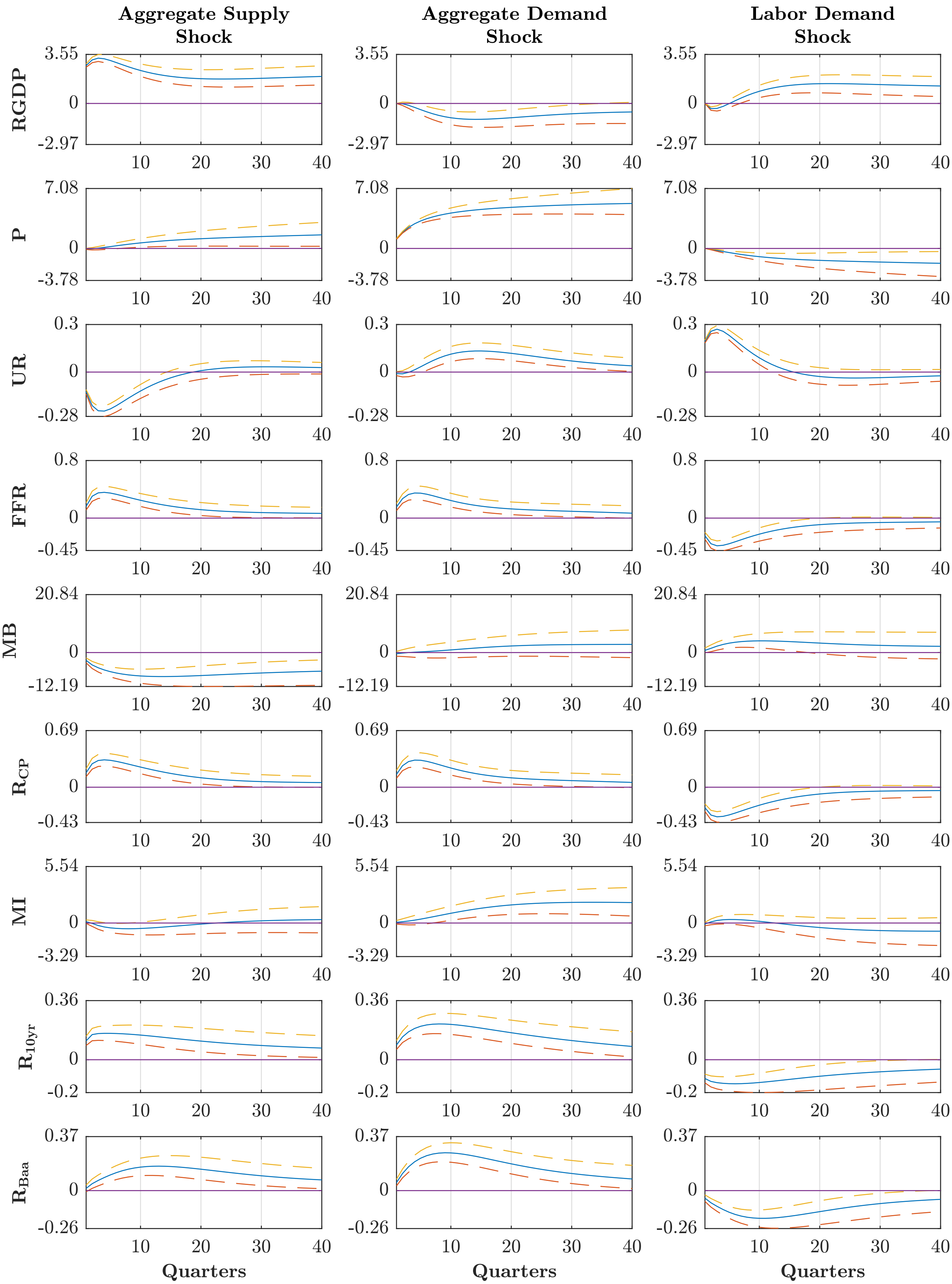
The IRFs to a credit demand shock are reported in the second column of Figure R3. A positive innovation in MI results in hump-shaped responses in RGDP and UR. Similar evidence is reported by King and Plosser (1984). They find that much of the co-movement between economic activity and money is attributable to the relationship between MI and RGDP. As a result, inflation is a phenomenon generated by movements in MI. Nevertheless, credit demand shocks appear to cause short-term fluctuations in output and employment.

The last two shocks are the term premium and risk premium shocks. Both shocks cause fluctuations in RGDP and UR, while P remains constant. These IRFs support the claim that changes in existing asset prices lead to relative price of new production changes. However, an increase in RGDP following a term premium shock is puzzling.

Table R2 reports FEVDs for the "Recursive Identification: Interest Rate Rule" identification scheme. FEVDs are tools to measure the percentage of variation in the forecast errors of a variable that can be attributed to a structural shock. Similar to the IRFs, the FEVDs are reported up to a 40 quarter horizon.

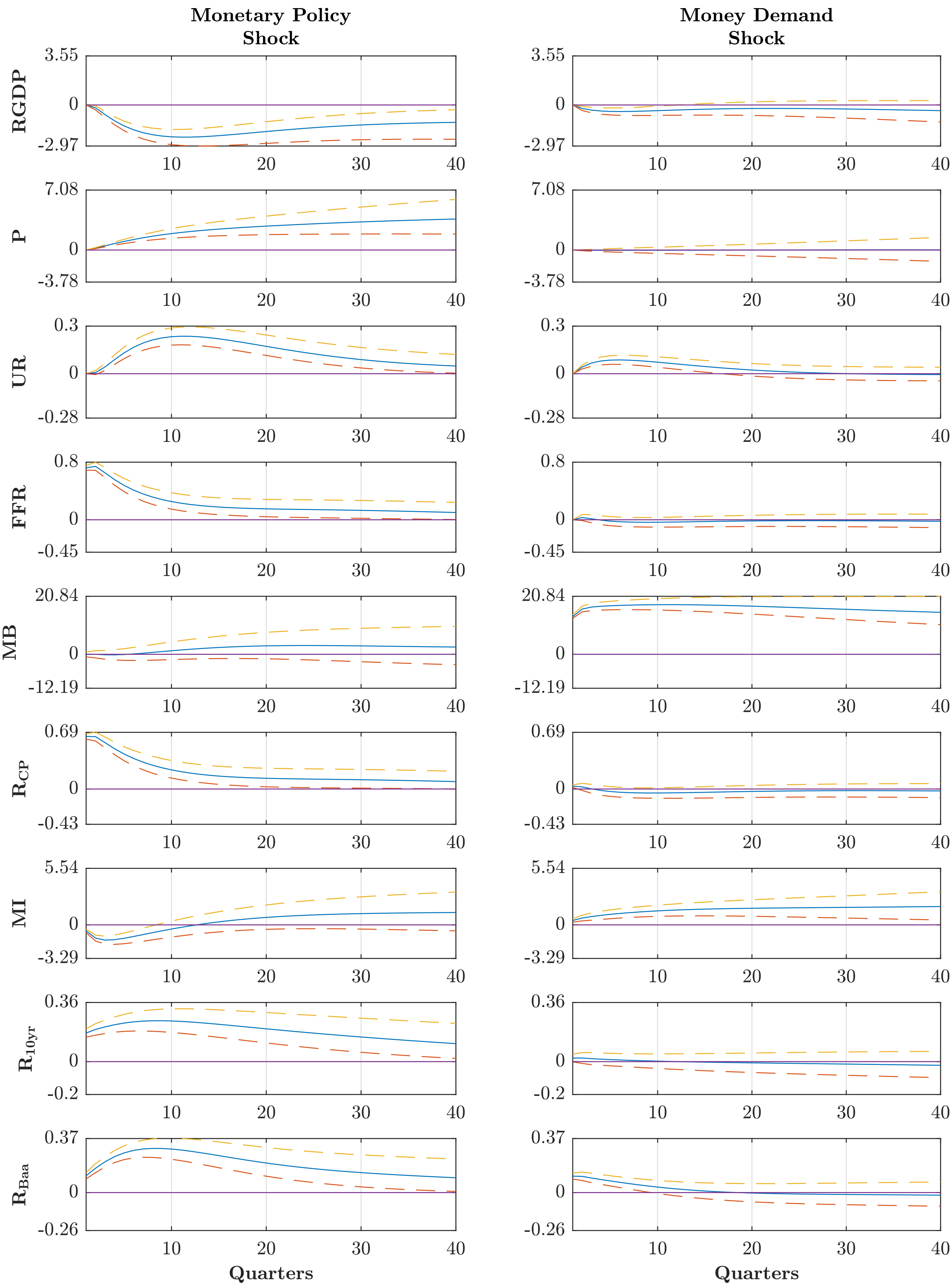
Several FEVDs stand out. First, aggregate supply and aggregate demand shocks explain most of the fluctuations in RGDP and P across all 40 quarters. Aggregate supply and aggregate demand shocks also explain a considerable portion of fluctuations in the financial block variables after 8 quarters. Second, monetary policy shocks contribute to 23%-26% of the variation in RGDP and 17%-20% of the variation in P in the later horizons after the initial shock. Interestingly, monetary policy shocks appear cause noticeable fluctuations in the financial block variables. However, monetary policy shocks fail to generate MB fluctuations, reaffirming the liquidity puzzle. Third, outside money demand shocks initially contributes to R_{Baa} fluctuations. As expected, the FFR stays steady in the face of outside money demand shocks and outside money demand shocks explain a small percentage of RGDP fluctuations after 4 quarters. Finally, the shocks originating from the financial block explain a small percentage of RGDP and P fluctuations. Two notable financial block shocks are the credit supply and term premium shocks.

