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RESOLVING THE LIQUIDITY PUZZLE

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This paper considers a nonborrowed-monetary-base VAR and a targets and instrument framework favored by the monetarists to resolve the puzzles thrown up by monetary VAR studies. The results show that nonborrowed-monetary-base shocks produce responses consistent with a priori expectations about the effects of monetary policy on interest rates, prices, and output.

Keywords: Nonborrowed-Monetary-Base Shocks; VAR Model; Monetary Aggregates

1. INTRODUCTION

The monetary VAR literature has tried on various variables as indicators of the stance of monetary policy and has produced results that are not always consistent with traditional monetarist or Keynesian analysis. For example, in federal-fund. VAR's, monetary-policy shocks produce results consistent with a priori expectations about the effects of monetary policy on output, but also produce a price puzzle—increases in the federal-funds rate (that is, contractionary monetary policy) produces increases, rather than decreases, in prices.

Similarly, in VAR's that identify policy shocks with innovations in Federal Reserve balance-sheet measures of money, policy shocks produce results consistent with common priors about the qualitative effects of monetary policy on output and prices, but produce a liquidity puzzle—expansionary monetary policy increases, rather than decreases, interest rates. Moreover, most such money measures explain a very small percentage of the forecast error variance of output and do not Granger-cause output, even in single-equation frameworks.

There have been many attempts to unravel the substantive puzzles thrown up by the VAR studies. For example, Eichenbaum's (1992) solution to the price puzzle is to use a nonborrowed-reserves VAR, whereas Sims' (1992) solution to the same puzzle is to extend his federal-funds VAR by including a measure of commodity prices as a proxy for the Fed's information about inflation. In general, as more variables are introduced and as the VAR specification is refined [fished, in the terminology of Cochrane (1995)], monetary VAR's produce results that capture reasonable monetary dynamics.

We attempt to resolve the liquidity and price puzzles by considering a nonborrowed-monetary-base VAR and a targets and instrument framework favored by the monetarists. We use the nonborrowed monetary base (instead of nonborrowed

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reserves) because it is tied to open-market operations and is directly under the control of the Fed. Moreover, in the spirit of Christiano et al. (1996) and Leeper et al. (1996), we include multiple monetary aggregates in the analysis to explicitly take into account the relationship between operating targets and intermediate targets as well as the relationship between intermediate targets and the variables that constitute the Fed's ultimate objectives.

The paper is organized as follows. Section 2 examines nonborrowed-monetary-base shocks in a simple five-variable VAR. Section 3 refines the specification by adding a monetary aggregate to the VAR and examines the performance of 12 such aggregates, to deal with anomalies that arise because of different methods of aggregation. Section 4 closes with a brief summary and conclusions.

2. A SIMPLE NONBORROWED-MONETARY-BASE VAR

We start by using the nonborrowed monetary base to identify monetary-policy shocks and investigate the dynamic effects of such shocks in a simple unrestricted five-variable VAR, consisting of the (logged) industrial production index (Y), the price level (P), commodity prices (PC), the nonborrowed monetary base ($NBMB$), and the interest rate (R), in that order—reflecting the standard assumption that, when setting the monetary base, the Fed sees the price level and aggregate output. We fit the VAR to monthly data (to be consistent with recent studies) over the period 1960:1–1996:6, measuring the interest rate by the federal-funds rate, the price level by the log of the consumer price index, and the output by the log of the industrial production index. We ignore low-frequency variables (such as linear trends) and we set the lag length equal to 13.

Table 1 reports p-values of Granger-causality F-tests and five-year forecast-error-variance decompositions. In particular, p-values are for the null hypothesis of no causality from the variable indicated in the column heading to the variable indicated in the row heading. Clearly, the hypothesis of no causality from the nonborrowed monetary base to industrial production can be rejected at conventional significance levels. The hypothesis, however, of no causality from the federal-funds rate to industrial production cannot be rejected. Note that, because the VAR is run in (logged) levels and the coefficients have nonstandard unit root distributions, the marginal significance levels are not exact. Nevertheless, they are still useful for relative comparisons.

The forecast-error-variance decompositions (in Table 1), however, show that innovations in the nonborrowed monetary base explain a very small percentage of the variance of output (about 3%), whereas innovations in the federal-funds rate explain a very high percentage of that variance, in fact, about 45%. Hence, on the basis of significance levels, the nonborrowed monetary base performs better than the federal-funds rate, whereas, according to the variance decomposition metric, the federal-funds rate outperforms the nonborrowed monetary base.

Solid lines in Figure 1 show the impulse response functions (over an expanse of five years) for each of the five variables. Dashed lines denote ± 1-standard-deviation bands, computed using the Monte Carlo method described in RATS with 500

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Table 1. Unrestricted VAR results for $\{Y, P, PC, NBMB, R\}$ model[a]

	A. Marginal significance levels for exclusion of lags					B. Forecast-error-variance decomposition (60-month horizon)				
Equation	*Y*	*P*	*PC*	*NBMB*	*R*	*Y*	*P*	*PC*	*NBMB*	*R*
Y	0.000	0.049	0.001	0.047	0.326	31.302	7.401	12.343	3.305	45.649
P	0.009	0.000	0.000	0.001	0.000	3.883	15.302	46.534	3.334	30.947
PC	0.361	0.585	0.000	0.044	0.063	1.139	3.434	55.316	4.212	35.897
NBMB	0.041	0.181	0.731	0.000	0.001	2.960	5.210	11.490	54.741	25.626
R	0.042	0.690	0.006	0.343	0.000	16.715	1.635	40.282	3.030	38.338

[a] Sample period, monthly data: 1960:1–1996:6. The model has been estimated with 13 monthly lags. Low p-values imply strong marginal predictive power.

