

The Price of Gold and Monetary Policy

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ABSTRACT

Pronouncements by Alan Greenspan and others suggest a role for the price of gold in shaping monetary policy. Here, we look for evidence of such a role by examining the comovement of gold prices and the federal funds rate, by reviewing FOMC minutes, and by estimating a VAR model that identifies the Fed's response to fluctuations in the price of gold by controlling for other relevant policy variables. We find evidence that, since the early 1980's, the Fed has responded to sustained changes in gold's price, thereby limiting long-run changes in that price.

JEL classification: E4, E5

1. Introduction

Does the price of gold play a role in formulating current monetary policy? Historically, gold has served a unique role as the most pervasive form of commodity money, and continues to be perceived as a safe haven from fiat money. 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 gold’s 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 an aggregate variable (e.g. the price level) whose value it ultimately wishes to control. The Fed is thus supposed to interpret a rising gold price as a sign of excess liquidity or inflationary expectations, to which it responds by reducing bank reserves

We examine this claim empirically by focusing on the following question: how have the stock of bank reserves and the federal funds rate, the Fed’s monetary instruments, dynamically responded to independent changes in the price of gold in recent years? We answer this question in two ways. First, we informally examine the monthly data record of the federal funds rate, a rough indicator of monetary policy, and the price of gold. We then assess this record in light of a brief review of the minutes from FOMC meetings. This informal analysis suggests a role for the price of gold in guiding monetary policy. Second, we estimate a formal statistical model of the reserve market that attempts to control for other potentially useful indicators of monetary policy. The statistical model is a vector autoregression, from which the behavior of the Fed is carefully identified along lines suggested by Gordon and Leeper (1994). The formal analysis also suggests that the price of gold has been among the Fed’s important information variables.

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 by relating gold to more commonly cited policy variables.

2. A first look at gold prices and the federal funds rate

Figure 1 plots monthly data on the price of gold and the federal funds rate from December 1982 to November 1995.¹ Throughout this period the Fed directly targeted borrowed reserves, thereby indirectly targeting the federal funds rate.² Under such a regime, the federal funds rate serves as a good indicator of the stance of monetary policy (Bernanke and Blinder 1992, Bernanke and Mihov 1995). According to most authorities, the Fed's primary policy goal during this period was price level stability (Timberlake, 1993, 390-401). The sample period therefore allows us to examine the role of gold in a relatively stable policy environment.

To the extent that the federal funds rate provides information about the Fed's behavior, Figure 1 offers an informal picture of the response of monetary policy to fluctuations in the price of gold. For ease of interpretation, we have shaded periods of persistent decline

¹ The gold price is the COMEX closing price on the last Wednesday of the month. The federal funds interest rate data are daily averages, and were obtained from the St. Louis Federal Reserve Data Base.

² Under a borrowed reserve procedure, the federal funds rate does not respond to unexpected shocks in reserve demand, but might react to shifts in bank demand for discount window borrowing. If the latter are small, a borrowed reserves and federal funds target are indistinguishable.

in the federal funds rate, thus revealing major turning points in policy during this period. The figure shows that each turning point follows a similar turning point in the price of gold, albeit with a lag of a year to a year and a half. For example, gold reaches a peak of \$490 per ounce in early 1983, and falls steadily to \$290 by the first quarter of 1985; the federal funds rate peaks in mid-1984 at 11.64% and gradually declines to 5.85% by late 1986. Likewise, gold rises from early 1985 to late 1987, while the federal funds rate follows suit from late 1986 to early 1989. The final shift in the direction of the federal funds rate occurs at the end of 1993, following an upward movement in gold's price commencing the beginning of that year.

Thus, at a glance, the Fed appears to loosen reserve pressure after a persistent fall in the price of gold, and to tighten reserves after a persistent rise in gold's price, as one might expect were the Fed using the price of gold as an indicator of excess liquidity or inflationary expectations. A more precise interpretation might be that the Fed allows the federal funds rate to rise so long as the price of gold exceeds a specified target level, and allows the rate to fall once gold drops below this level. Consider a hypothesized target gold price of \$380, the sample mean over this period (plotted as the horizontal line in Figure 1). The figure seems to show a major shift in policy soon after the price of gold crosses this target: the rate generally rises when the price of gold exceeds this level, and generally falls otherwise. The one clear exception occurs in late 1989 through 1990, a time of great uncertainty following Iraq's invasion of Kuwait, when the price of gold rose sharply above the target range.³