Figure R1: IRFs to Identified Production Block Shocks — Recursive Identification: Interest Rate Rule BVAR



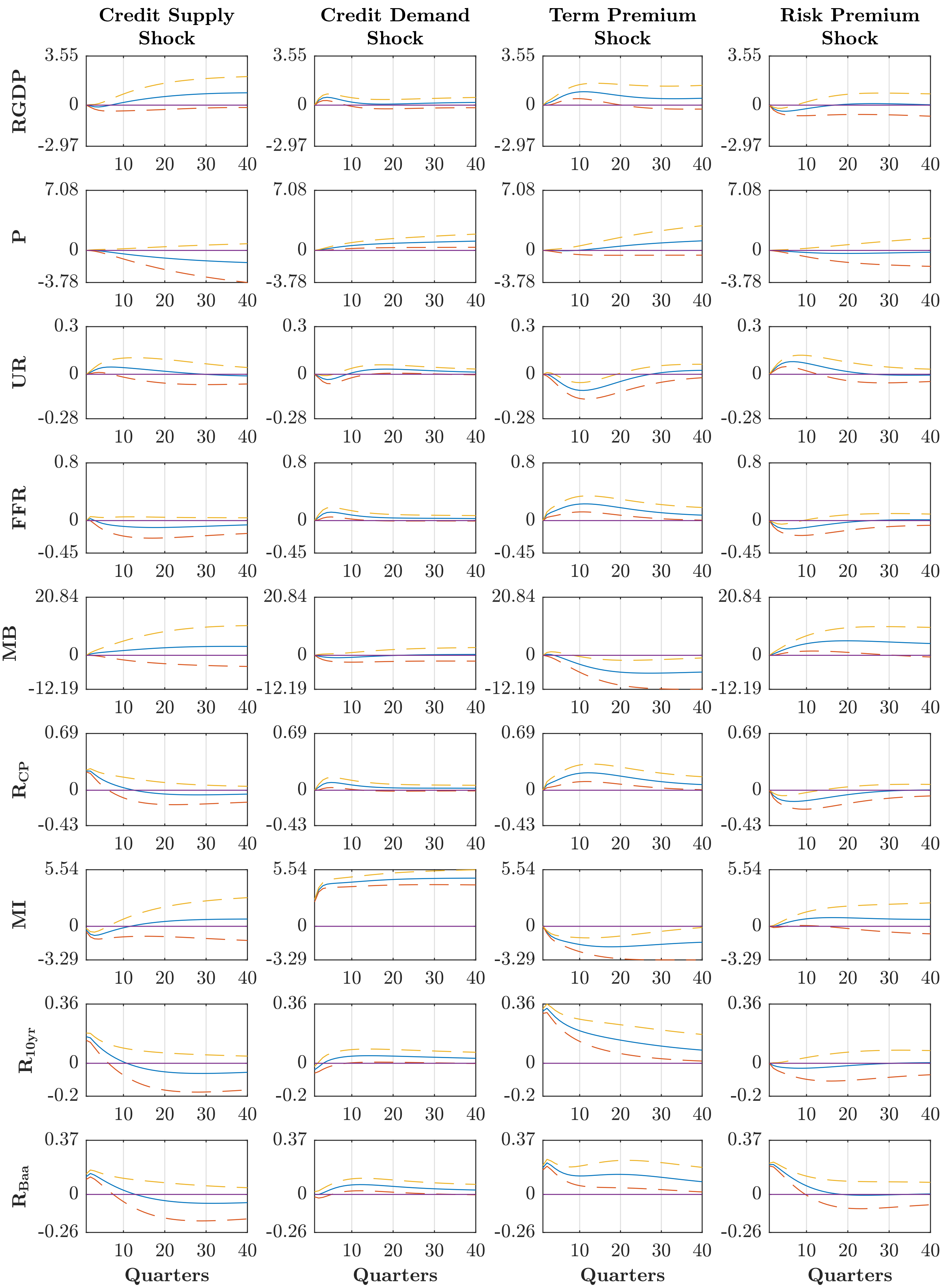
Notes: IRFs to an one standard deviation shock to RGDP, P, and UR. In each graph, the solid line represents the posterior median estimate and the two dashed lines represent the 68% uncertainty bands. Results are based on 500,000 MCMC draws.

Figure R2: IRFs to Identified Monetary Policy Block Shocks — Recursive Identification: Interest Rate Rule BVAR



Notes: IRFs to an one standard deviation shock to FFR and MB. In each graph, the solid line represents the posterior median estimate and the two dashed lines represent the 68% uncertainty bands. Results are based on 500,000 MCMC draws.

Figure R3: IRFs to Identified Financial Block Shocks — Recursive Identification: Interest Rate Rule BVAR



Notes: IRFs to an one standard deviation shock to R_{CP}, MI, R_{10yr}, and R_{Baa}. In each graph, the solid line represents the posterior median estimate and the two dashed lines represent the 68% uncertainty bands. Results are based on 500,000 MCMC draws.

Table R2: FEVDs of Recursive Identification: Interest Rate Rule BVAR

		Shock								
	Horizon	Aggregate Supply	Aggregate Demand	Labor Supply	Monetary Policy	Money Demand	Credit Supply	Credit Demand	Term Premium	Risk Premium
RGDP	1	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.97	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
	4	0.89	0.01	0.01	0.05	0.01	0.00	0.02	0.01	0.01
	8	0.71	0.03	0.01	0.16	0.02	0.01	0.02	0.03	0.02
	20	0.44	0.07	0.08	0.26	0.02	0.04	0.01	0.06	0.02
	40	0.37	0.07	0.13	0.23	0.03	0.08	0.01	0.06	0.03
P	1	0.01	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.01	0.98	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	4	0.01	0.93	0.01	0.04	0.00	0.00	0.00	0.00	0.00
	8	0.01	0.83	0.03	0.10	0.00	0.01	0.01	0.01	0.01
	20	0.03	0.65	0.05	0.17	0.01	0.03	0.02	0.02	0.02
	40	0.05	0.52	0.06	0.20	0.02	0.07	0.02	0.04	0.03
UR	1	0.29	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.36	0.00	0.62	0.00	0.01	0.00	0.00	0.00	0.00
	4	0.39	0.01	0.52	0.02	0.03	0.01	0.01	0.00	0.02
	8	0.33	0.03	0.37	0.14	0.04	0.02	0.01	0.03	0.04
	20	0.19	0.10	0.20	0.31	0.04	0.04	0.01	0.06	0.04
	40	0.16	0.12	0.17	0.32	0.04	0.06	0.01	0.07	0.05
FFR	1	0.05	0.04	0.10	0.82	0.00	0.00	0.00	0.00	0.00
	2	0.08	0.07	0.13	0.71	0.00	0.00	0.00	0.01	0.00
	4	0.12	0.11	0.15	0.58	0.00	0.00	0.01	0.02	0.01
	8	0.15	0.14	0.16	0.45	0.01	0.01	0.02	0.04	0.02
	20	0.15	0.14	0.15	0.35	0.01	0.04	0.02	0.10	0.03
	40	0.14	0.14	0.13	0.33	0.02	0.07	0.02	0.11	0.04
MB	1	0.04	0.00	0.01	0.00	0.94	0.00	0.00	0.00	0.00
	2	0.06	0.01	0.01	0.01	0.91	0.00	0.00	0.00	0.00
	4	0.09	0.01	0.02	0.01	0.87	0.00	0.00	0.00	0.01
	8	0.12	0.01	0.03	0.01	0.78	0.01	0.01	0.01	0.02
	20	0.13	0.02	0.04	0.03	0.64	0.04	0.01	0.05	0.05
	40	0.12	0.03	0.04	0.05	0.54	0.07	0.01	0.08	0.06
R_{CP}	1	0.06	0.04	0.11	0.70	0.00	0.09	0.00	0.00	0.00
	2	0.09	0.07	0.13	0.61	0.00	0.08	0.00	0.00	0.00
	4	0.12	0.11	0.16	0.50	0.00	0.06	0.01	0.01	0.01
	8	0.15	0.15	0.17	0.40	0.01	0.05	0.01	0.04	0.03
	20	0.15	0.15	0.15	0.31	0.01	0.06	0.02	0.09	0.05
	40	0.14	0.14	0.14	0.30	0.02	0.08	0.02	0.11	0.05
MI	1	0.01	0.00	0.01	0.05	0.03	0.02	0.88	0.00	0.00
	2	0.01	0.01	0.01	0.09	0.03	0.03	0.81	0.01	0.00
	4	0.01	0.01	0.01	0.10	0.04	0.04	0.76	0.04	0.00
	8	0.02	0.02	0.01	0.07	0.05	0.03	0.72	0.07	0.01
	20	0.02	0.06	0.02	0.05	0.07	0.04	0.62	0.11	0.03
	40	0.02	0.08	0.03	0.06	0.08	0.06	0.52	0.10	0.04
R_{10yr}	1	0.07	0.04	0.07	0.16	0.01	0.13	0.01	0.51	0.00
	2	0.09	0.07	0.07	0.16	0.01	0.12	0.01	0.48	0.00
	4	0.10	0.11	0.08	0.18	0.01	0.09	0.01	0.42	0.00
	8	0.11	0.15	0.09	0.22	0.01	0.06	0.01	0.34	0.01
	20	0.11	0.18	0.09	0.26	0.01	0.06	0.01	0.25	0.02
	40	0.11	0.17	0.09	0.26	0.02	0.08	0.02	0.22	0.03
R_{Baa}	1	0.01	0.03	0.03	0.11	0.10	0.12	0.00	0.27	0.33
	2	0.01	0.06	0.04	0.14	0.09	0.12	0.00	0.27	0.28
	4	0.03	0.12	0.06	0.21	0.06	0.10	0.01	0.21	0.20
	8	0.05	0.19	0.09	0.29	0.04	0.06	0.01	0.14	0.12
	20	0.10	0.21	0.12	0.29	0.02	0.05	0.02	0.12	0.07
	40	0.10	0.19	0.12	0.27	0.03	0.08	0.02	0.13	0.06

R.2.3. Results for the Recursive Identification: Money Supply Rule BVAR

Figures R4 to R6 present the IRFs for each variable to a one standard deviation shock under the "Recursive Identification: Money Supply Rule" identification scheme. The IRFs are qualitatively similar to those under the "Recursive Identification: Interest Rate Rule" identification scheme except for the monetary policy and outside money demand shocks. For the sake of brevity, I only focus on these two shocks.

