GOLD PRICE TARGETING BY THE FED*

William D. Lastrapes
Associate Professor

and

George Selgin
Assistant Professor

Department of Economics
University of Georgia
Athens, Georgia 30602

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Corresponding Author: William D. Lastrapes, Department of Economics, University of Georgia, Athens, GA 30602. Phone: 706/542-3569. Fax: 706/542-3376. E-mail: last@rigel.econ.uga.edu.

William D. Lastrapes
Associate Professor
Department of Economics
University of Georgia
Athens, GA 30602

George Selgin
Assistant Professor
Department of Economics
University of Georgia
Athens, GA 30602

ABSTRACT

This paper estimates a vector autoregression using weekly data to identify the response of monetary policy to the price of gold. A simple model of the reserve market is used to identify economic shocks. We find that over Greenspan's tenure as Board chairman of the Federal Reserve System, the evidence is consistent with gold price stabilization, although the response of nonborrowed reserves to gold price shocks is strongest over intermediate horizons. The evidence for the use of gold as an intermediate target is much weaker for the period prior to Greenspan's appointment. These results hold even when alternative informational variables are considered.

JEL classification: E4, E5

1. Introduction

What role does the price of gold play in formulating current monetary policy? Fed Chairman Alan Greenspan has called the price of gold a "very good indicator of future inflation," and there has long been speculation in the popular press (e.g. Forbes 1991, Ullmann 1994) concerning a role for the gold price as an intermediate monetary policy target: the Federal Reserve responds to changes in the price of gold in the short-run because it cannot afford to wait for lower-frequency information concerning changes in the aggregate variable (e.g. the price level) whose value it ultimately wishes to control. Thus, the Fed is supposed to interpret a rising gold price as indicative of excess liquidity or inflationary expectations, in which case the Fed reduces bank reserves to stabilize gold's price. Here we examine this claim empirically by focusing on the narrow question: how does monetary policy, as measured by changes in nonborrowed reserves and the federal funds rate, dynamically respond to independent changes in the price of gold?

To this end, we consider a linear, time series model of reserve market variables and the price of gold. We identify, without severely restricting dynamic relationships, economic shocks of interest by imposing a contemporaneous structural model of reserve market behavior, similar to Strongin's (1992), on the statistical model. Using high frequency (weekly) data for the recent period over which the Fed has targetted borrowed reserves, we estimate the dynamic response of the Fed's policy instruments – nonborrowed reserves and the funds rate – to gold price shocks.

Surprisingly, there has been little empirical research on the relationship between gold prices and monetary policy under fiat money regimes. Many writings have, of course, looked into the workings of gold standard regimes; others have studied the efficiency of the market for gold (Moore 1990, Solt and Swanson 1981) and the statistical properties of gold price time series (Frank and Stengos 1989). However, while some more recent VAR studies of monetary policy include monthly commodity price indices (e.g. Cody and Mills 1991, Furlong 1989, Gordon and Leeper 1994), these and earlier studies of the

Fed's reaction function (e.g. Khoury 1990) do not include gold prices. Laurent (1994) looks at gold in the context of monetary policy, but takes a normative perspective on the desirability of stabilizing gold under a fiat standard, and does not investigate whether any link actually exists between the gold price and monetary policy. Our study attempts to provide additional insight into the mechanics of monetary policy behavior by relating gold to policy variables using weekly data.

2. Empirical model and identifying restrictions

We examine the link between gold and monetary policy using a linear, dynamic structural model of the market for bank reserves. The structure represents agents' behavioral rules and equilibrium conditions, and defines the economic sources of fluctuations in observable variables. Let $y_t = \begin{pmatrix} TR_t \\ NBR_t \\ r_t \\ g_t \end{pmatrix}$ denote the vector of endogenous variables in the model, where TR is the quantity of total reserves in the banking system, NBR is the quantity of nonborrowed reserves, r is the federal funds rate and g is the dollar price of gold. The structure is given by:

$$A_0 y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + u_t, \tag{1}$$

where u_t is a 4×1 vector of serially uncorrelated, latent exogenous shocks, and $\mathrm{E} u_t u_t' = \Omega$ is normalized to be diagonal, so that the 4×4 matrix A_0 has a 1 in each of its diagonal elements. The matrices $A_i, i = 0, \cdots, p$, contain structural parameters measuring dynamic correlations, while the elements of u are economically interpretable fundamental innovations to the agents' decision rules and market equilibrium conditions (e.g. supply and demand shocks).

We interpret the first row of (1) as the demand schedule for total reserves, the second as the supply schedule for nonborrowed reserves (the policy reaction function), the third as the supply schedule of borrowed reserves (assumed to be a function of the gap between r and the discount rate), and the fourth as the equilibrium price of gold. Thus, u_1 is an exogenous innovation to total reserve demand, u_2 is a monetary policy innovation that is independent of the other variables in the system, u_3 is a shock to the supply of borrowed reserves (which is tantamount to a shift in bank demand for Fed discount loans), and u_4 is a shock to the equilibrium gold price. The main objective of this paper is to identify the dynamic response of the Fed to changes in u_4 to make inferences about the relationship between monetary policy and the gold price.

Dynamic responses are obtained by "solving" the structural model:

$$y_t = (D_0 + D_1\mathrm{L} + D_2\mathrm{L}^2 + \cdots)u_t = D(\mathrm{L})u_t, \tag{2}$$

where $D_0 = A_0^{-1}$ is nonsingular, and $D(\mathrm{L}) = (A_0 - A_1\mathrm{L} - A_2\mathrm{L}^2 - \cdots - A_p\mathrm{L}^p)^{-1}$. Thus, $D_k = \frac{\partial y_t}{\partial u_{t-k}}$. These dynamic multipliers show the average impact of an exogenous structural impulse at time $t-k$ on the equilibrium values of the endogenous variables at time t. If the Fed attempts to stabilize the gold price, the reserve market should tighten in the face of exogenous positive gold price impulses. This would imply that $\frac{\partial NBR_t}{\partial u_{4t-k}} < 0$ and $\frac{\partial r_t}{\partial u_{4t-k}} > 0$. The dynamics of the policy response depend on how these multipliers vary over k.