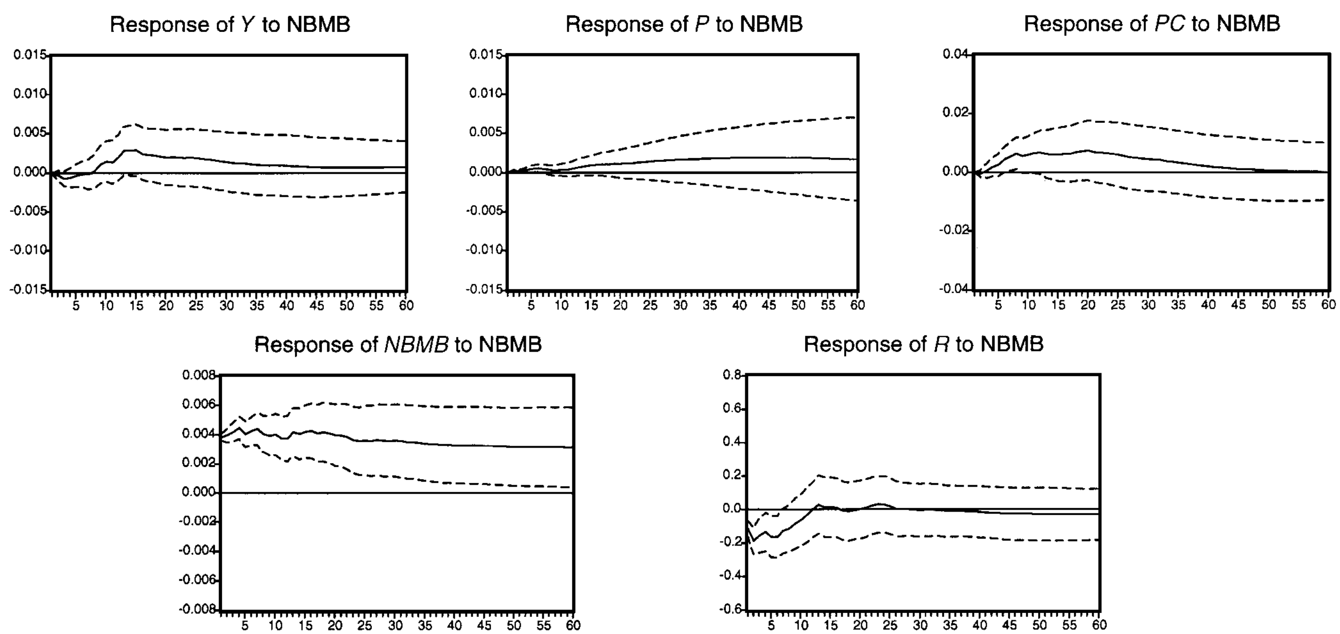

Figure 1. Impulse responses for $\{Y, P, PC, NBMB, R\}$ model.

draws from the posterior distribution of the VAR coefficients and the covariance matrix of the innovations. In general, the qualitative pattern exhibited by output, the price level, commodity prices, and the federal-funds rate, following a positive innovation in the nonborrowed monetary base, is consistent with our priors—there is a strong and statistically significant liquidity effect and plausible effects on prices and output.

3. MULTIPLE-MONETARY-AGGREGATE VAR'S

We have completely ignored the relationship between operating targets (such as the nonborrowed monetary base) and intermediate targets (such as monetary aggregates), as well as the relationship between intermediate targets and the variables that constitute the Fed's ultimate objectives. To account for such relationships we extend the simple nonborrowed-monetary-base VAR by including a monetary aggregate and search for relationships over 12 monetary aggregates in an attempt to deal with problems that arise because of different definitions of money.

The measures employed are official simple-sum aggregates [Barnett's (1980); see also Barnett et al. (1992)] monetary-services indices (also known as Divisia aggregates), and Rotemberg's (1991) [see also Poterba et al. (1995)] currency-equivalent (CE) indices. The data were obtained from the St. Louis MSI database, maintained by the Federal Reserve Bank of St. Louis as a part of the Bank's Federal Reserve Economic Database (FRED) [see Anderson et al. (1996a,b) for details regarding the construction of the Divisia and CE aggregates and related data].

In Table 2, we report marginal significance levels for exclusion of lags in the industrial production equation as well as forecast-error-variance decompositions of industrial production for 12 VAR's, one for each monetary aggregate. Clearly, the hypothesis that the federal-funds-rate lags can be excluded from the industrial production equation is rejected and, similarly, the hypothesis that nonborrowed-monetary-base lags can be excluded from that equation is rejected, in each of the 12 VAR's. Moreover, the forecast-error-variance decompositions (in Table 2, panel B) show that, in the Sum M1, Divisia M1, and Divisia M2 VAR's, innovations in the nonborrowed monetary base and the corresponding monetary aggregate account for a large percentage of the variance of output (about 50% in the case of the Divisia M1 VAR) whereas federal-funds-rate innovations account for a very small percentage of that variance (about 9% in the case of the Divisia M1 VAR). In fact, on the basis of significance levels and the variance decomposition metric, Divisia M1 produces the best results, followed by Divisia M2 and Sum M1.

The impulse response functions relating to the nonborrowed monetary base are presented in Figures 2–13 for 12 VAR's (one for each monetary aggregate) ordered as $\{Y, P, PC, NBMB, M, R\}$, where M is a monetary aggregate. For example, Figures 2–5 present the impulse response functions relating to the nonborrowed monetary base for each of four simple-sum (Sum M1, Sum M2, Sum M3, and Sum L) VAR's, and Figures 6–9 and 10–13 present similar results for the Divisia and CE VAR's, respectively.

TABLE 2. Marginal significance levels for Granger Causality and forecast-error-variance decompositions of industrial production[a]

	A. Marginal significance levels for exclusion of lags in industrial production equation						B. Forecast-error-variance decomposition of industrial production (60-month horizon)					
VAR with	*Y*	*P*	*PC*	*NBMB*	*M*	*R*	*Y*	*P*	*PC*	*NBMB*	*M*	*R*
Sum M1	0.000	0.004	0.002	0.032	0.456	0.010	27.628	4.107	10.826	10.234	35.089	12.115
Sum M2	0.000	0.006	0.004	0.022	0.052	0.009	14.865	12.588	19.310	2.531	27.609	23.097
Sum M3	0.000	0.004	0.002	0.007	0.446	0.006	22.829	7.896	16.658	4.538	17.843	30.235
Sum L	0.000	0.007	0.004	0.004	0.034	0.004	27.540	6.043	12.058	5.699	7.605	41.055
Divisia M1	0.000	0.011	0.003	0.016	0.102	0.007	25.071	5.928	10.241	11.459	38.740	8.559
Divisia M2	0.000	0.008	0.002	0.018	0.228	0.010	0.713	4.085	10.527	18.785	28.040	37.850
Divisia M3	0.000	0.009	0.005	0.028	0.711	0.014	22.160	8.991	20.355	3.005	17.671	27.817
Divisia L	0.000	0.030	0.006	0.018	0.154	0.025	26.509	5.546	16.985	3.873	10.410	36.675
CE M1	0.000	0.010	0.002	0.022	0.313	0.009	28.422	8.638	11.128	7.438	5.479	38.896
CE M2	0.000	0.005	0.002	0.008	0.201	0.018	28.679	7.225	15.472	1.884	8.766	37.974
CE M3	0.000	0.008	0.001	0.009	0.791	0.017	28.388	6.925	15.094	2.055	16.209	31.328
CE L	0.000	0.009	0.002	0.016	0.274	0.004	28.511	6.990	13.738	2.293	16.789	31.679

[a] Sample period, monthly data: 1960:1–1996:6. Models have been estimated with 13 lags. Low *p*-values imply strong marginal predictive power.