The first column of Figure R5 plots the IRFs to an expansionary monetary policy shock (i.e., a positive innovation in MB). Once again, the liquidity puzzle appears. The policy-induced injection of outside money to the banking system does not cause the FFR to fall as expected. However, the increased stock of outside money leads to an increase in MI. The money and credit markets should, in turn, exert downward pressure on the short-term nominal interest rate and upward pressure on the price of long-term private and government securities. These predictions are not supported by the results here. Nevertheless, a monetary policy shock contributes to a short-run contraction in RGDP and a temporary rise in UR. The IRFs of RGDP and UR to an unexpected monetary policy shock are not as pronounced as the IRFs under the "Recursive Identification: Interest Rate Rule" identification scheme. Interestingly, more inside and outside money does not contribute to inflation.

The IRFs to an outside money demand shock appear in the second column of Figure R5. As expected under a money supply rule, the Fed does not allow the stock of outside money to significantly deviate from its target level. The combination of increased demand and scarcity of outside money drives up the FFR. Financial intermediaries not only demand more outside money but also face a higher cost of issuing new credit. As a result, the inside money creation process declines as borrowers face higher loan costs. One implication of this is that the price of long-term private and government securities declines further than under the interest rate rule. The IRFs of R_{10yr} and R_{Baa} show strong responses in contrast to the IRFs under the "Recursive Identification: Interest Rate Rule" identification scheme. Outside money demand shocks also generate larger fluctuations in RGDP, P, and UR than the IRFs mentioned earlier.

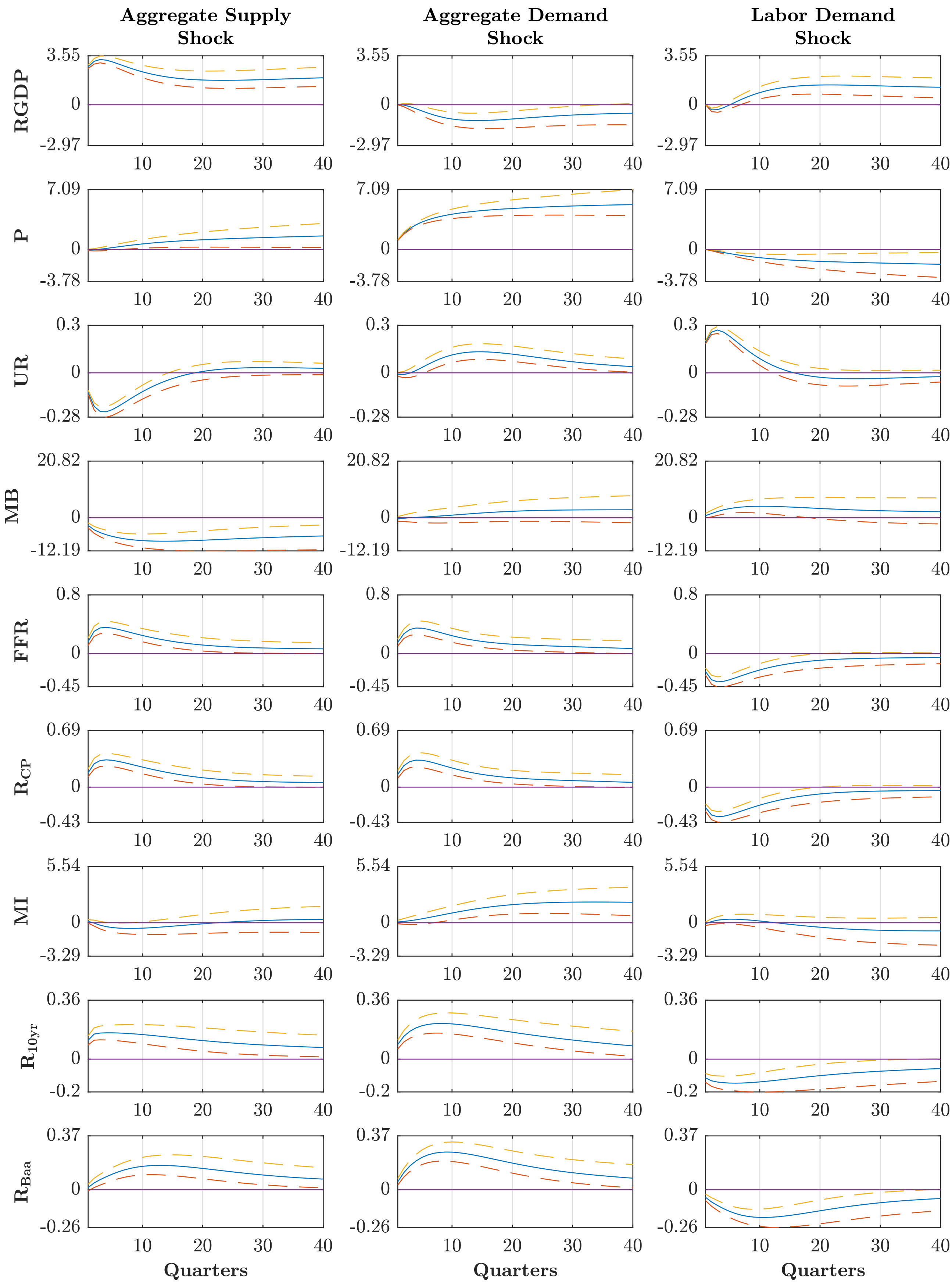
I now turn to the FEVDs to see if an interest rate rule or a money supply rule generates larger financial and real fluctuations.

Table R3 reports FEVDs for the "Recursive Identification: Money Supply Rule" identification scheme. The FEVDs are similar to the ones under the "Recursive Identification: Interest Rate Rule" identification scheme except for the monetary policy and outside money demand shocks. Once again, I only focus on these two shocks.

Starting with the monetary policy shock, MB movements do not explain variations in RGDP, P, and UR. These results stand in contrast with the results under the "Recursive Identification: Interest Rate Rule" identification scheme. One interpretation of these results is that unanticipated monetary policy shocks do not generate business cycle fluctuations. Monetarists, such as McCallum (1987) and Meltzer (1987), claim that this is a desirable trait of a money supply rule. Monetary policy shocks also produce similar initial FEVDs for R_{10yr} and R_{Baa} compared to the ones under the interest rate rule. However, after four quarters, a money supply rule explains less variation in the financial block variables than an interest rate rule.

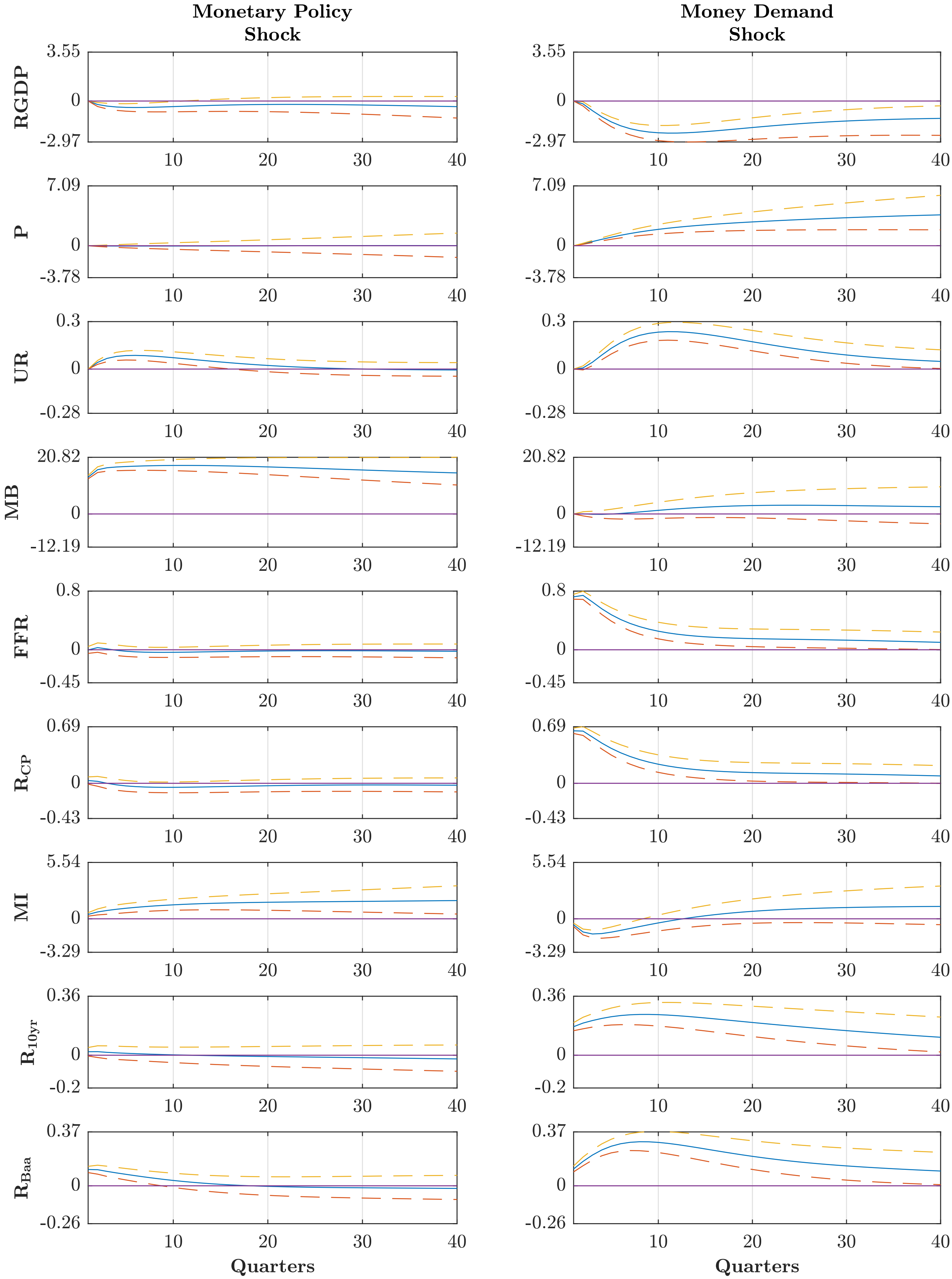
The FEVDs to an outside money demand shock has several interesting results. First, outside money demand shocks explain a significant portion of the variation in the FFR. These results are consistent with the view that the Fed cannot control the MB and the FFR at the same time. This one argument made by Poole (1970). As a result, outside money demand shocks generate larger interest rate fluctuations under a money supply rule than an interest rate rule. Second, a money supply rule produces larger FEVDs in R_{10yr} and R_{Baa} than under an interest rate rule. Finally, outside money demand shocks are shown to explain 26% and 17% of the fluctuations in RGDP and P 20 quarters after the initial shock.