The correspondence between $D(\mathrm{L})$ and the data generating process is not unique. This process is:

$$y_t = (\mathrm{I} + C_1\mathrm{L} + C_2\mathrm{L}^2 + \cdots)\epsilon_t = C(\mathrm{L})\epsilon_t \tag{3}$$

$$\mathrm{E}\epsilon_t\epsilon_t' = \Sigma,$$

which fully summarizes the second moments of the joint probability distribution of y_t. $C(\mathrm{L})$ and Σ are directly recoverable from the vector autoregressive (VAR) representation of the data. The mapping between (3) and the structure is given by

$$C(\mathrm{L}) = D(\mathrm{L})D_0^{-1} \tag{4}$$

$$\epsilon_t = D_0 u_t.$$

Clearly, this mapping can only be made unique by imposing further restrictions on the structure.

To identify $D(\mathrm{L})$, the parameters of interest, from $C(\mathrm{L})$, we do not restrict dynamic interactions by imposing strict econometric exogeneity on the variables in the system, but focus on the information contained in the covariance of the residuals from an unrestricted VAR, Σ. Note from (3) and (4) that

$$\Sigma = D_0 \Omega D_0'. \tag{5}$$

Because Σ is symmetric, there are ten independent, nonlinear relations between the estimable elements in Σ and the sixteen structural parameters in D_0 (or A_0) and Ω. Six restrictions are required on the structure to just-identify these parameters. Note again from (4) that knowledge of D_0 is sufficient to estimate $D(\mathrm{L})$.

The restrictions we impose are based on a simple model of contemporaneous interaction of the variables in y_t, which restricts the elements of A_0. The model is not recursive, so that the Choleski decomposition of Σ is not an appropriate identifying scheme.[1] The model implies:

$$A_0 = \begin{pmatrix} 1 & 0 & 0 & 0 \\ a_{21} & 1 & a_{23} & a_{24} \\ a_{31} & -a_{31} & 1 & 0 \\ 0 & a_{42} & a_{43} & 1 \end{pmatrix}. \tag{6}$$

The zero restrictions in the first row of A_0 ($a_{12} = a_{13} = a_{14} = 0$) imply that the demand for reserves by depository institutions is perfectly inelastic with respect to the current federal funds rate and does not respond *contemporaneously* to changes in the other variables; thus, u_1 is simply the reduced form innovation from the total reserves equation. These restrictions do *not* rule out adjustment of reserves over time and therefore allows for an elastic demand at longer horizons.

Strongin (1992) makes a similar identifying restriction and provides a rationalization for why banks' demand for reserves might be independent of interest rates and supply factors in the short run. In particular, the restriction relies on two institutional rigidities: 1) required reserve demand is predetermined by current and past deposits, the demand for which is inelastic in the short-run; and 2) excess reserve demand is independent of policy.

These rigidities are *a fortiori* more plausible over a weekly horizon than in Strongin's monthly horizon application.

As noted above, the second row reflects the policy behavior of the central bank. We impose no restrictions on how the Fed responds to contemporaneous movements in total reserves, the federal funds rate, or the price of gold. This specification is sufficiently general to allow for *any* targetting or policy procedure undertaken by the Fed. For example, under a pure borrowed reserves procedure, the Fed immediately accommodates reserve demand shocks; thus, $a_{21} = -1$. If the Fed targets the federal funds rate by smoothing private sector shocks to borrowed reserves, then $a_{23} < 0$. If $a_{24} > 0$, the Fed reduces nonborrowed reserves in response to an increase in g_t and thus (assuming that the price of gold is perceived to respond positively to increases in money) attempts to stabilize the price of gold contemporaneously. Regardless of the particular procedure chosen by the Fed, u_2 is a policy shock that does not depend on feedback from the other variables in the system; it is the only sort of shock that can tell us how exogenous monetary policy is transmitted to the real economy (Christiano, Eichenbaum and Evans 1994).

Two restrictions are placed on the third row, the borrowed reserve supply equation: $a_{32} = -a_{31}$, which defines borrowed reserves, and $a_{34} = 0$, which implies that borrowed reserve supply is independent of the gold price. Recall that u_3 represents shocks to factors other than the federal funds rate that influence the desire for borrowed reserves, such as the implicit costs and benefits of utilizing the discount window (Thornton 1988). When $u_3 > 0$, borrowed reserve supply *decreases* for a given federal funds rate (it represents an increase in the cost of borrowing from the Fed relative to borrowing in the federal funds market).

In the final row – the reduced form equation for gold (where the supply and demand for gold implicitly have been solved for price by eliminating quantity) – the only restriction imposed is that total reserves may affect the demand for gold, but only with a lag.[2] A negative value for a_{42} implies that increases in reserve market liquidity lead to a contemporaneous increase in the demand for, and therefore price of, gold. The shock u_4 can include shocks to inflationary expectations that affect the demand for gold but that come from information external to the reserve market.

The six restrictions in A_0 are sufficient to just-identify D_0 and thus $D(\mathrm{L})$ from the VAR estimates of Σ (assuming the rank condition for identification holds). Keep in mind that these restrictions are *contemporaneous* and do not place theoretical restrictions on dynamic interactions.

3. Results

Our statistical analysis focuses on Greenspan's tenure as chairman of the Fed, beginning in August 1987. Operating procedures have been fairly stable over this period, with price level stability arguably being the Fed's sole long-run (or ultimate) objective (Timberlake, 1993, pp. 390-401). However, we also estimate the model over the borrowed reserve period prior to Greenspan's appointment, beginning in October 1982, to see if Greenspan's appointment has affected the Fed's response to gold. In addition, we consider the robustness of the results to potential omitted variable problems.

The full sample contains weekly observations of the reserve market and gold price variables from October 6, 1982 to April 27, 1994. The subsample spanning Greenspan's term begins August 11, 1987. The pre-Greenspan subsample begins October 6, 1982 and end August 5, 1987. Weekly data allow us to examine the possibility that the Fed responds quickly to asset price changes. They also enhance the plausiblity of the model's identifying restrictions. The data set consists of the adjusted monetary base (Wednesday), the currency component of M1 (Tuesday), total borrowings from the discount window (Wednesday), and the federal funds rate (Wednesday). Total reserves are measured as the difference between the monetary base and currency holdings, while nonborrowed reserves are obtained by subtracting borrowings from total reserves.[3] The gold price is the Wednesday close from Comex.