Shock to NBMB

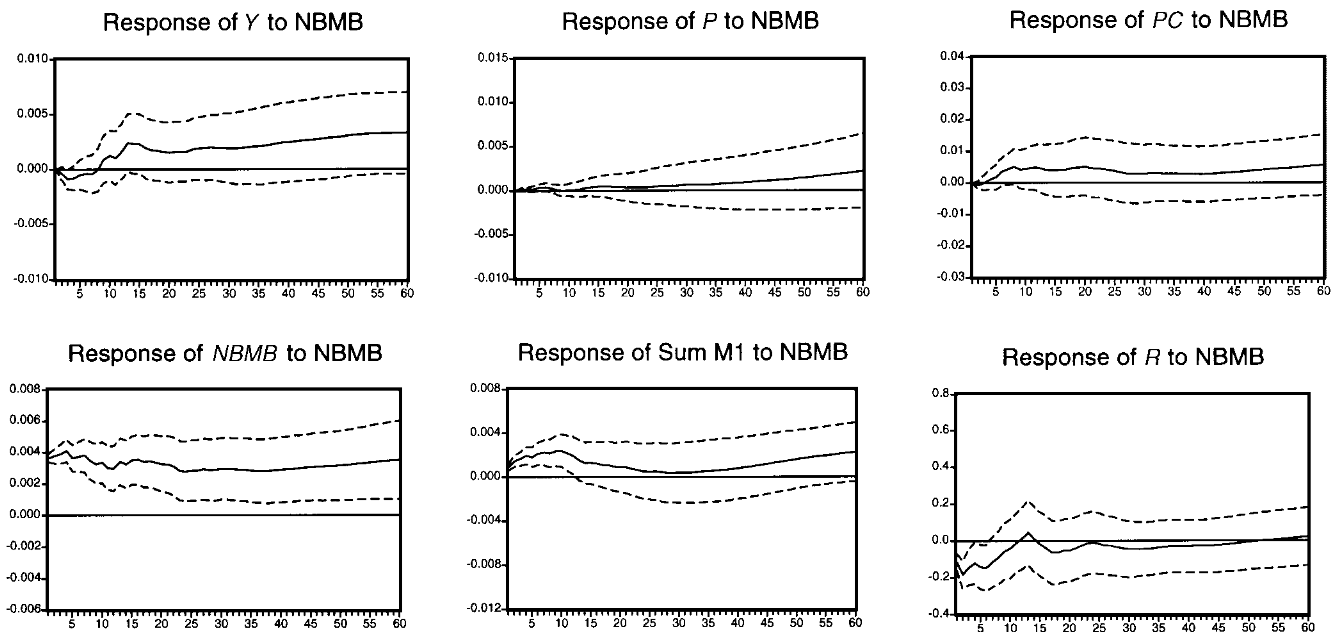

Figure 2. Impulse responses for {*Y*, *P*, *PC*, *NBMB*, Sum M1, *R*} model.

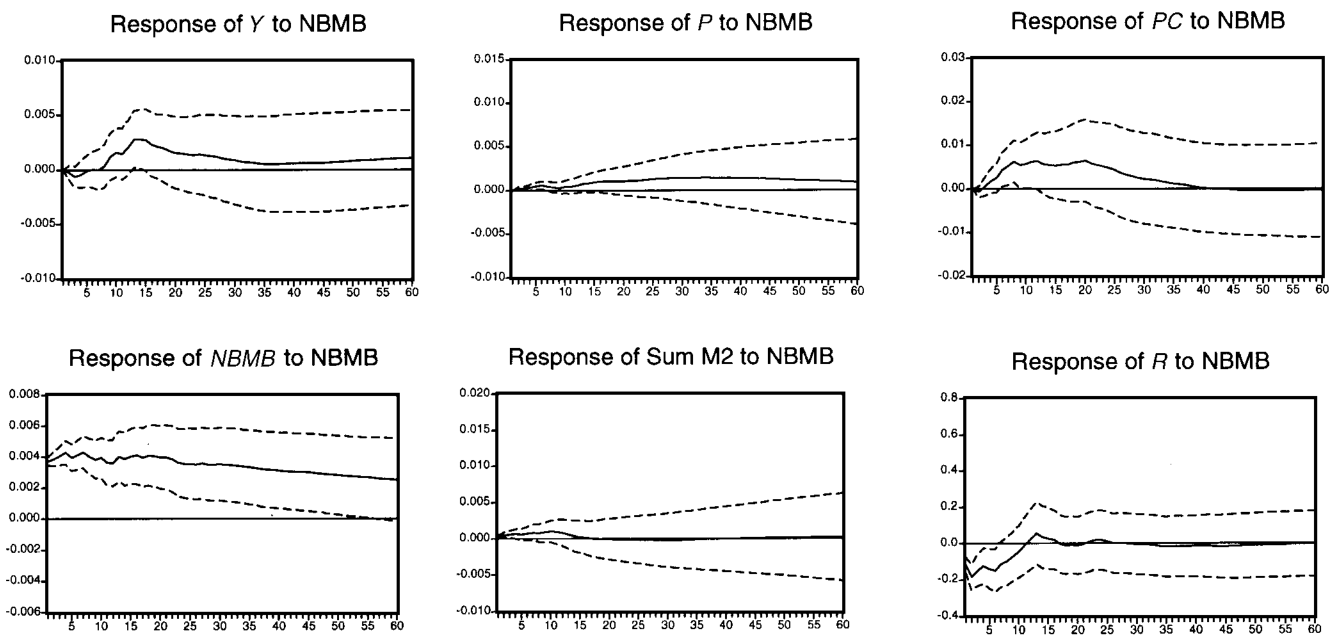

FIGURE 3. Impulse responses for {Y, P, PC, $NBMB$, Sum M2, R} model.