Figure R4: IRFs to Identified Production Block Shocks — Recursive Identification: Money Supply Rule BVAR



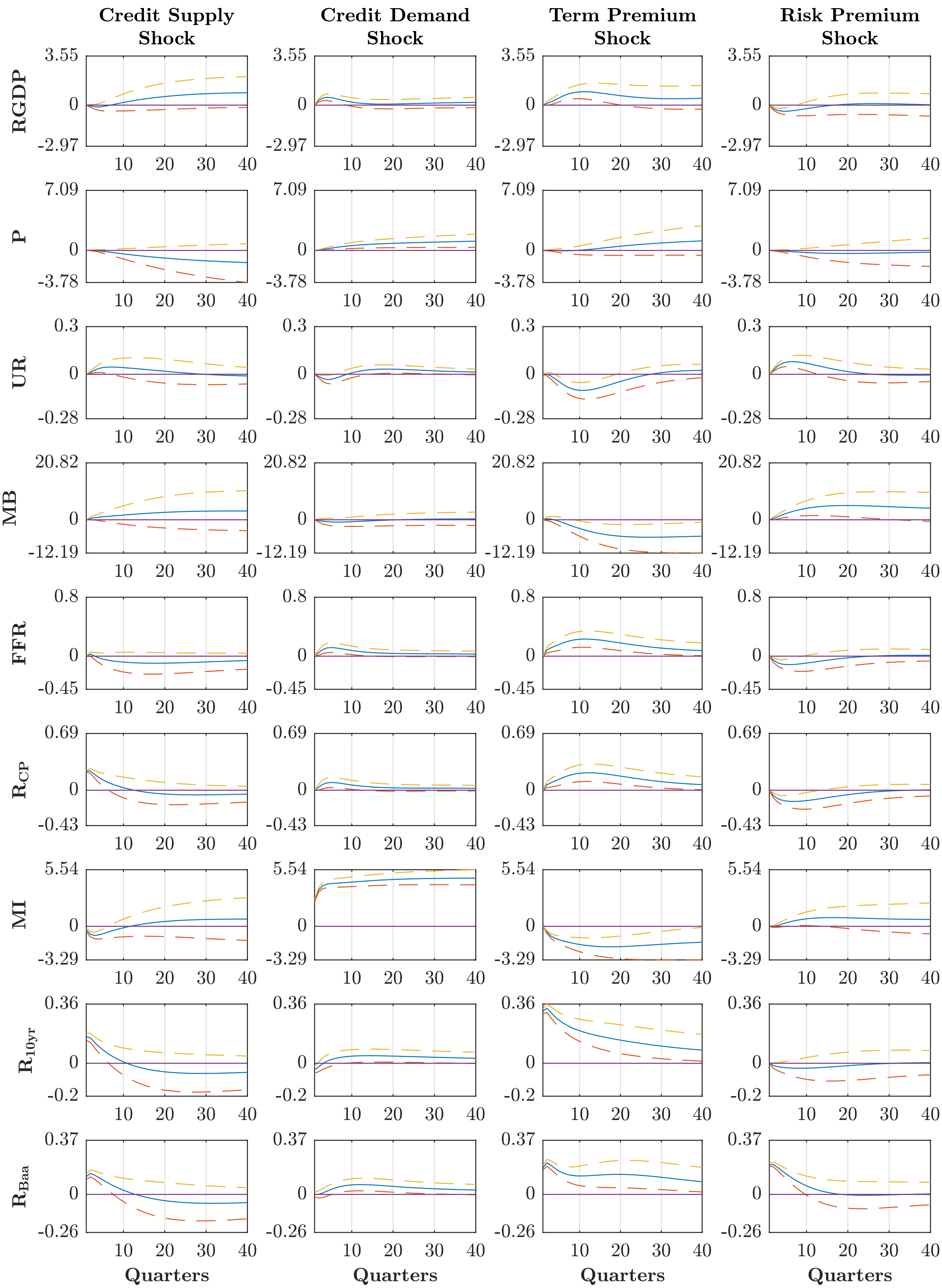
Notes: IRFs to an one standard deviation shock to RGDP, P, and UR. In each graph, the solid line represents the posterior median estimate and the two dashed lines represent the 68% uncertainty bands. Results are based on 500,000 MCMC draws.

Figure R5: IRFs to Identified Monetary Policy Block Shocks — Recursive Identification: Money Supply Rule BVAR



Notes: IRFs to an one standard deviation shock to the MB and FFR. In each graph, the solid line represents the posterior median estimate and the two dashed lines represent the 68% uncertainty bands. Results are based on 500,000 MCMC draws.

Figure R6: IRFs to Identified Financial Block Shocks — Recursive Identification: Money Supply Rule BVAR



Notes: IRFs to an one standard deviation shock to R_{CP}, MI, R_{10yr}, and R_{Baa}. In each graph, the solid line represents the posterior median estimate and the two dashed lines represent the 68% uncertainty bands. Results are based on 500,000 MCMC draws.