Table 1 formalizes this relationship. The first panel reports results from a regression of the change in the federal funds rate on a constant, six of its own lags, and a dummy variable that is one when the price of gold exceeds its mean value of \$380 and zero otherwise. The coefficient on the constant term implies an average annual reduction in the federal funds

³ Notice how, even during this period, the federal funds rate became stable after the large gold price rise in late 1989, and then begins to fall again after gold resumes a steady decline.

rate of 6.7 basis points when gold is below \$380 per ounce, while the sum of the constant term and dummy coefficients implies an average annual increase in the federal funds rate of 5.17 basis points when gold is above that price. In the second panel of Table 1 we add to the original regression contemporaneous and lagged values of the deviation of gold's price from the hypothesized target. The results here suggest that, while the average change in the federal funds rate still depends on whether gold lies above or below its sample mean, the magnitude of the change in the funds rate is proportional, following a three-month lag, to the magnitude of the deviation of gold from the hypothesized target.

Statements by members of the FOMC are another source of informal information regarding the role of gold in setting monetary policy. Consider for example the general tightening in the market for reserves that began at the end of 1993 (see Figure 1). Note that the price of gold began to rise sharply in April of that year. At the May 18, 1993 meeting of the FOMC (*Federal Reserve Bulletin*, September 1993, p. 864), the significance of movements in unspecified "sensitive commodity prices" was discussed:

[T]he potential for a sustained increase in the rate of inflation could not be dismissed.... Indeed, in one view *sensitive commodity prices* and other key measures of inflation already indicated the need for a prompt move toward restraint.... In the view of a majority of the members, wage and price developments over recent months were sufficiently worrisome to warrant positioning policy for a move toward restraint should signs of intensifying inflation continue to multiply. In addition to new information on prices and costs, such signs could include developments in markets affected by inflation psychology, such as those for bonds, foreign exchange, and *sensitive commodities*, all of which need to be monitored carefully (emphasis added).

Two months later, on July 7, Governor Wayne Angell referred specifically to gold in continuing to press for "a prompt move to tighten policy" (*Federal Reserve Bulletin*, October 1993, p. 947):

[M]onetary policy was overly expansive at this point as evidenced by ... excessive liquidity in financial markets.... Given indications of worsening inflationary expectations, such as the substantial rise in the *price of gold*, as well as projections of an increase in inflation, a policy that led to a steady federal funds rate in fact implied a further easing of an already stimulative monetary policy (emphasis added).

Angell's view was again evident at the meeting of December 21 (*Federal Reserve Bulletin*, April 1994, p. 320), where the minutes note that

broad indexes of consumer and producer prices pointed to little change in inflation trends, although *prices of some commodities* and industrial materials had firmed recently.... [Furthermore,] the firming of some commodity prices tended to push up longer-term interest rates (p. 317).... [I]n the view of some members, the rise in long-term interest rates *and in gold prices* might well have been caused in part by heightened inflation concerns.... Despite the absence of any general indication of rising inflation, a number of members expressed concern about the potential for increasing inflationary pressures in the economy and saw a need to monitor possible future sources of inflation with special care over the period ahead, especially in light of the considerable lags between monetary policy actions and their effects on prices....

Looking forward, many of the members commented that the Committee probably would have to firm reserve conditions at some point to adjust monetary policy from its currently quite accommodative stance to a more neutral position, and that such a policy move might have to be made sooner rather than later to contain inflation.... The low level of real short-term interest rates and in the view of some members the continued rapid growth of reserves or *increases in a variety of commodity prices* provided evidence of a quite accommodative monetary policy (emphasis added).

Although it is unclear how influential Angell's view were in promoting monetary policy, Alan Greenspan, whose influence cannot be denied, is also on record supporting a role for gold. In a statement before the House of Representatives in December 1987 (*Federal Reserve Bulletin*, February 1988, pp. 104-05), he notes

[The] judgement [that a return to the gold standard is ill-advised] is quite consistent with the view that the price of gold should be included along with other commodities as one indicator of global inflation or disinflation. Gold is relevant and useful in that regard wholly because of the historic and widespread perception of gold as an indicator of a flight from currency. However, we must be careful not to interpret every change in the price of gold as meaning that.... As in the case of other commodities, special demand or supply factors need to be considered in connection with the price of gold. Nevertheless, the fact remains that a significant flight from currencies in general without an increase in the price of gold in terms of those currencies is unlikely.