Shock to NBMB

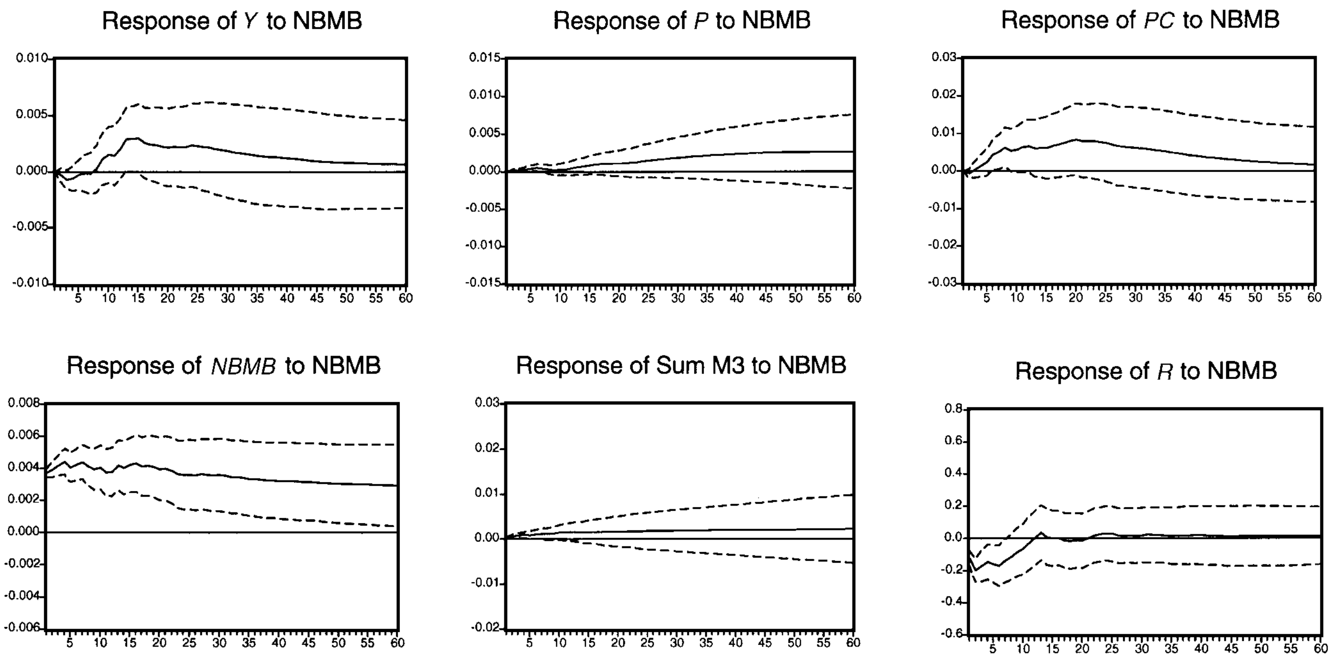

Figure 4. Impulse responses for {Y, P, PC, $NBMB$, Sum M3, R} model.

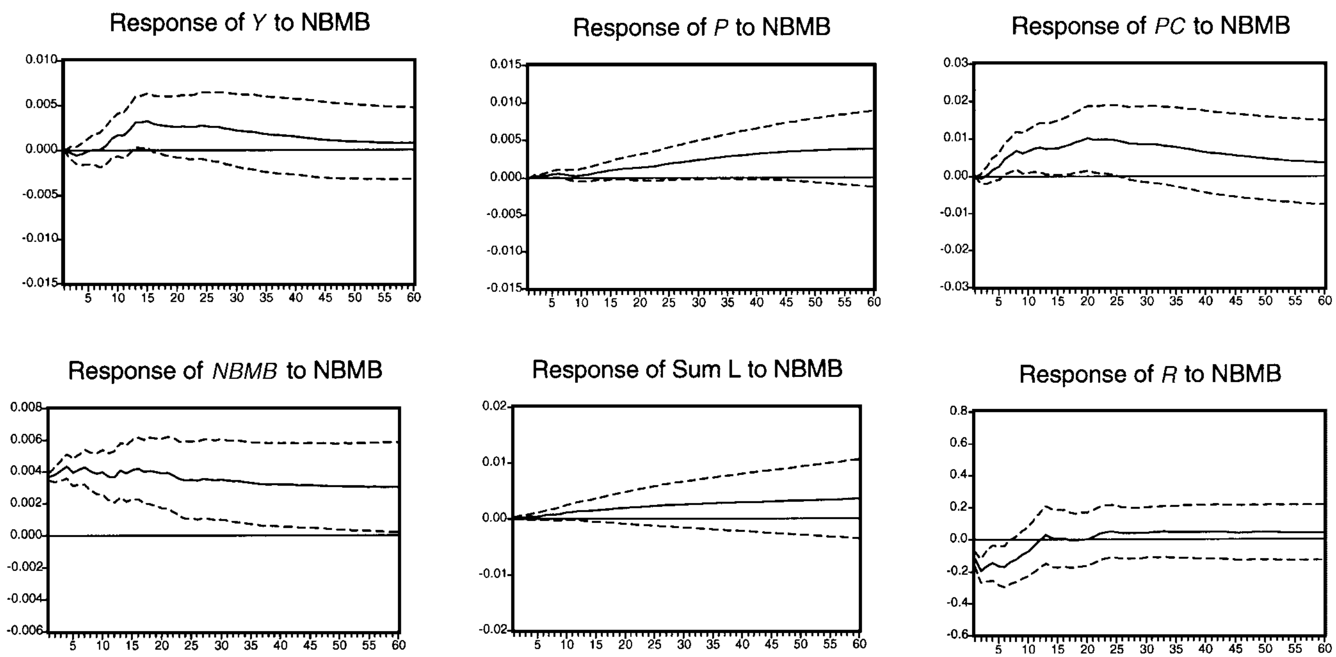

FIGURE 5. Impulse responses for {*Y*, *P*, *PC*, *NBMB*, Sum L, *R*} model.