Table R3: FEVDs of Recursive Identification: Money Supply Rule BVAR

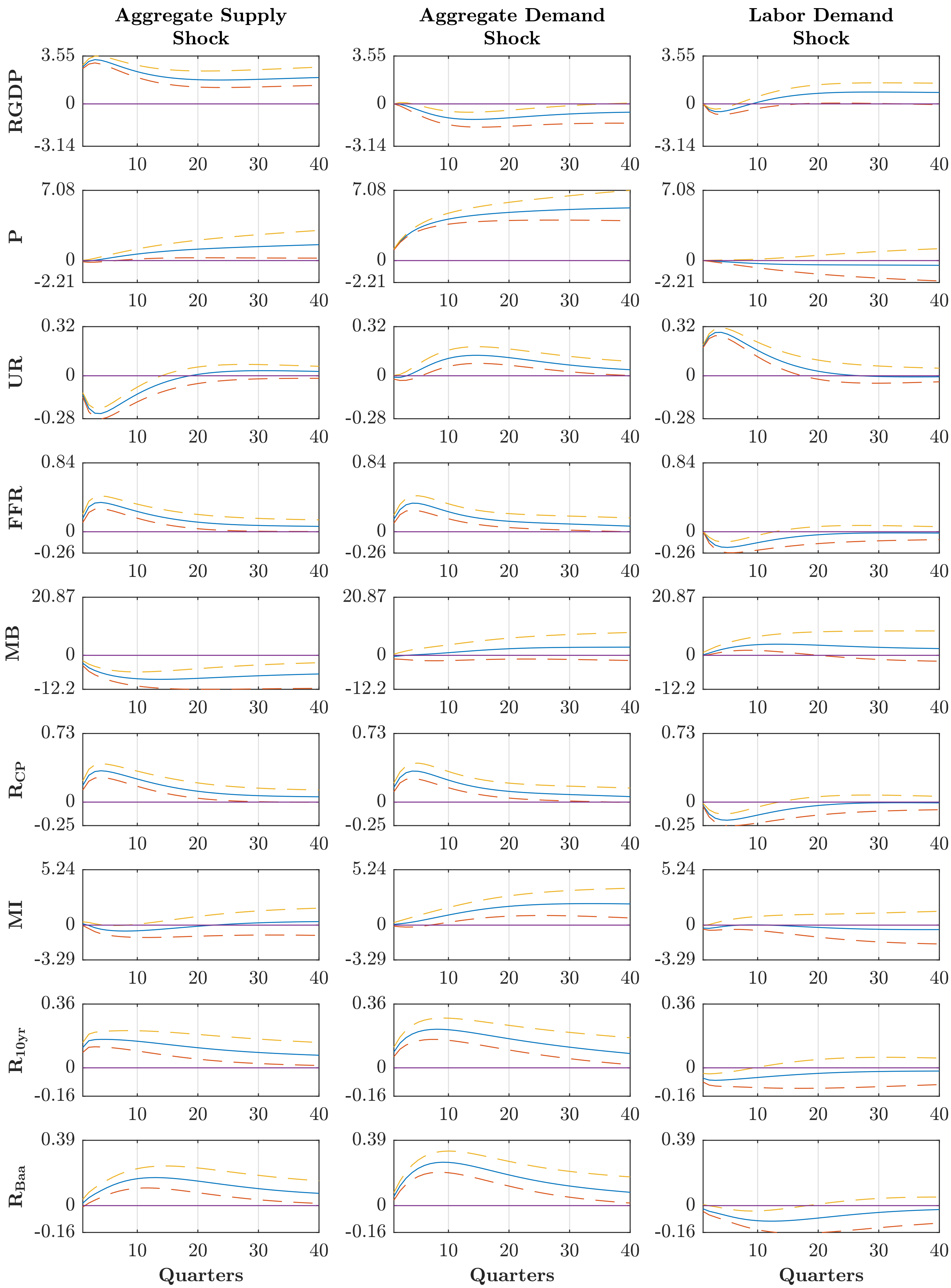
	Horizon	Aggregate Supply	Aggregate Demand	Labor Supply	Monetary Policy	Money Demand	Credit Supply	Credit Demand	Term Premium	Risk Premium
		Shock								
RGDP	1	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.97	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
	4	0.89	0.01	0.01	0.01	0.05	0.00	0.02	0.01	0.01
	8	0.71	0.03	0.01	0.02	0.16	0.01	0.02	0.03	0.02
	20	0.44	0.07	0.08	0.02	0.26	0.04	0.01	0.06	0.02
	40	0.36	0.07	0.13	0.03	0.23	0.08	0.01	0.06	0.03
P	1	0.01	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.01	0.98	0.00	0.00	0.01	0.00	0.00	0.00	0.00
	4	0.01	0.93	0.01	0.00	0.04	0.00	0.00	0.00	0.00
	8	0.01	0.83	0.03	0.00	0.10	0.01	0.01	0.01	0.01
	20	0.03	0.65	0.05	0.01	0.17	0.03	0.02	0.02	0.02
	40	0.05	0.52	0.06	0.02	0.20	0.07	0.02	0.04	0.03
UR	1	0.29	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.36	0.00	0.61	0.01	0.00	0.00	0.00	0.00	0.00
	4	0.39	0.01	0.52	0.03	0.02	0.01	0.01	0.00	0.02
	8	0.33	0.03	0.37	0.04	0.14	0.02	0.01	0.03	0.04
	20	0.19	0.10	0.20	0.04	0.31	0.04	0.01	0.06	0.04
	40	0.16	0.12	0.17	0.04	0.32	0.06	0.01	0.07	0.05
MB	1	0.04	0.00	0.01	0.94	0.00	0.00	0.00	0.00	0.00
	2	0.06	0.01	0.01	0.92	0.00	0.00	0.00	0.00	0.00
	4	0.09	0.01	0.02	0.87	0.00	0.00	0.00	0.00	0.01
	8	0.12	0.01	0.03	0.79	0.01	0.01	0.01	0.01	0.02
	20	0.13	0.02	0.04	0.64	0.03	0.04	0.01	0.05	0.05
	40	0.12	0.03	0.04	0.54	0.05	0.07	0.01	0.08	0.06
FFR	1	0.05	0.04	0.10	0.00	0.81	0.00	0.00	0.00	0.00
	2	0.08	0.07	0.13	0.00	0.71	0.00	0.00	0.01	0.00
	4	0.12	0.11	0.15	0.01	0.57	0.00	0.01	0.02	0.01
	8	0.15	0.14	0.16	0.01	0.45	0.01	0.02	0.04	0.02
	20	0.15	0.14	0.15	0.01	0.35	0.04	0.02	0.10	0.03
	40	0.14	0.14	0.13	0.02	0.32	0.07	0.02	0.11	0.04
R_{CP}	1	0.06	0.04	0.11	0.01	0.69	0.09	0.00	0.00	0.00
	2	0.09	0.07	0.13	0.01	0.61	0.08	0.00	0.00	0.00
	4	0.12	0.11	0.16	0.01	0.50	0.06	0.01	0.01	0.01
	8	0.15	0.15	0.17	0.01	0.40	0.05	0.01	0.03	0.03
	20	0.15	0.15	0.15	0.02	0.31	0.06	0.02	0.09	0.05
	40	0.14	0.14	0.14	0.03	0.29	0.08	0.02	0.11	0.05
MI	1	0.01	0.00	0.01	0.03	0.05	0.02	0.88	0.00	0.00
	2	0.01	0.01	0.01	0.03	0.09	0.03	0.81	0.01	0.00
	4	0.01	0.01	0.01	0.04	0.10	0.04	0.76	0.04	0.00
	8	0.02	0.02	0.01	0.05	0.07	0.03	0.72	0.07	0.01
	20	0.02	0.06	0.02	0.07	0.05	0.04	0.62	0.11	0.03
	40	0.02	0.08	0.03	0.08	0.06	0.06	0.52	0.10	0.04
R_{10yr}	1	0.07	0.04	0.07	0.01	0.16	0.13	0.01	0.51	0.00
	2	0.09	0.07	0.07	0.01	0.16	0.12	0.01	0.48	0.00
	4	0.10	0.11	0.08	0.01	0.18	0.09	0.01	0.42	0.00
	8	0.11	0.15	0.09	0.01	0.22	0.06	0.01	0.34	0.01
	20	0.11	0.18	0.09	0.01	0.26	0.06	0.01	0.25	0.02
	40	0.11	0.17	0.09	0.02	0.26	0.08	0.02	0.22	0.03
R_{Baa}	1	0.01	0.03	0.03	0.10	0.11	0.12	0.00	0.27	0.33
	2	0.01	0.06	0.04	0.09	0.14	0.12	0.00	0.27	0.28
	4	0.03	0.12	0.06	0.06	0.21	0.10	0.01	0.21	0.20
	8	0.05	0.19	0.09	0.04	0.29	0.06	0.01	0.14	0.12
	20	0.10	0.21	0.12	0.02	0.29	0.05	0.02	0.12	0.07
	40	0.10	0.19	0.12	0.03	0.27	0.08	0.02	0.13	0.06

R.2.4. Results for the Non-Recursive Identification: Interest Rate Rule BVAR

Figures R7 to R9 present the IRFs for each variable to a one standard deviation shock under the "Non-Recursive Identification: Interest Rate Rule" identification scheme. Table R4 reports FEVDs. The IRFs and FEVDs are similar to those under the "Recursive Identification: Interest Rate Rule" identification scheme.

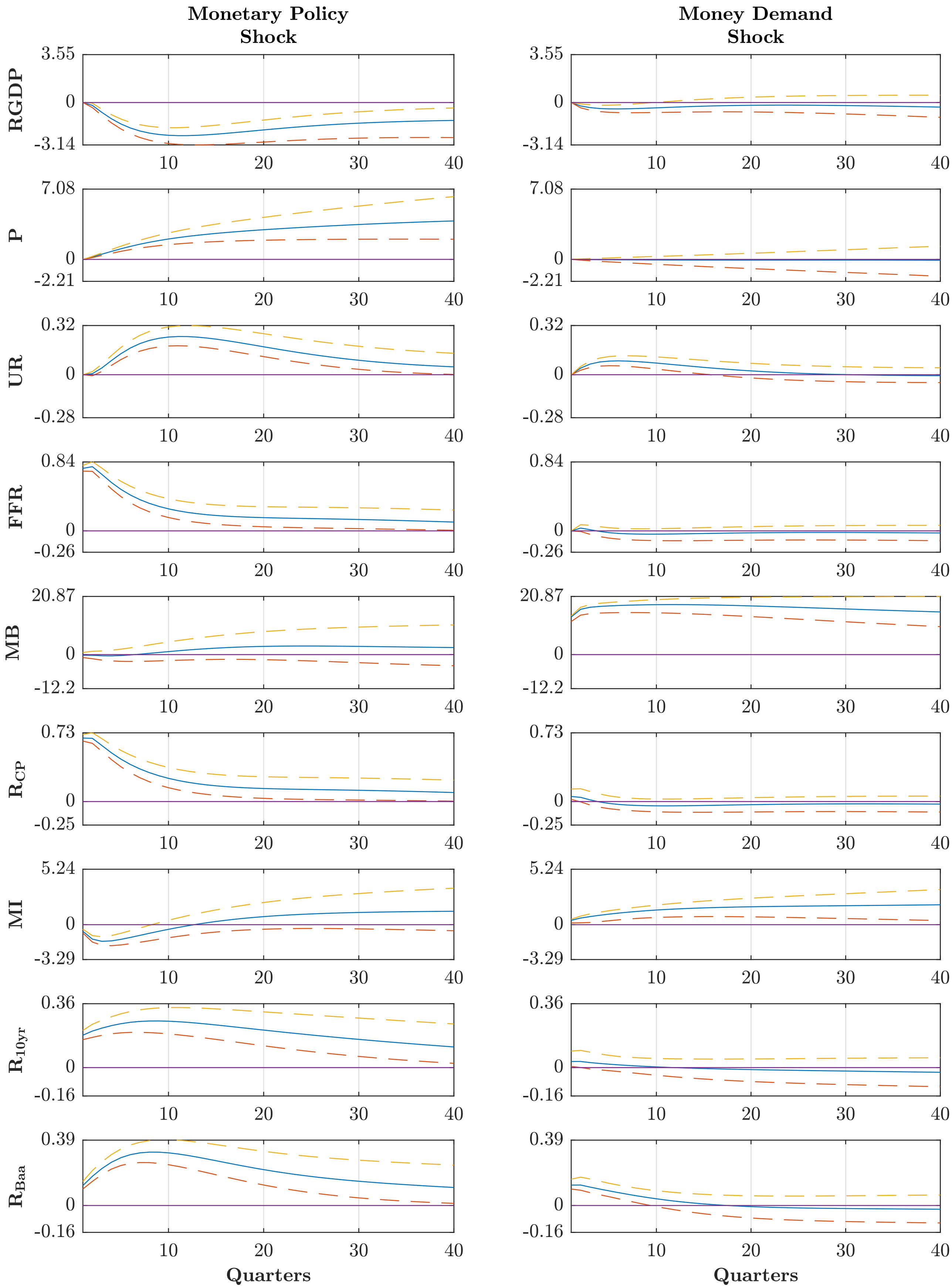
One point is worth mentioning. The same liquidity and price puzzles in the recursive model appear in the non-recursive model. This finding suggests there still is a specification issue lingering in the background. Specifically, the constant coefficient BVAR assumes that an interest rate rule adequately describes U.S. monetary policy over the entire estimation sample. According to Sims and Zha (2006), this is an unreasonable assumption to make.