Over both samples, we estimate a VAR with a common lag of 15, which sufficiently whitens the residuals. To allow for these lags, the first 15 observations are taken as given, so that the estimation period begins January 26, 1983 (237 observations) for the early subsample and December 2, 1987 (335 observations) for the Greenspan subsample. Deterministic variables include a constant and the Fed discount rate. All variables in the system except the federal funds rate are transformed into logs.[4] We use a two-step procedure to efficiently estimate the structural parameters. In the first step, OLS equation-by-equation yields $\hat{\Sigma}$. In the second step, maximizing the log likelihood

$$L(\hat{\Sigma}, A_0, \Omega) = -\frac{Tn}{2} log 2\pi + \frac{T}{2} log|A_0|^2 - \frac{T}{2} log|\Omega| - \frac{T}{2}\text{trace}[(A_0'\Omega^{-1}A_0)\hat{\Sigma}] \qquad (7)$$

with respect to A_0 and Ω yields (assuming they are identified) the FIML estimators of these parameters, $\hat{A}_0$ and $\hat{\Omega}$ (Hamilton 1994). Because our restrictions just-identify the system, $\hat{\Sigma} = \hat{A}_0^{-1}\hat{\Omega}(\hat{A}_0^{-1})'$, and there are no over-identifying restrictions to test.

Figures 1 and 2 report the dynamic response functions, where the responses are scaled to a standard deviation impulse to each shock, and the variance decompositions of the variables, estimated over the Greenspan subsample. Each figure also shows asymmetric standard error bands obtained from a bootstrap simulation. The bands give some indication of the precision of the estimates.[5]

Consider the first column of panels in the figures. In Figure 1, this column shows the average dynamic response of each of the system variables to an impulse in the demand for reserves. The results are consistent with a borrowed reserve operating procedure: nonborrowed reserves track the movement in total reserves closely, meaning that borrowed reserves do not respond to demand shocks. The response of the federal funds rate is essentially zero, with virtually no contribution of reserve demand shocks to the variance of the rate.

Column two reports the responses to exogenous monetary policy shocks. A u_2 shock that has a positive impact effect on nonborrowed reserves causes a decline in the federal funds rate: a shock causing a 1% increase (measured on a weekly basis) in nonborrowed reserves on impact brings about an average decline in the federal funds rate of 30.67 basis points. This finding is further evidence for a liquidity effect of nominal money shocks, which has recently been a focus of several empirical studies (Lastrapes and Selgin 1994, Christiano and Eichenbaum 1992a,b, Strongin 1992, Gordon and Leeper 1994).[6] Such shocks on average explain about 50% of the variance of the federal funds rate at a one-week horizon and beyond. The rate response is surprisingly persistent given the apparent transitory nature of the shock on non-borrowed reserves and the lack of an effect on total reserves. The positive response of gold price to the policy shock is also somewhat surprising given the small effect of the shock on reserves. However, the contribution of the shock to gold price variance is relatively small.

The results in column three suggest that an increase in the implicit costs of discount borrowing has a transitory but strong effect on the federal funds rate. This, coupled with the essentially zero response of nonborrowed reserves, suggests that the Fed is reluctant to smooth the federal funds rate in the face of borrowed reserve shocks.[7]

Responses to exogenous gold price shocks are reported in column four. (For clarity, Figure 3 contains these response functions only, without standard error bands.) There is clear evidence of market tightening in response to positive innovations in the price of gold. Although the response is weak initially, non-borrowed reserves gradually fall as the federal funds rate rises. Total reserves do not respond over short-horizons, but eventually fall as the demand for reserves becomes elastic and the federal funds rate rises. Furthermore, if the nonborrowed reserve response were simply an accommodation of a gold-induced leftward shift in the demand for reserves, the federal funds rate response would be negative rather than positive. According to the variance decompositions, gold price shocks explain 25% of the 52-week forecast error variance of nonborrowed reserves, and 41% of the variance of the federal funds rate at that horizon. Finally, note that the gold price itself responds only temporarily to its own shocks. This finding is also consistent with long-run gold price stabilization – after 52 weeks, gold's response to u_4 is only one-eighth of its immediate response.[8]

Though modest, the magnitudes of these intermediate-horizon responses of policy variables are not trivial: a shock to u_4 that causes a 10% rise in the price of gold on impact brings about a 1.5% fall in nonborrowed reserves and a 50.7 basis point rise in the federal funds rate at the 52 week horizon. In 1994, for example, this would have meant a decline in nonborrowed reserves of about $1.6 billion. This response is larger than the estimated standard deviation of the policy shock error of 0.60%.

Because our empirical model includes only the price of gold, it cannot distinguish the influence of the gold price on Fed policy from the influence of other information variables that may correlated with the gold price. For example, past studies have considered, with mixed results, the role of commodity prices other than gold in influencing monetary policy (Cody and Mills 1991, Furlong 1989). The price of gold might proxy for a more general commodity price index in the Fed's reaction function. It might also proxy for more direct measures of the Fed's goals, such as the price level and output.

To analyze the robustness of our results, we create three series representing a measure of the "relative" price of gold. The first is the dollar gold price deflated by a weekly commodity price index. The second deflates the gold price by the price level, while the third is the ratio of gold price to output. We then estimate three separate VARs in which the relative prices alternately replace the nominal price of gold. If the Fed attempts to stabilise commodity prices, the price level or output directly rather than the price of gold, then nonborrowed reserves should respond *positively* to an exogenous shock in the relative price measure.[9]

Figure 4 plots the dynamic responses of the system variables to these relative gold price shocks estimated over the Greenspan period. The basic patterns of the responses of the reserve market variables to these shocks are unchanged. In particular, there is no tendency for the Fed to expand reserves following a relative decrease in the variable in the denominator of the relative price variable. The unreported response functions are also robust. These results do not rule out a role for other commodity prices, the price level or output in setting monetary policy. They do suggest, nonetheless, that gold plays a larger role in the setting of policy than either the commodity price index or the less-frequently observed aggregate variables.[10]

Figures 5 and 6, finally, show the response functions and variance decompositions for the original system estimated over the pre-Greenspan subsample. The primary finding of reserve tightening in response to positive gold price shocks is much less evident before Greenspan. Note the weaker response of both nonborrowed reserves and the federal funds rate in column 4. In fact, the federal funds rate declines over short horizons. Both figures indicate that exogenous policy shocks (u_2) are more persistent and explain much more of the variation in nonborrowed reserves.[11] We infer that targeting the price of gold has been more important during Greenspan's tenure as Board Chairman than during the borrowed reserve period prior to his appointment.

4. Conclusion

In this paper, we statistically investigate the response of monetary policy to movements in the price of gold, taking care to appropriately identify policy reactions and to account for dynamic relationships. The results of this empirical exercise confirm the widespread belief that Alan Greenspan's Fed *has* used the price of gold to guide monetary policy over medium-term horizons: the responses of nonborrowed reserves and the federal funds rate to gold price shocks are gradual and peak between 26 and 40 weeks. The inclusion of other potential target variables – commodity prices, inflation and output – in the statistical model does not alter our basic findings.