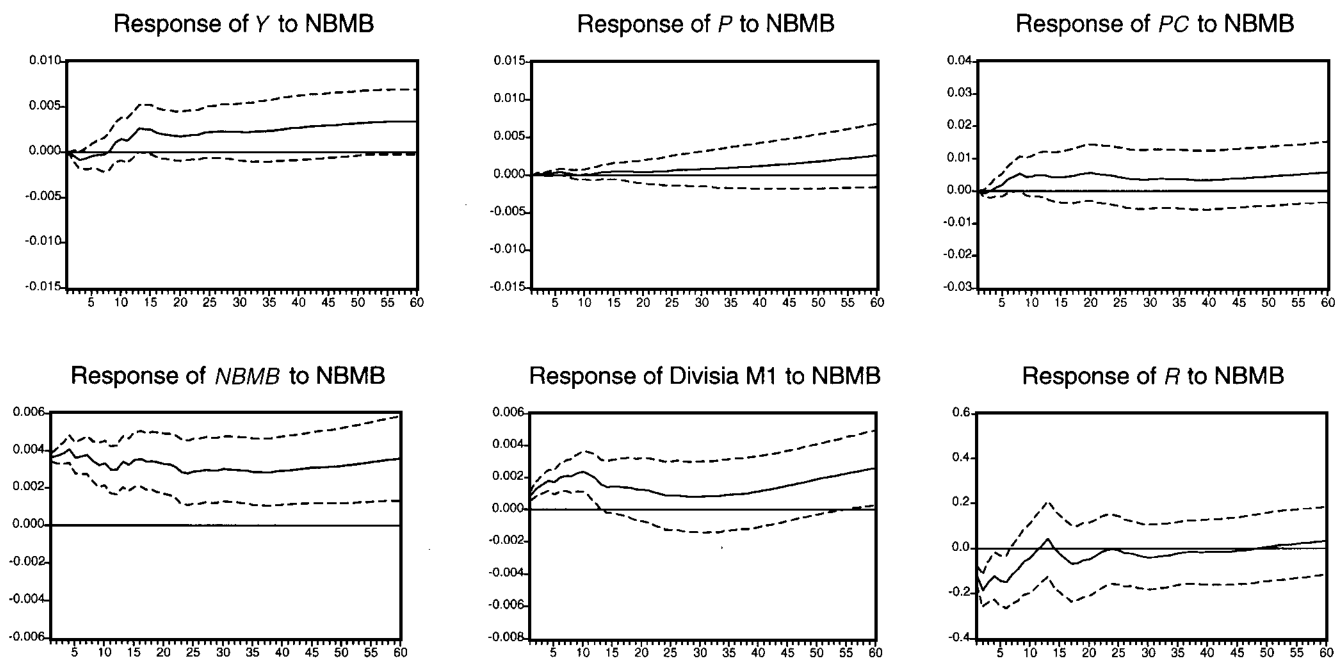

FIGURE 6. Impulse responses for $\{Y, P, PC, NBMB$, Divisia M1, $R\}$ model.

Shock to NBMB

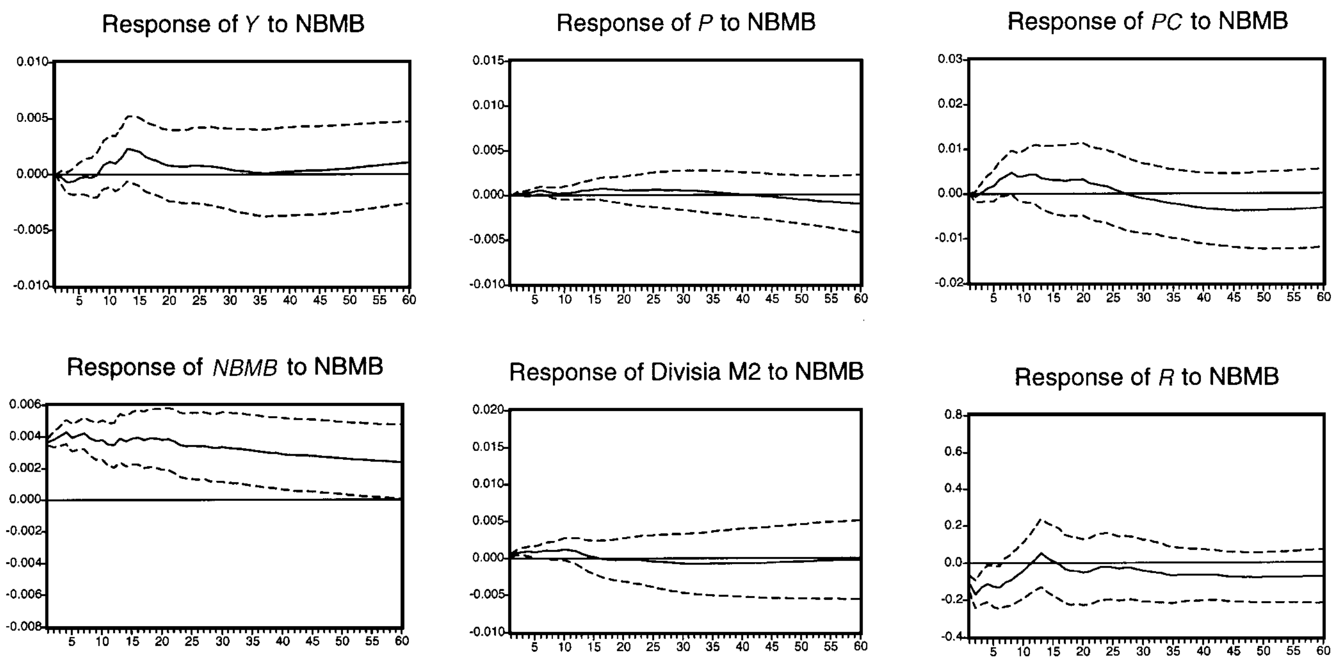

FIGURE 7. Impulse responses for {Y, P, PC, $NBMB$, Divisia M2, R} model.

Shock to NBMB

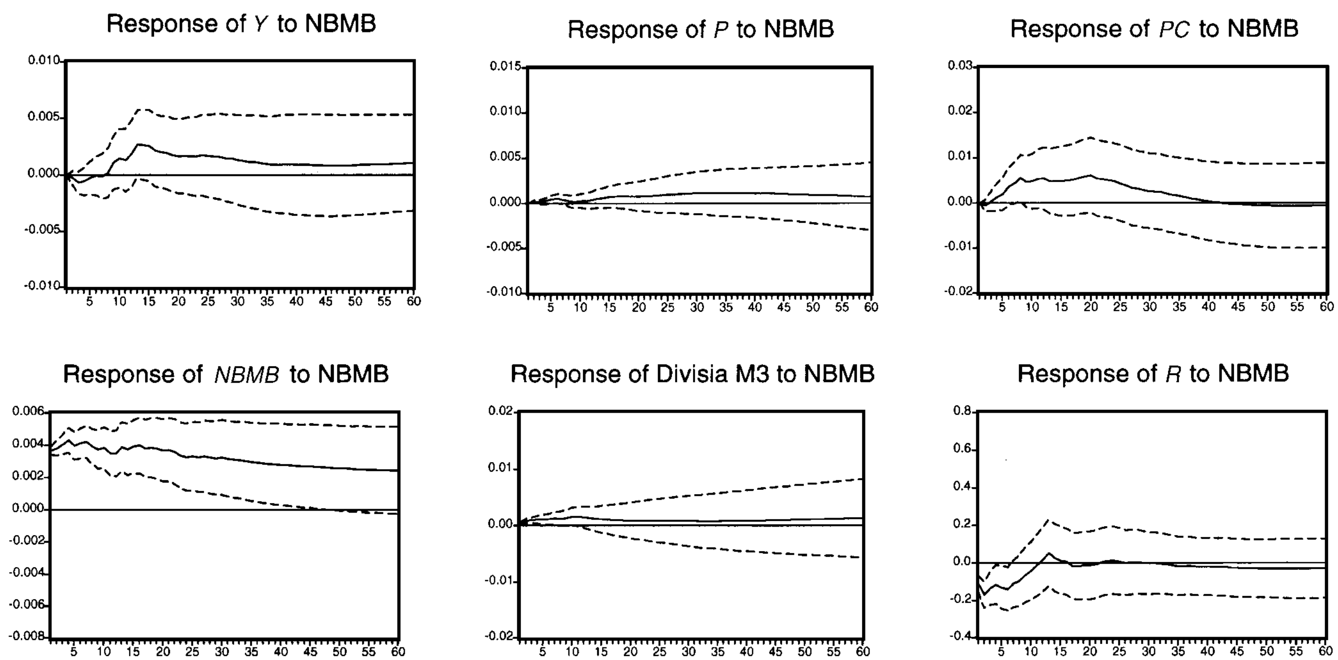

FIGURE 8. Impulse responses for {Y, P, PC, $NBMB$, Divisia M3, R} model.