Figure R7: IRFs to Identified Production Block Shocks — Non-Recursive Identification: Interest Rate Rule BVAR



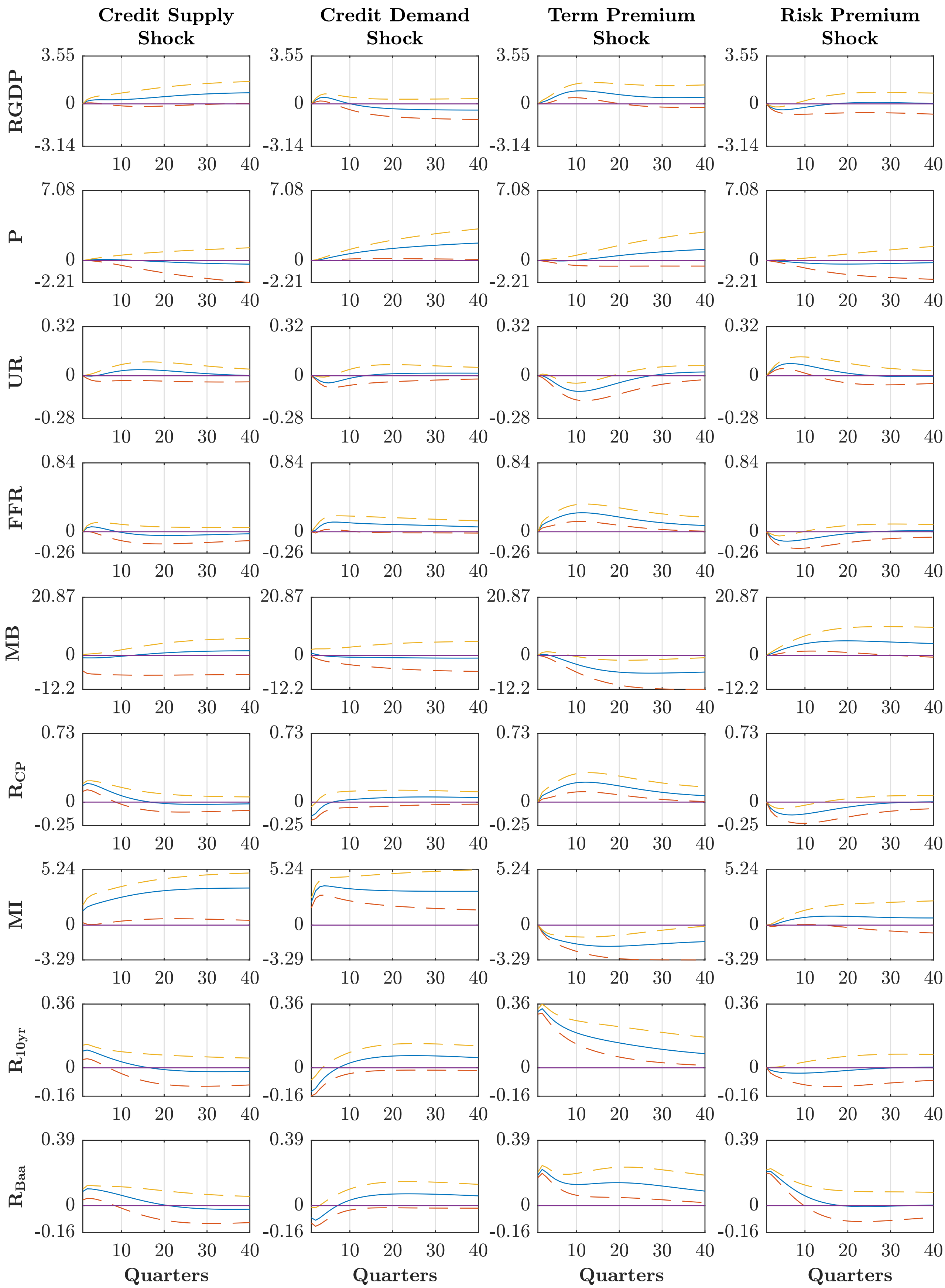
Notes: IRFs to an one standard deviation shock to RGDP, P, and UR. In each graph, the solid line represents the posterior median estimate and the two dashed lines represent the 68% uncertainty bands. Results are based on 500,000 MCMC draws.

Figure R8: IRFs to Identified Monetary Policy Block Shocks — Non-Recursive Identification: Interest Rate Rule BVAR



Notes: IRFs to an one standard deviation shock to the FFR and MB. In each graph, the solid line represents the posterior median estimate and the two dashed lines represent the 68% uncertainty bands. Results are based on 500,000 MCMC draws.

Figure R9: IRFs to Identified Financial Block Shocks — Non-Recursive Identification: Interest Rate Rule BVAR



Notes: IRFs to an one standard deviation shock to R_{CP}, MI, R_{10yr}, and R_{Baa}. In each graph, the solid line represents the posterior median estimate and the two dashed lines represent the 68% uncertainty bands. Results are based on 500,000 MCMC draws.