Notes

[1] The type of contemporaneous restrictions we use were initially used to identify VAR models by Bernanke (1986) and Sims (1986). Giannini (1992) discusses in general identification of VAR models.

[2] We also identified A_0 by relaxing the restriction on a_{41} and restricting a_{43} to be zero; our results were unaffected.

[3] A direct measure of total reserves is available on a biweekly basis. We compared our measure to the direct measure for this frequency – they were almost identical. Thus, our results are not sensitive to the possible mismatch of the base and currency.

[4] Note that this transformation does not preserve the definition of borrowed reserves in terms of total and nonborrowed reserves. Thus, our identification scheme is an approximation. However, we also estimated a system in which reserve variables are normalized as in Strongin (1992) by dividing TR_t and NBR_t by TR_{t-1}, and a system without normalization. The results in these cases were not qualitatively different from those reported.

[5] The simulation proceeded as follows. A pseudo realization of $y_t, t = 1 \cdots T$ was generated using bootstrapped residuals and the initial values of the variables. With the pseudo data, a VAR was estimated, the structural parameters were identified using (7), and the dynamic multipliers and variance decompositions calculated. This procedure was replicated 1000 times. However, in 201 cases, the optimization algorithm failed to converge for a common set of starting conditions. We therefore constructed the empirical density of the estimated coefficients over the remaining 799 replications. The standard errors reported in Figures 1 and 2 were calculated separately for pseudo responses above, and below, the actual estimates; hence, the asymmetry of the bands (Blanchard and Quah 1989).

[6] The only other studies, of which we are aware, to provide evidence of a liquidity effect over data frequencies higher than monthly are Bernanke and Blinder 1992 and Cochrane 1989.

[7] For research that finds some evidence for accommodation of borrowed reserve shocks, see Thornton (1988, pp. 42-43).

[8] The estimate of a_{24} is 0.037 with a standard error of 0.004. Thus, nonborrowed

reserve supply is significantly negatively related contemporaneously to changes in the price of gold.

[9] We use the KR-CRB (BLS) spot commodity price index from Knight-Ridder. The Commodity Research Bureau daily index includes 23 commodity prices, excluding gold. As with the other data, Wednesday figures are chosen to form the weekly sample. The price level is the consumer price index for all urban consumers, and output is the seasonally adjusted index of industrial production. The latter two series are obtained from the Federal Reserve Bank of St. Louis Electronic Data Base. The price level and output proxies are converted to a weekly basis by assuming that they are constant over the month. Since these variables are available to the Fed only on a monthly basis as well, this is a reasonable assumption. In addition, while the monthly variables cannot effect the high frequency responses, they can be used to determine if the longer-run responses of the reserve market variables we estimate in the initial system overstate the case for gold.

[10] Greenspan himself has deemed the gold price to be a much better indicator of inflationary expectations that other commodity prices.

[11] An interesting sidelight of these figures is the response of gold to policy shocks: while the federal funds rate drops immediately, the price of gold rises more gradually when nonborrowed reserves rise. This result is consistent with a distribution effect of money (Fuerst 1992 and others) – the monetary impulse is first felt in the reserves market, and later spills over into other asset markets.

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Figure 1. Dynamic Response Functions: Greenspan era (8/11/87 to 4/27/94)

Notes: Response functions are bounded by standard error bands derived from a bootstrap simulation with 799 replications.

Figure 2. Variance Decompositions: Greenspan era (8/11/87 to 4/27/94)

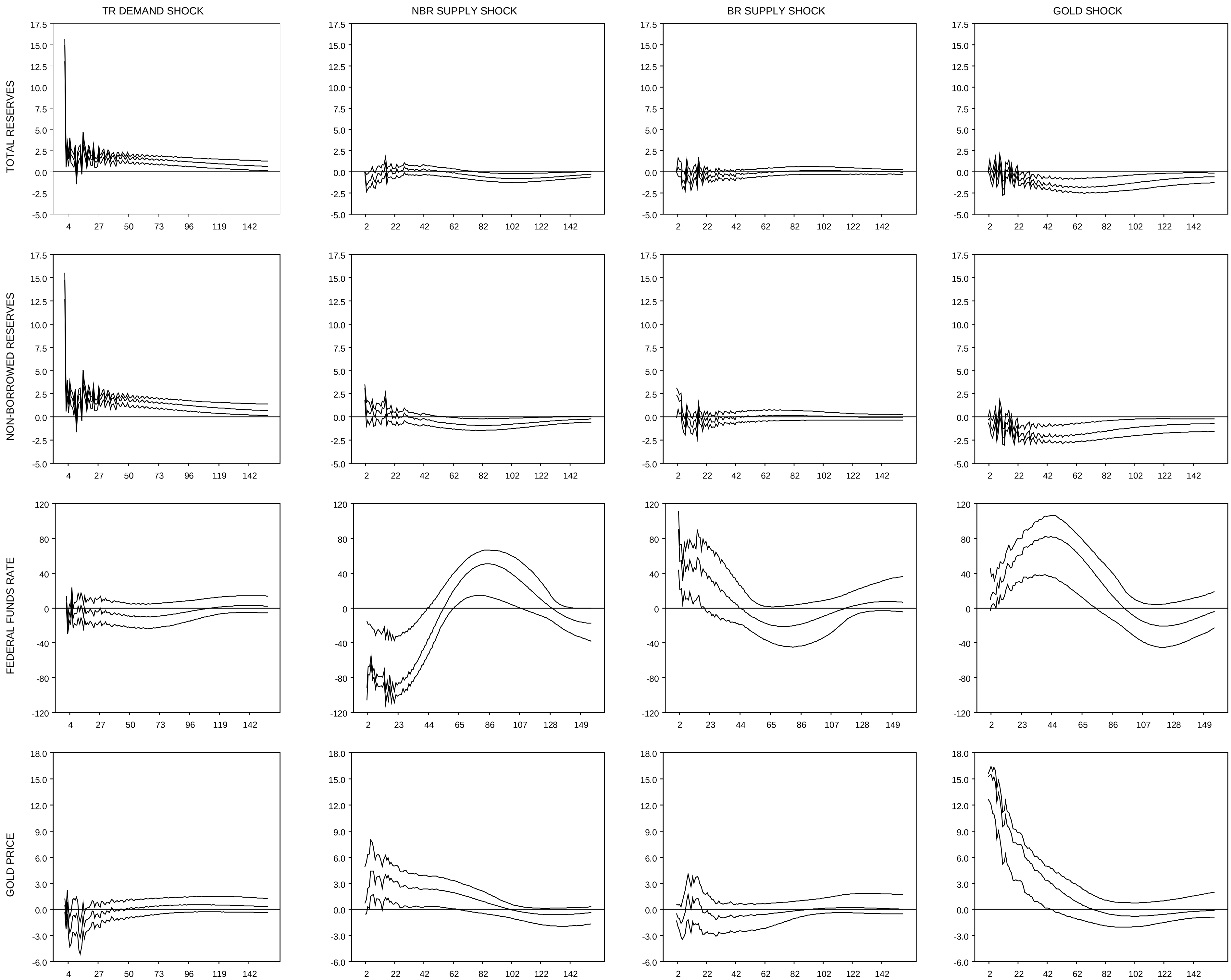
Notes: Variance decompositions are bounded by standard error bands derived from a bootstrap simulation with 799 replications.