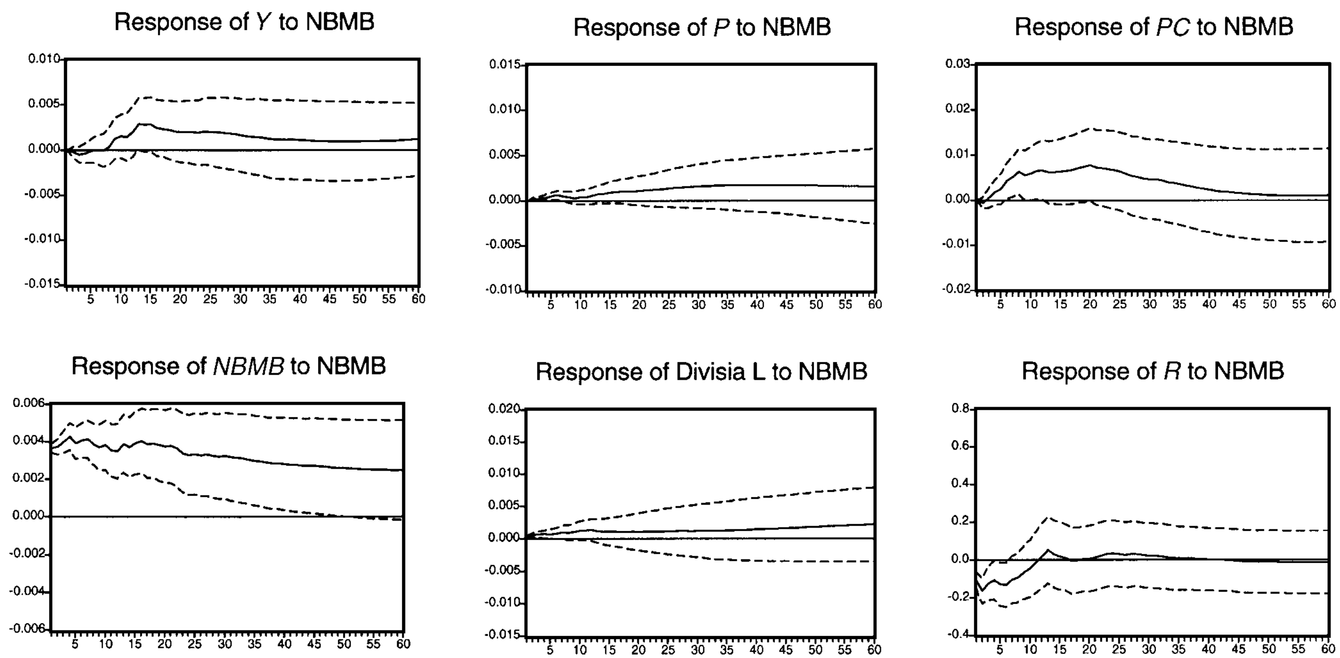

Figure 9. Impulse responses for {Y, P, PC, $NBMB$, Divisia L, R} model.

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Shock to NBMB

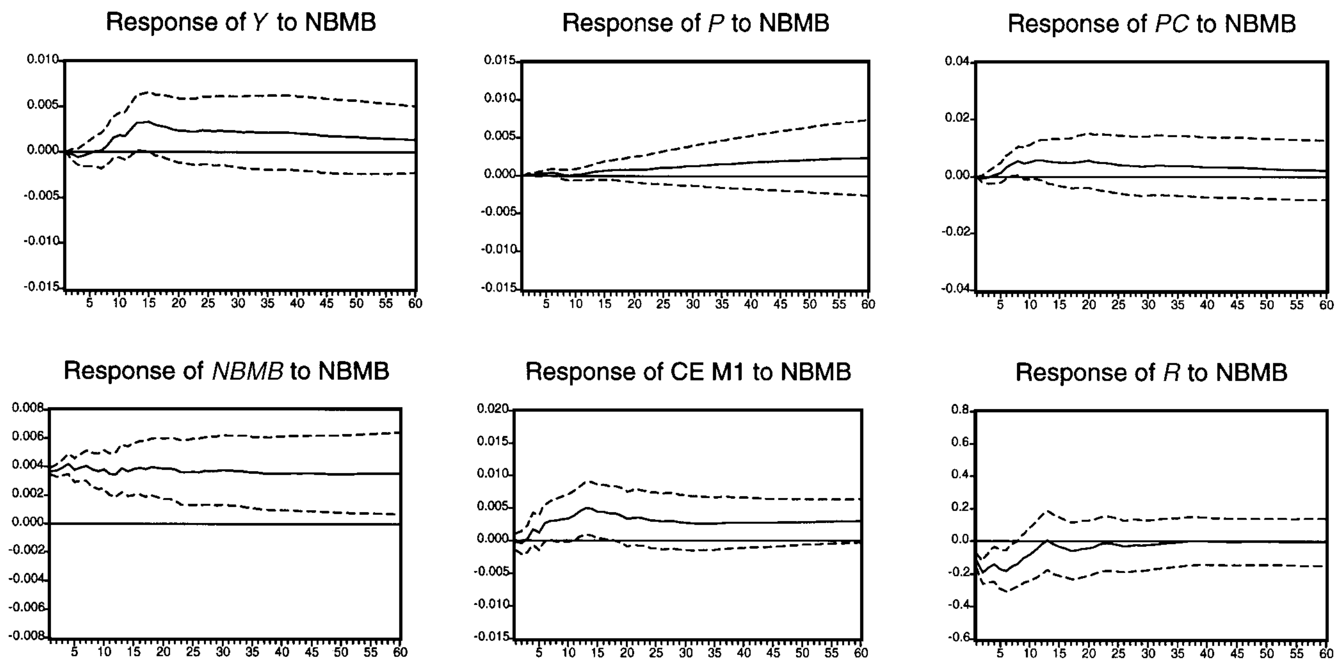

FIGURE 10. Impulse responses for {*Y*, *P*, *PC*, *NBMB*, Currency Equivalent M1, *R*} model.