Table R4: FEVDs of Non-Recursive Identification: Interest Rate Rule BVAR

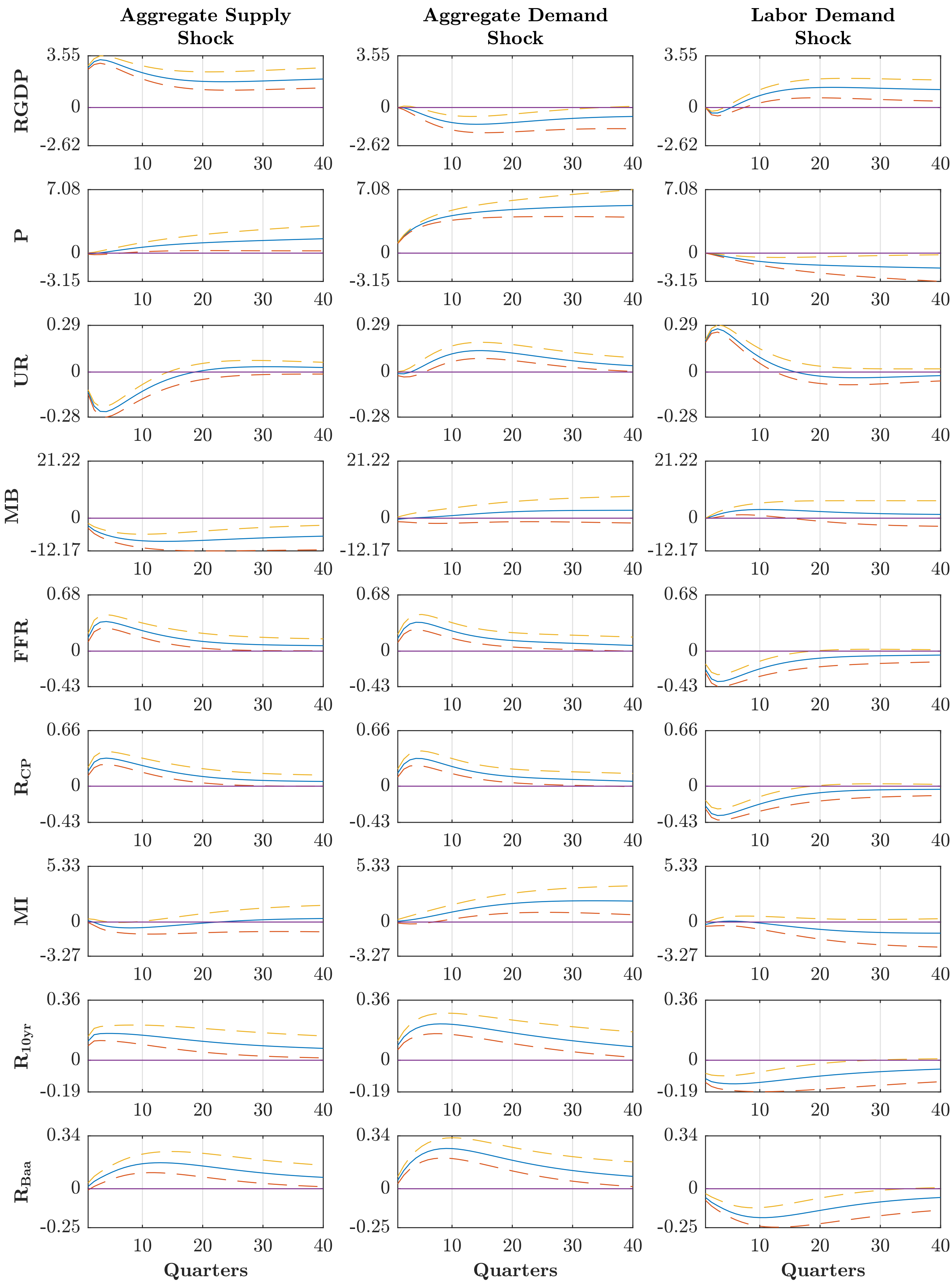
		Shock								
	Horizon	Aggregate Supply	Aggregate Demand	Labor Supply	Monetary Policy	Money Demand	Credit Supply	Credit Demand	Term Premium	Risk Premium
RGDP	1	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.97	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
	4	0.87	0.01	0.02	0.05	0.01	0.01	0.01	0.01	0.01
	8	0.69	0.03	0.02	0.18	0.02	0.01	0.02	0.03	0.02
	20	0.45	0.07	0.03	0.30	0.02	0.03	0.02	0.06	0.02
	40	0.38	0.07	0.07	0.27	0.03	0.05	0.04	0.06	0.03
P	1	0.01	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.01	0.98	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	4	0.01	0.93	0.00	0.05	0.00	0.00	0.00	0.00	0.00
	8	0.01	0.83	0.01	0.11	0.00	0.01	0.01	0.01	0.01
	20	0.03	0.66	0.02	0.19	0.01	0.02	0.03	0.02	0.02
	40	0.05	0.52	0.03	0.22	0.02	0.03	0.05	0.04	0.03
UR	1	0.29	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.36	0.00	0.62	0.00	0.01	0.00	0.00	0.00	0.00
	4	0.37	0.01	0.54	0.02	0.03	0.00	0.01	0.00	0.02
	8	0.29	0.02	0.43	0.13	0.04	0.01	0.01	0.02	0.03
	20	0.17	0.09	0.26	0.30	0.04	0.02	0.02	0.06	0.04
	40	0.14	0.11	0.22	0.31	0.04	0.03	0.03	0.06	0.05
FFR	1	0.05	0.04	0.00	0.91	0.00	0.00	0.00	0.00	0.00
	2	0.09	0.07	0.01	0.82	0.00	0.00	0.00	0.01	0.00
	4	0.13	0.12	0.03	0.69	0.00	0.01	0.01	0.02	0.01
	8	0.16	0.15	0.04	0.54	0.01	0.01	0.02	0.04	0.02
	20	0.16	0.15	0.05	0.42	0.02	0.02	0.04	0.11	0.03
	40	0.14	0.15	0.06	0.38	0.03	0.04	0.05	0.12	0.04
MB	1	0.04	0.00	0.00	0.00	0.84	0.09	0.01	0.00	0.00
	2	0.06	0.01	0.01	0.01	0.83	0.08	0.01	0.00	0.00
	4	0.09	0.01	0.01	0.01	0.79	0.08	0.01	0.00	0.01
	8	0.12	0.01	0.03	0.01	0.72	0.07	0.01	0.01	0.02
	20	0.13	0.02	0.04	0.03	0.59	0.06	0.02	0.05	0.05
	40	0.12	0.03	0.05	0.05	0.50	0.07	0.04	0.08	0.06
R_{CP}	1	0.06	0.05	0.00	0.80	0.02	0.05	0.03	0.00	0.00
	2	0.09	0.08	0.01	0.72	0.01	0.05	0.03	0.00	0.00
	4	0.13	0.12	0.03	0.60	0.01	0.05	0.02	0.01	0.01
	8	0.16	0.16	0.05	0.48	0.01	0.05	0.02	0.04	0.03
	20	0.17	0.16	0.06	0.38	0.02	0.05	0.03	0.10	0.05
	40	0.15	0.15	0.06	0.35	0.03	0.05	0.04	0.12	0.05
MI	1	0.01	0.00	0.01	0.05	0.02	0.24	0.66	0.00	0.00
	2	0.01	0.01	0.01	0.09	0.02	0.20	0.65	0.01	0.00
	4	0.01	0.01	0.01	0.10	0.03	0.18	0.62	0.04	0.00
	8	0.02	0.02	0.01	0.08	0.04	0.19	0.56	0.07	0.01
	20	0.02	0.06	0.02	0.05	0.06	0.22	0.44	0.11	0.03
	40	0.02	0.08	0.03	0.07	0.08	0.23	0.35	0.10	0.04
R_{10yr}	1	0.07	0.05	0.02	0.18	0.02	0.05	0.08	0.53	0.00
	2	0.09	0.07	0.02	0.18	0.02	0.05	0.06	0.50	0.00
	4	0.10	0.11	0.02	0.21	0.02	0.04	0.04	0.44	0.00
	8	0.11	0.16	0.02	0.26	0.01	0.03	0.03	0.35	0.01
	20	0.11	0.19	0.03	0.30	0.02	0.03	0.03	0.26	0.02
	40	0.11	0.18	0.04	0.29	0.03	0.04	0.05	0.22	0.03
R_{Baa}	1	0.01	0.03	0.01	0.12	0.14	0.05	0.04	0.27	0.34
	2	0.01	0.06	0.01	0.16	0.12	0.05	0.04	0.27	0.28
	4	0.03	0.12	0.01	0.24	0.09	0.04	0.03	0.22	0.21
	8	0.06	0.20	0.02	0.33	0.06	0.04	0.02	0.15	0.13
	20	0.10	0.23	0.04	0.34	0.03	0.03	0.03	0.12	0.07
	40	0.11	0.20	0.05	0.31	0.04	0.04	0.05	0.13	0.06

R.2.5. Results for the Non-Recursive Identification: Money Supply Rule BVAR

Figures R10 to R12 present the IRFs for each variable to a one standard deviation shock under the "Non-Recursive Identification: Money Supply Rule" identification scheme. Table R5 reports FEVDs. The IRFs and FEVDs are similar to those under the "Recursive Identification: Money Supply Rule" identification scheme.

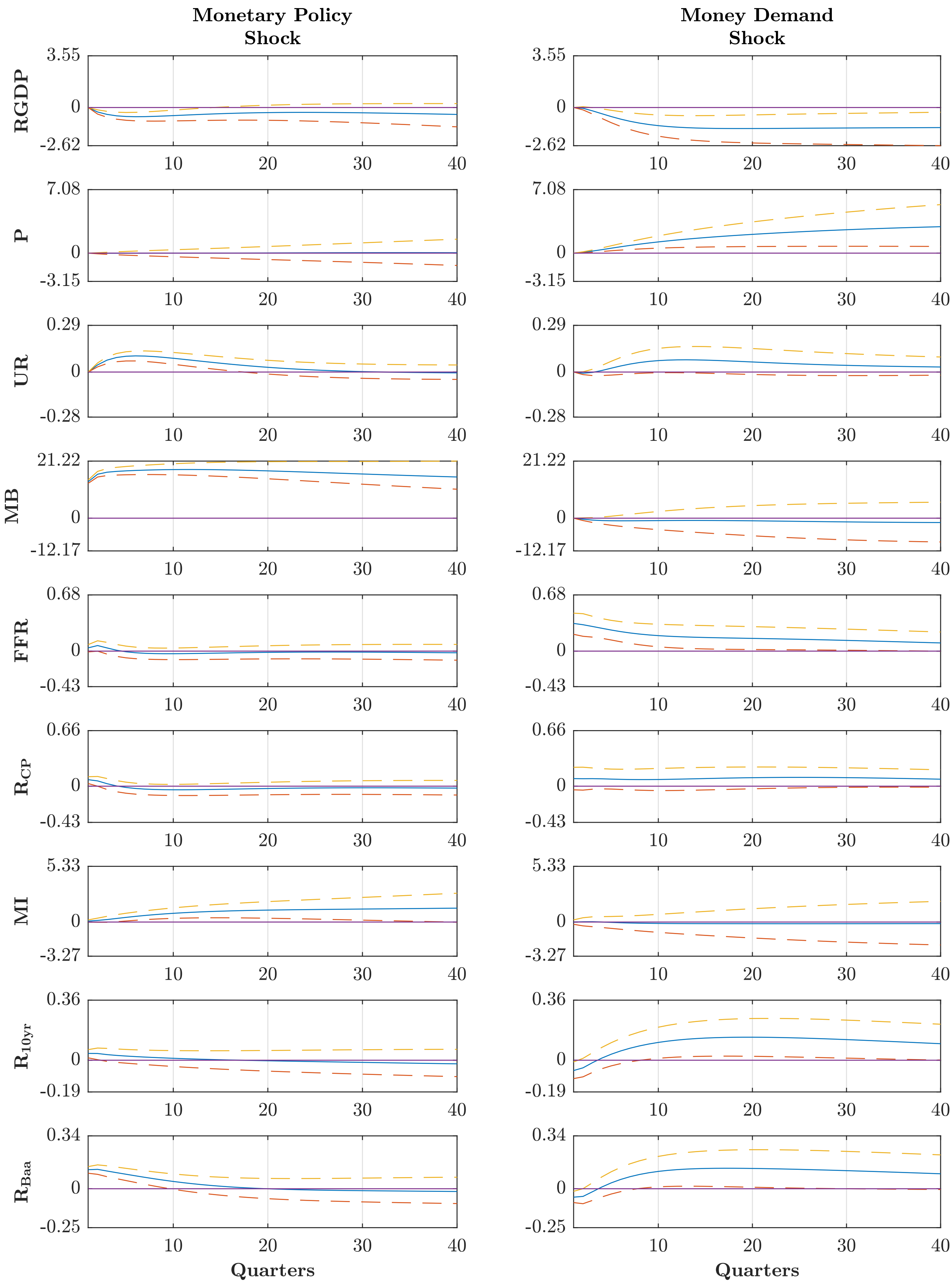
The credit supply and credit demand shocks produce economically interesting IRFs. Both shocks generate the expected *a priori* response of R_{10yr} and R_{Baa}. For example, an exogenous decrease in the supply of credit shifts the credit market curve inward. As the credit market curve shifts inward, both the money and credit markets put downward pressure on the price of long-term private and government securities. As the price these assets falls, the relative price of new production should increase. As a result, new production becomes relatively more expansive. The IRF of RGDP shows the predicted decrease in output.