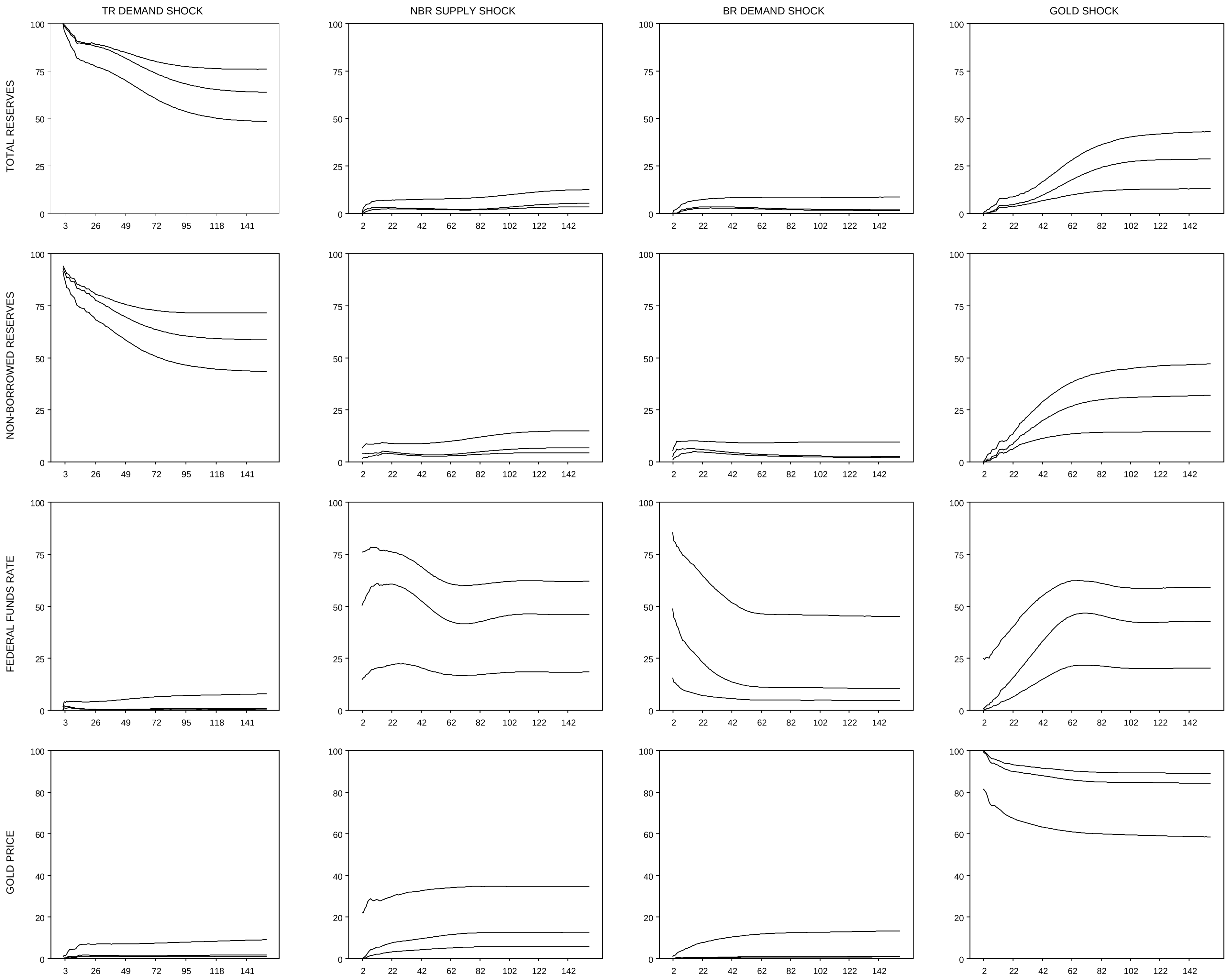
Figure 3. Dynamic Responses to Gold Price Shock: Greenspan era (8/11/87 to 4/27/94)

Figure 4. Dynamic Responses to Relative Gold Price Shocks: Greenspan era (8/11/87 to 4/27/94)

Figure 5. Dynamic Response Functions: Prior sample (10/6/82 to 8/5/87)

Figure 6. Variance Decompositions: Prior sample (10/6/82 to 8/5/87)


TR DEMAND SHOCK
NBR SUPPLY SHOCK
BR SUPPLY SHOCK
GOLD SHOCK
TOTAL RESERVES
NON-BORROWED RESERVES
FEDERAL FUNDS RATE
GOLD PRICE