Shock to NBMB

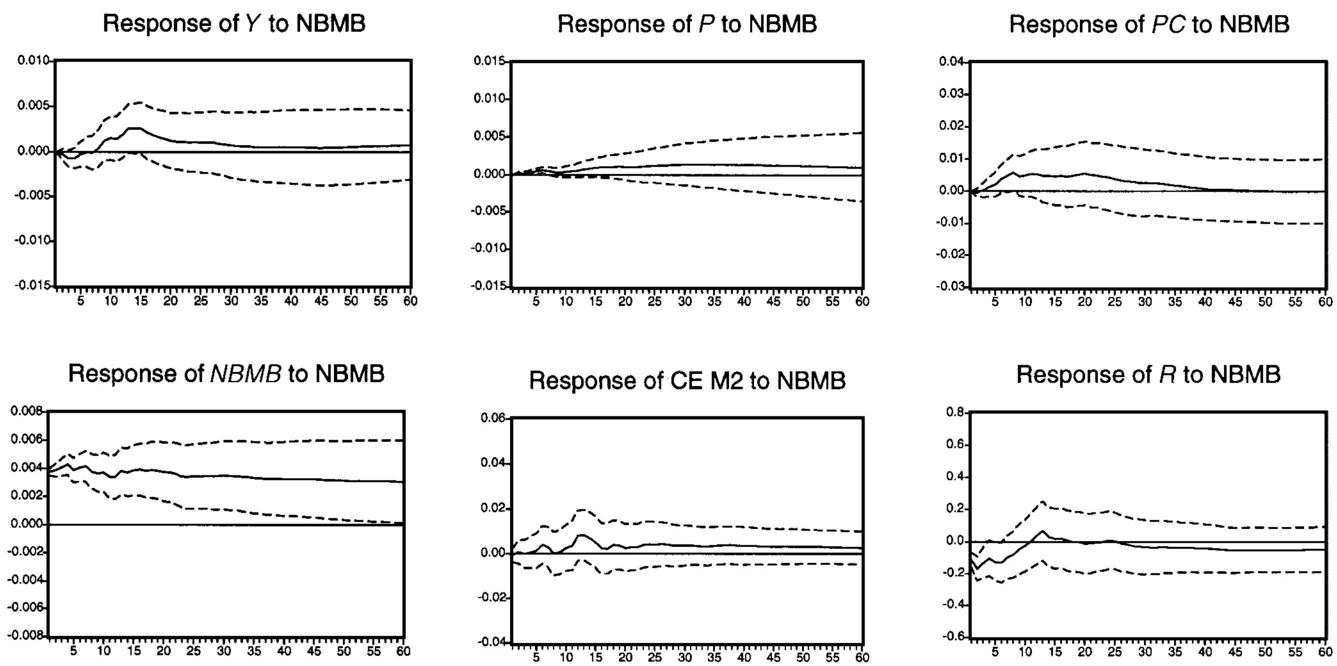

Figure 11. Impulse responses for {*Y*, *P*, *PC*, *NBMB*, Currency Equivalent M2, *R*} model.

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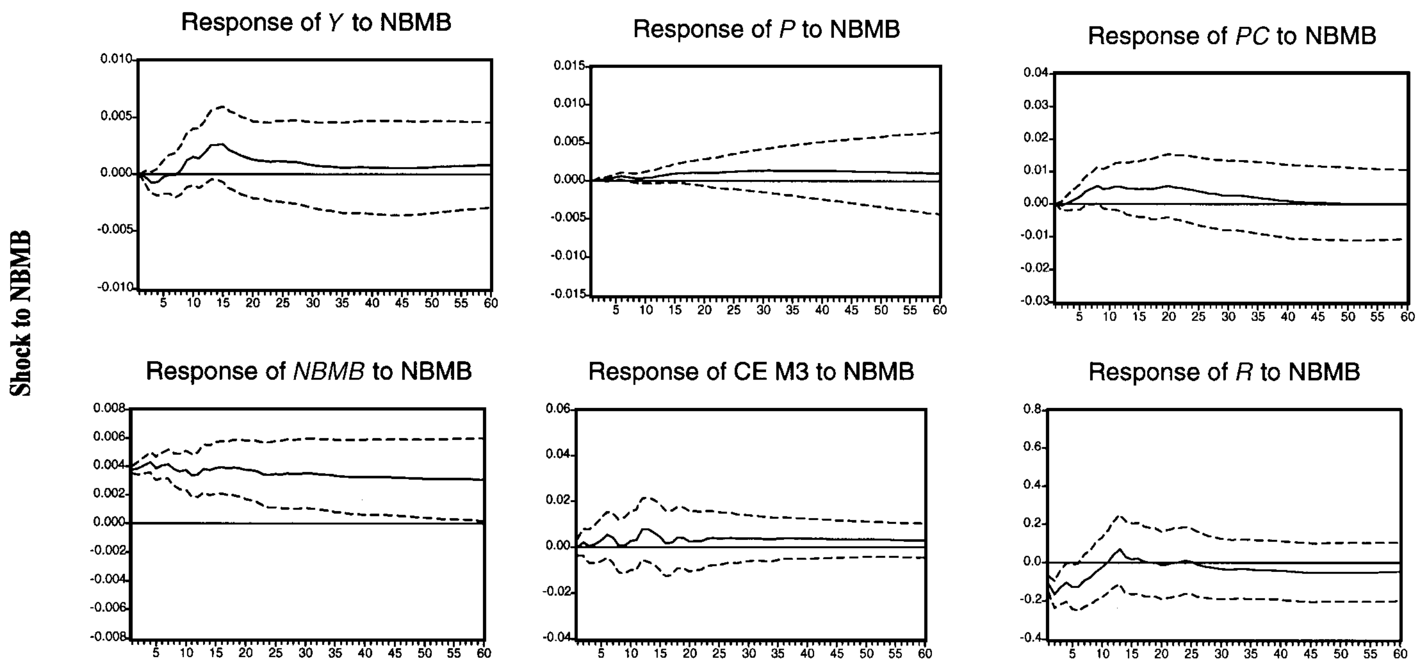

Figure 12. Impulse responses for {Y, P, PC, $NBMB$, Currency Equivalent M3, R} model.