Figure R10: IRFs to Identified Production Block Shocks — Non-Recursive Identification: Money Supply Rule BVAR



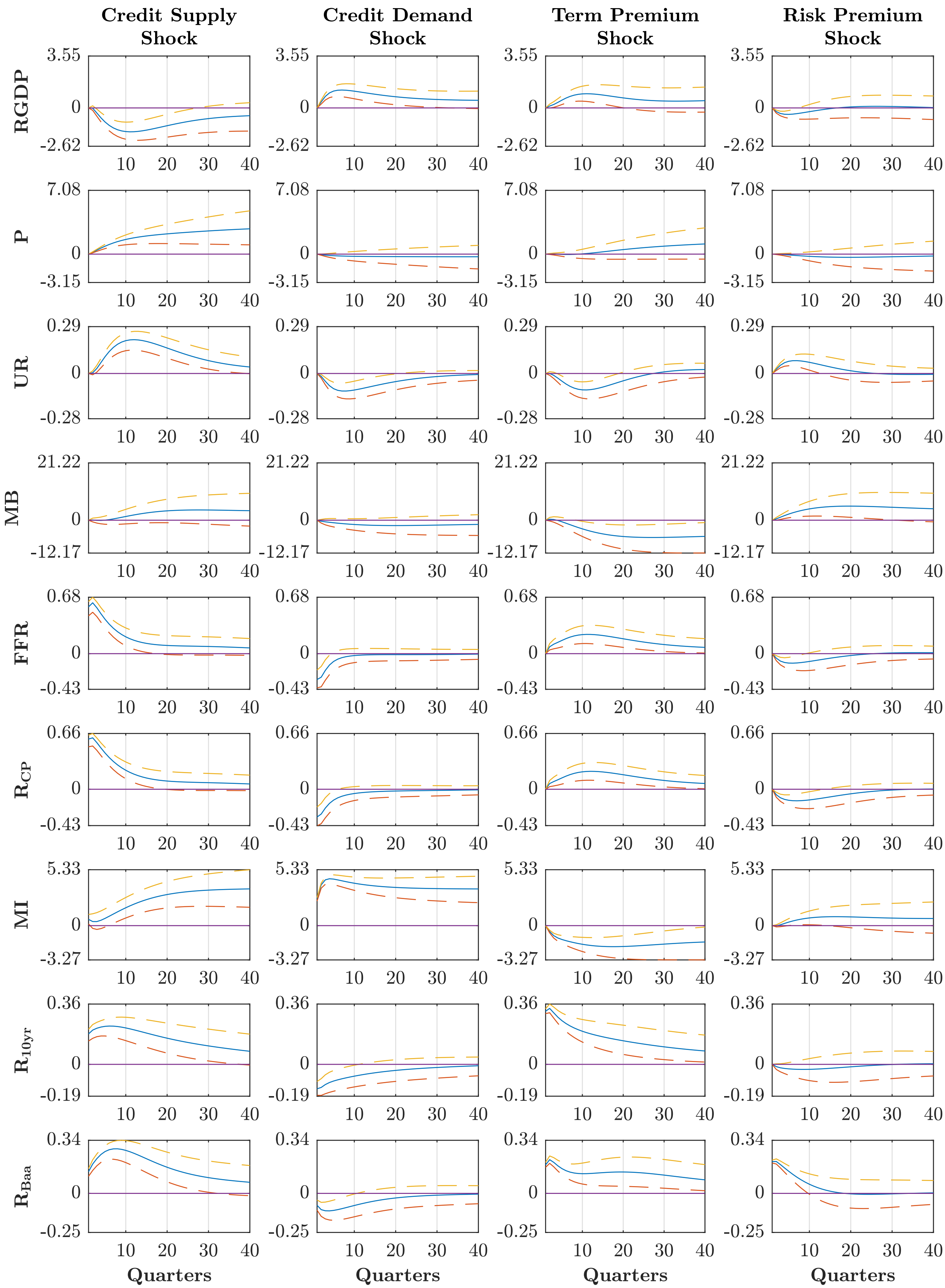
Notes: IRFs to an one standard deviation shock to RGDP, P, and UR. In each graph, the solid line represents the posterior median estimate and the two dashed lines represent the 68% uncertainty bands. Results are based on 500,000 MCMC draws.

Figure R11: IRFs to Identified Monetary Policy Block Shocks — Non-Recursive Identification: Money Supply Rule BVAR



Notes: IRFs to an one standard deviation shock to the MB and FFR. In each graph, the solid line represents the posterior median estimate and the two dashed lines represent the 68% uncertainty bands. Results are based on 500,000 MCMC draws.

Figure R12: IRFs to Identified Financial Block Shocks — Non-Recursive Identification: Money Supply Rule BVAR



Notes: IRFs to an one standard deviation shock to R_{CP}, MI, R_{10yr}, and R_{Baa}. In each graph, the solid line represents the posterior median estimate and the two dashed lines represent the 68% uncertainty bands. Results are based on 500,000 MCMC draws.

Table R5: FEVDs of Non-Recursive Identification: Money Supply Rule BVAR

		Shock								
	Horizon	Aggregate Supply	Aggregate Demand	Labor Supply	Monetary Policy	Money Demand	Credit Supply	Credit Demand	Term Premium	Risk Premium
RGDP	1	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.97	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00
	4	0.88	0.01	0.01	0.02	0.01	0.02	0.04	0.01	0.01
	8	0.70	0.03	0.01	0.02	0.04	0.07	0.08	0.03	0.02
	20	0.44	0.07	0.07	0.02	0.12	0.12	0.08	0.06	0.02
	40	0.36	0.07	0.12	0.03	0.16	0.11	0.06	0.06	0.03
P	1	0.01	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.01	0.98	0.00	0.00	0.00	0.01	0.00	0.00	0.00
	4	0.01	0.93	0.01	0.00	0.01	0.03	0.01	0.00	0.00
	8	0.01	0.83	0.02	0.00	0.04	0.07	0.01	0.01	0.01
	20	0.03	0.65	0.04	0.01	0.10	0.11	0.01	0.02	0.02
	40	0.05	0.52	0.06	0.02	0.14	0.13	0.02	0.04	0.03
UR	1	0.29	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.36	0.00	0.61	0.01	0.00	0.00	0.00	0.00	0.00
	4	0.38	0.01	0.51	0.04	0.00	0.01	0.02	0.00	0.02
	8	0.32	0.03	0.37	0.05	0.02	0.09	0.05	0.03	0.04
	20	0.19	0.10	0.20	0.05	0.07	0.22	0.07	0.06	0.04
	40	0.16	0.12	0.17	0.05	0.09	0.23	0.06	0.07	0.05
MB	1	0.04	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00
	2	0.06	0.01	0.00	0.93	0.00	0.00	0.00	0.00	0.00
	4	0.09	0.01	0.01	0.88	0.00	0.00	0.00	0.00	0.01
	8	0.12	0.01	0.02	0.80	0.01	0.01	0.01	0.01	0.02
	20	0.13	0.02	0.03	0.65	0.03	0.02	0.01	0.05	0.05
	40	0.12	0.03	0.03	0.55	0.06	0.05	0.02	0.08	0.06
FFR	1	0.05	0.04	0.07	0.00	0.20	0.47	0.16	0.00	0.00
	2	0.08	0.07	0.10	0.01	0.16	0.44	0.13	0.01	0.00
	4	0.12	0.11	0.13	0.01	0.14	0.37	0.09	0.02	0.01
	8	0.15	0.14	0.14	0.01	0.13	0.30	0.06	0.04	0.02
	20	0.15	0.15	0.13	0.01	0.14	0.23	0.05	0.10	0.03
	40	0.14	0.14	0.12	0.02	0.16	0.21	0.05	0.12	0.04
R_{CP}	1	0.06	0.05	0.08	0.01	0.05	0.56	0.20	0.00	0.00
	2	0.09	0.07	0.11	0.01	0.04	0.51	0.16	0.00	0.00
	4	0.13	0.11	0.14	0.01	0.04	0.44	0.12	0.01	0.01
	8	0.15	0.15	0.15	0.01	0.04	0.36	0.08	0.04	0.03
	20	0.16	0.15	0.14	0.02	0.06	0.27	0.06	0.10	0.05
	40	0.14	0.14	0.12	0.03	0.09	0.25	0.06	0.11	0.05
MI	1	0.01	0.00	0.01	0.00	0.01	0.08	0.89	0.00	0.00
	2	0.01	0.01	0.01	0.00	0.01	0.05	0.90	0.01	0.00
	4	0.01	0.01	0.01	0.01	0.01	0.05	0.87	0.04	0.00
	8	0.02	0.02	0.01	0.02	0.01	0.06	0.78	0.07	0.01
	20	0.02	0.06	0.02	0.03	0.03	0.16	0.54	0.11	0.03
	40	0.02	0.09	0.04	0.05	0.05	0.22	0.39	0.10	0.04
R_{10yr}	1	0.07	0.04	0.06	0.01	0.03	0.16	0.11	0.51	0.00
	2	0.09	0.07	0.06	0.01	0.03	0.16	0.10	0.49	0.00
	4	0.10	0.11	0.07	0.01	0.02	0.18	0.08	0.43	0.00
	8	0.11	0.16	0.08	0.01	0.03	0.20	0.07	0.34	0.01
	20	0.11	0.19	0.08	0.01	0.09	0.20	0.05	0.25	0.02
	40	0.11	0.17	0.08	0.03	0.13	0.19	0.04	0.22	0.03
R_{Baa}	1	0.01	0.03	0.03	0.12	0.03	0.15	0.05	0.26	0.33
	2	0.01	0.06	0.03	0.10	0.03	0.17	0.06	0.26	0.27
	4	0.03	0.12	0.05	0.08	0.02	0.22	0.07	0.21	0.20
	8	0.05	0.19	0.08	0.05	0.04	0.26	0.06	0.14	0.12
	20	0.10	0.22	0.11	0.03	0.08	0.24	0.04	0.12	0.07
	40	0.10	0.19	0.11	0.04	0.12	0.21	0.04	0.13	0.06

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