TR DEMAND SHOCK
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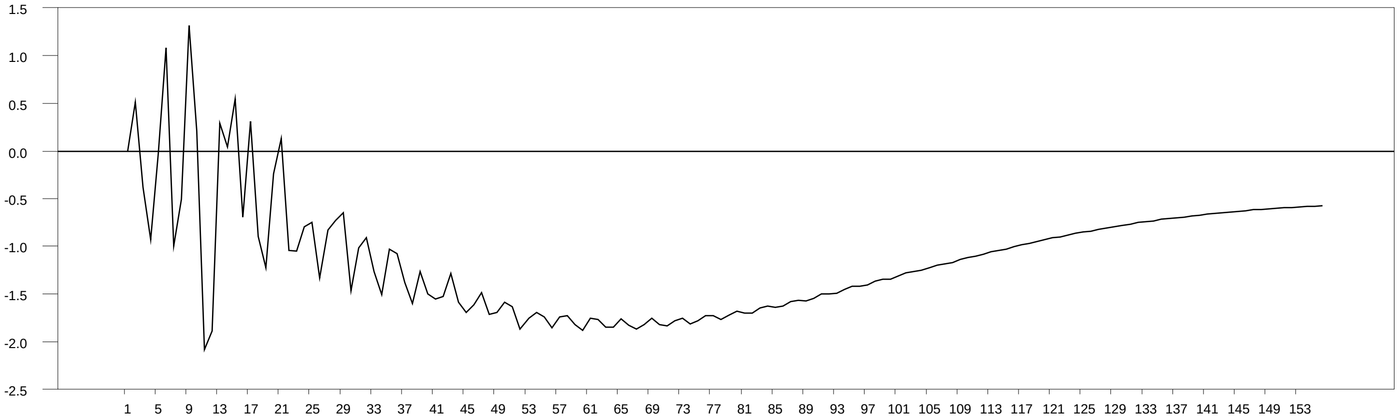
NON-BORROWED RESERVES
FEDERAL FUNDS RATE
GOLD PRICE

TOTAL RESERVES