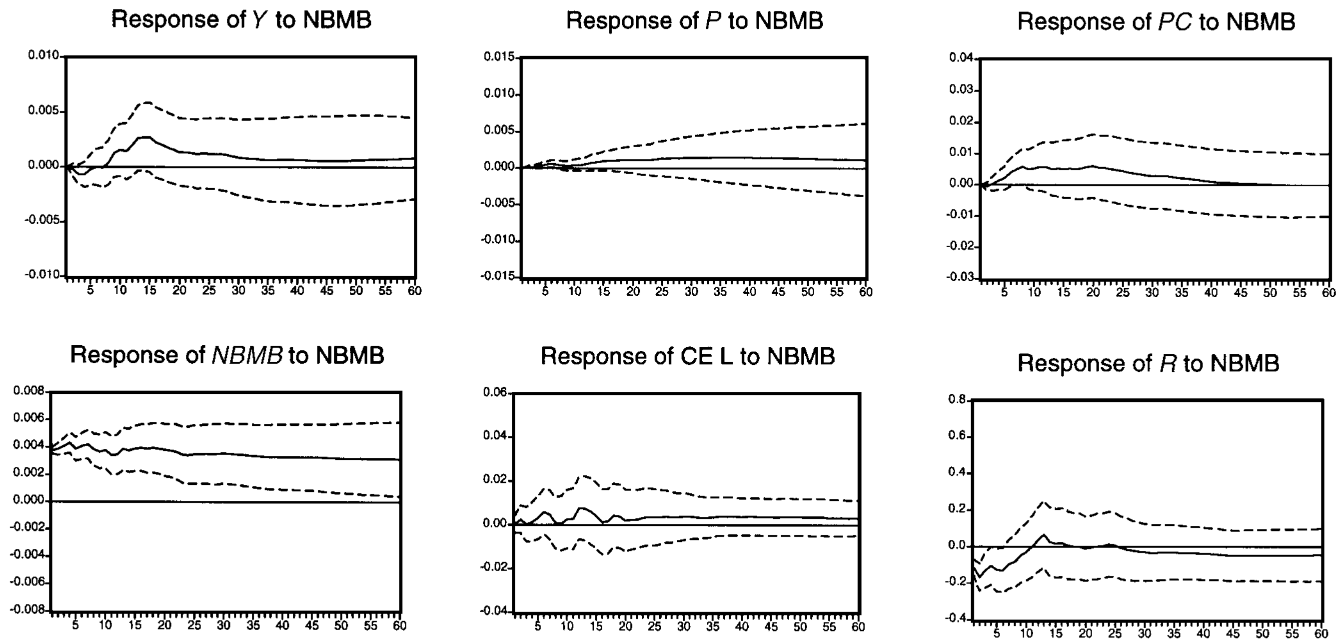

FIGURE 13. Impulse responses for {*Y*, *P*, *PC*, *NBMB*, Currency Equivalent L, *R*} model.

It is apparent that nonborrowed-monetary-base shocks generate increases in the money supply regardless of how it is measured, although the estimated responses are statistically significant only for the narrow monetary aggregates (Sum M1, Divisia M1, and CE M1). Moreover, the liquidity effect is still present and the price and income responses are broadly similar to those of the $\{Y, P, PC, NBMB, R\}$ VAR.

4. CONCLUSION

Over the years, various measures of exogenous shocks to monetary policy have been used. Monetarist authors of the 1960's and 1970's emphasized broad monetary aggregates (such as M1 and M2) as indicators of policy. Recently, however, the use of monetary aggregates as indicators of policy has been questioned, because changes in monetary aggregates can result from factors other than changes in policy. This has led many economists to consider either Federal Reserve balance-sheet measures such as nonborrowed reserves [see, e.g., Eichenbaum (1992), Strongin (1995), and Christiano et al. (1996)] or market-determined interest rates such as the federal-funds rate [see, e.g., Sims (1992), Bernanke and Blinder (1992)].

We have used a nonborrowed-monetary-base VAR and a targets-and-instrument framework favored by the monetarists (where the nonborrowed monetary base functions as the operating target and monetary aggregates function as intermediate targets) to resolve the liquidity and price puzzles thrown up by monetary VAR studies. We found a strong and statistically significant liquidity effect, plausible effects of monetary policy upon prices and output, and Granger causality from the policy variable to output. Moreover, variance decompositions indicate that nonborrowed-monetary-base shocks together with narrow-sum or Divisia money supply shocks account for a very high percentage of the forecast error variance of output.

We also investigated the performance of 12 measures of money, measured by simple sum, Divisia, and CE indices. The results differ across those techniques of aggregation and also differ considerably when compared by the broadness of the index. In general, however, it can be claimed (on the basis of marginal significance levels and forecast error variance decompositions) that Divisia M1, followed by Divisia M2 and Sum M2, performs best.

REFERENCES

Anderson, R.G., B. Jones & T. Nesmith (1996a) An Introduction to Monetary Aggregation Theory and Statistical Index Numbers. Working paper 96-007A, Federal Reserve Bank of St. Louis.

Anderson, R.G., B. Jones & T. Nesmith (1996b) Building New Monetary Services Indices: Methodology and Source Data. Working paper 96-008A, Federal Reserve Bank of St. Louis.

Barnett, W.A. (1980) Economic monetary aggregates: An application of aggregation and index number theory. *Journal of Econometrics* 14, 11–48.

Barnett, W.A., D. Fisher & A. Serletis (1992) Consumer theory and the demand for money. *Journal of Economic Literature* 30, 2086–2119.

Bernanke, B.S. & A.S. Blinder (1992) The federal funds rate and the channels of monetary transmission. *American Economic Review* 82, 901–921.

Christiano, L.J., M. Eichenbaum & C. Evans (1996) The effects of monetary policy shocks: Evidence from the flow of funds. *Review of Economics and Statistics* 78, 16–34.

Cochrane, J.H. (1995) Shocks. NBER working paper 2019.

Eichenbaum, M. (1992) Comments on "Interpreting the macroeconomic time series facts: The effects of monetary policy" by C. Sims. *European Economic Review* 36, 1001–1011.

Leeper, E.M., C.A. Sims & T. Zha (1996) What Does Monetary Policy Do? *Brookings Papers on Economic Activity*, 1–63.

Poterba, J., J. Rotemberg, and J. Driscoll (1995) Evidence from a new monetary aggregate. *Journal of Business and Economic Statistics* 13, 67–83.

Rotemberg, J. (1991) Commentary: Monetary aggregates and their uses. In M.T. Belongia (ed.), *Monetary Policy on the Seventy-Fifth Anniversary of the Federal Reserve System*, pp. 223–231. Norwell, MA: Kluwer Academic.

Sims, C.A. (1992) Interpreting the macroeconomic time series facts: The effects of monetary policy. *European Economic Review* 36, 975–1000.

Strongin, S. (1995) The identification of monetary policy disturbances: Explaining the liquidity puzzle. *Journal of Monetary Economics* 35, 463–497.