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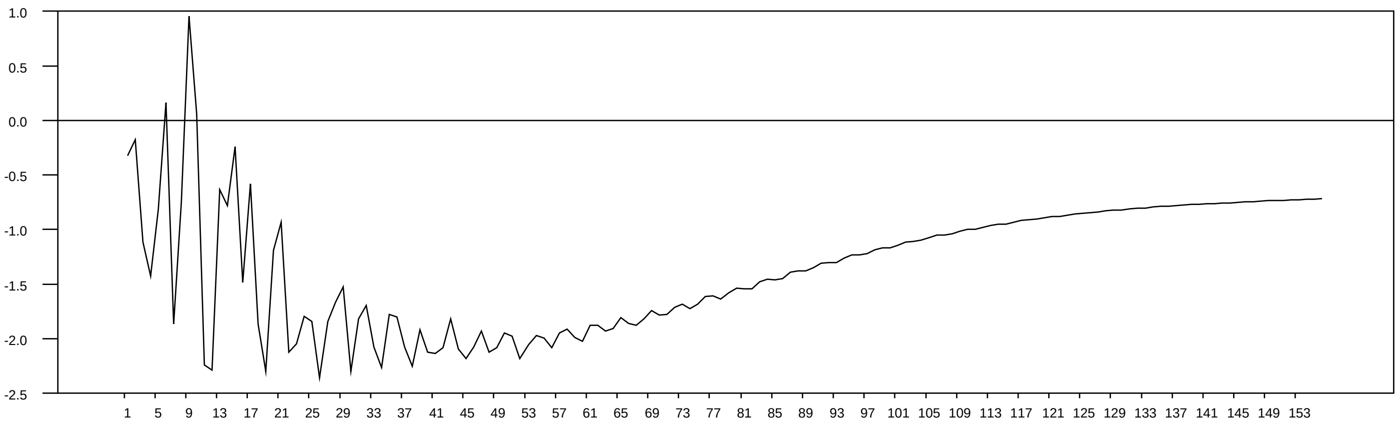
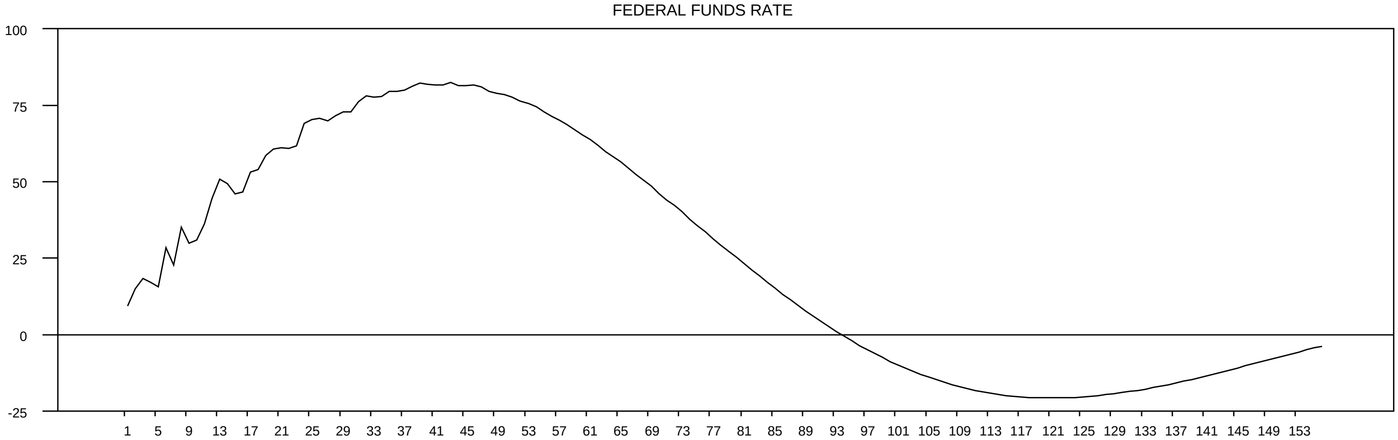
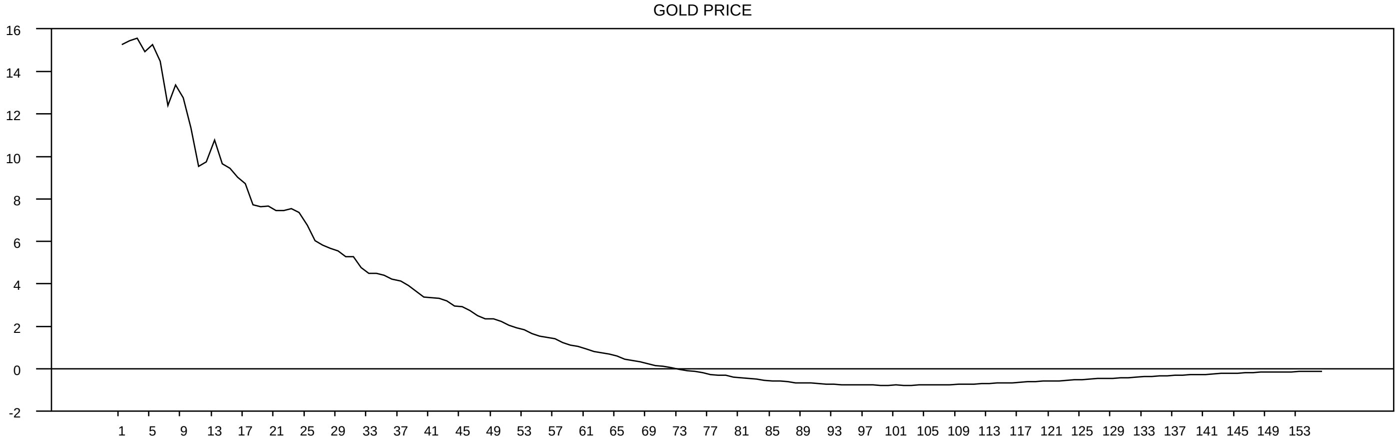
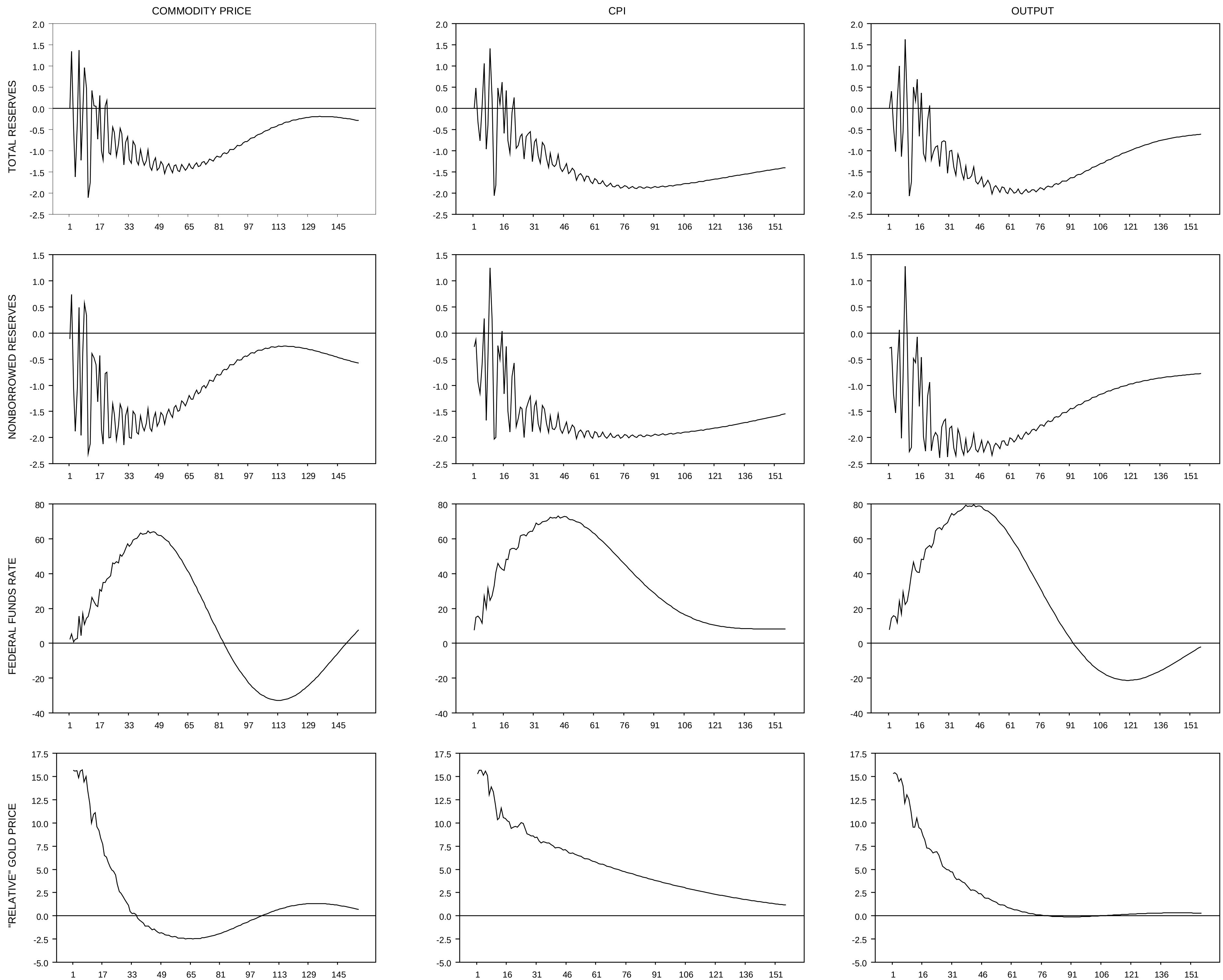


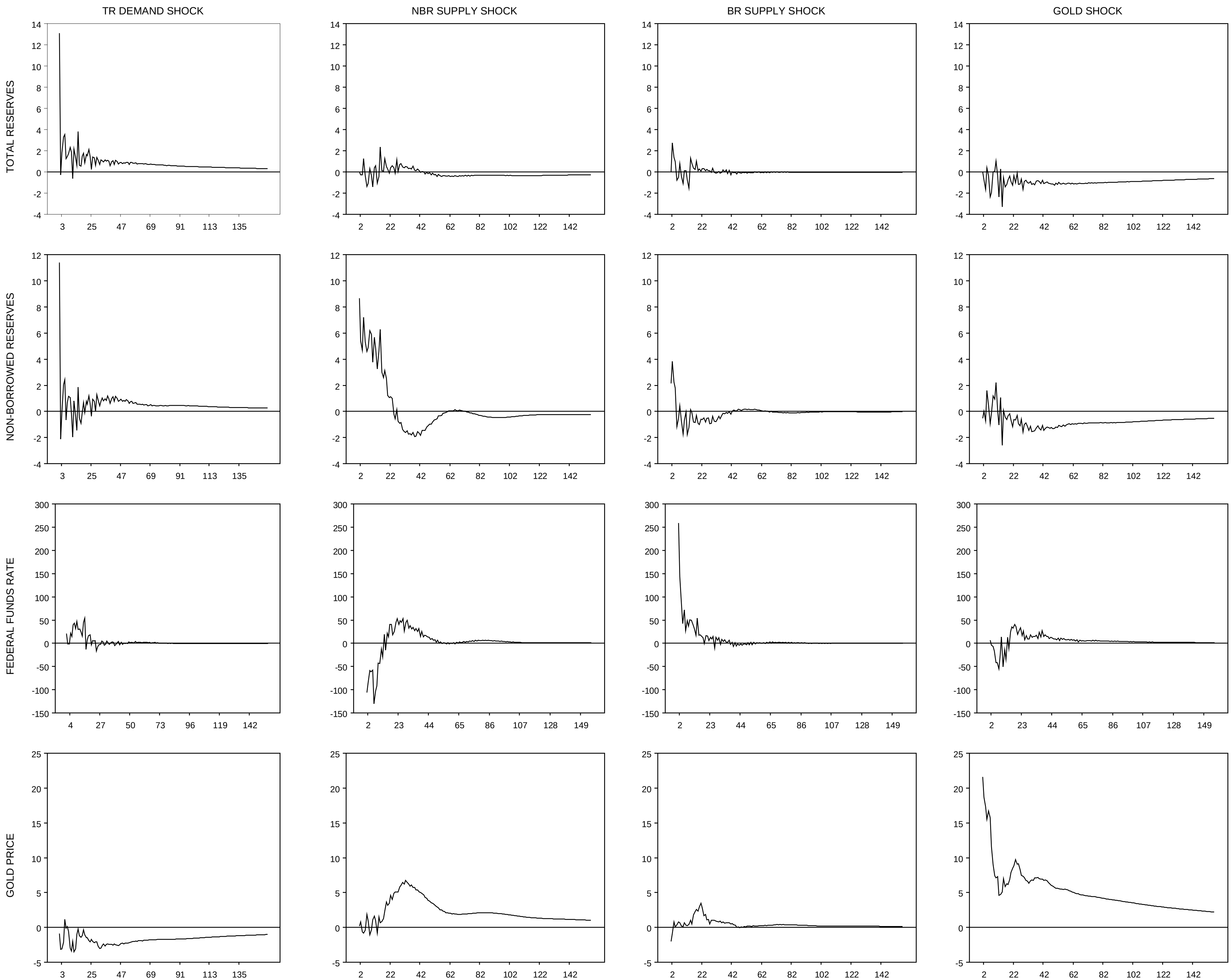
FEDERAL FUNDS RATE



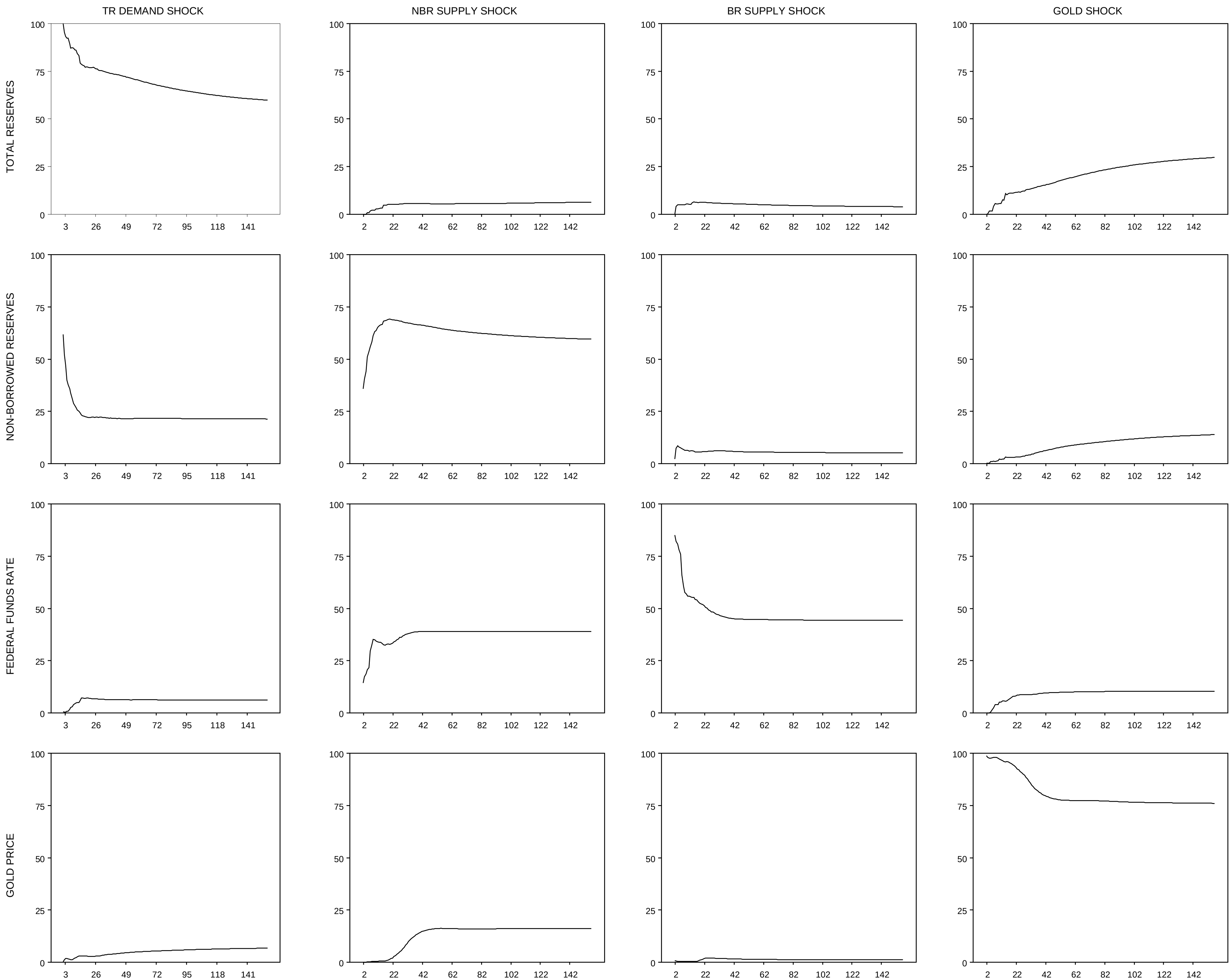
GOLD PRICE




COMMODITY PRICE
CPI
OUTPUT
TOTAL RESERVES
NONBORROWED RESERVES
FEDERAL FUNDS RATE
"RELATIVE" GOLD PRICE



TR DEMAND SHOCK
NBR SUPPLY SHOCK
BR SUPPLY SHOCK
GOLD SHOCK
TOTAL RESERVES
NON-BORROWED RESERVES
FEDERAL FUNDS RATE
GOLD PRICE


TR DEMAND SHOCK
NBR SUPPLY SHOCK
BR SUPPLY SHOCK
GOLD SHOCK
TOTAL RESERVES
NON-BORROWED RESERVES
FEDERAL FUNDS RATE
GOLD PRICE
0
25
50
75
100
3
26
49
72
95
118
141
2
22
42
62
82
102
122
142