Considered in light of the time series behavior of the federal funds rate and the price of gold, references to "sensitive commodity prices" and gold provide *prima facie* evidence

that gold carried some weight in the formulation of monetary policy. It is nonetheless impossible to assess and quantify the importance of the price of gold relative to other information variables, including prices of other “sensitive” commodities, from a simple reading of the minutes.⁴ Other variables certainly affect monetary policy, and the apparent correspondence between gold and the federal funds rate could reflect the Fed’s response to one or more of these other variables. Also, the causal relation between the price of gold and the federal funds rate might be opposite the one we have suggested: exogenous changes in Fed policy might sponsor private portfolio adjustments, which in turn could affect the price of other assets, including gold. Finally, fluctuations in the fed funds rate could reflect shocks to the demand for bank reserves.

For these and other reasons, further insights on gold and monetary policy require careful identification of the sources of fluctuations in the price of gold, the federal funds rate and total reserves in the context of a dynamic macroeconomic model. Such a model can control for other factors influencing monetary policy, and for the intrinsic dynamics of the economy, and so can serve to better quantify the role of gold in shaping policy.

3. Identifying the response of monetary policy to gold

We formally examine the link between Fed behavior and gold using a linear, dynamic macromodel. We start by estimating the vector autoregressive (VAR) process

$$z_t = \begin{pmatrix} y_t \\ p_t \\ r_t \\ cp_t \\ g_t \\ tr_t \\ fr_t \end{pmatrix}, \text{ where all variables are endogenous, and } y \text{ is a measure of aggregate output,}$$

p is the price level, r is a long-term interest rate, cp is a commodity price index, g is the price of gold, tr represents total bank reserves, and fr is the federal funds rate. These are either variables over which the Fed has direct, though imperfect, control (total reserves

⁴ The well-known study by Romer and Romer (1988) uses anecdotal evidence on policy contractions in a systematic way.

and the federal funds rate), or variables, like the price of gold, that are thought to influence the direction of monetary policy. We identify a simple structural model from the estimated VAR using an approach similar to that of Gordon and Leeper (1994): instead of fully identifying a stochastic, general equilibrium model, we focus on carefully distinguishing monetary policy behavior from other economic decisions. Assume that the economic structure of the model is given by:

$$A_0 z_t = A_1 z_{t-1} + \dots + A_p z_{t-p} + u_t, \quad (1)$$

where u_t is a 7×1 vector of serially uncorrelated, latent exogenous shocks, and $\text{Eu}_t u_t' = \Omega$ is assumed to be diagonal, so that the 7×7 matrix A_0 has a 1 in each of its diagonal elements. The matrices $A_i, i = 0, \dots, p$, 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 are mainly concerned with the final three rows of (1). The fifth row is taken to represent the equilibrium price of gold, so that u_{5t} accounts for exogenous shocks to supply of or demand for gold.⁵ The sixth row represents financial sector demand for total reserves, while the final row is the policy function of the Federal Reserve, that is, the supply of bank reserves.⁶ The final shock, u_{7t} , is interpreted as an exogenous policy shock, such as has been the focus of much empirical analysis in the search for the monetary transmission

⁵ We do not separately identify supply and demand shocks for gold; but this is not a problem for our analysis. Our technique estimates the average response to fluctuations in gold price. To the extent that the Fed sorts supply from demand shocks (the latter being relevant for gold to serve as an indicator of excess liquidity or expected inflation), the average response we estimate will be smaller than if we (and the Fed) knew the source of the shock. However, it is likely that the Fed does not know with certainty the source of fluctuations, and would therefore react instead to shocks to the equilibrium price of gold, on average.

⁶ The supply equation here is a generalization of the regressions reported in Table 1. The choice of the federal funds rate as the “dependent variable” in the policy equation is simply a normalization that implies no particular Fed operating procedure.

mechanism (e.g. Christiano and Eichenbaum, Gordon and Leeper 1994, Bernanke and Mihov 1995, and Lastrapes and Selgin 1995). As in Gordon and Leeper (1994, p.1233), we do not distinguish between borrowed and non-borrowed reserves in identifying policy behavior.

To assess the role of gold, we examine two summary measures of the structural model. The first is the elasticity of monetary policy with respect to changes in the price of gold, as represented by the corresponding coefficient in the final row of A_0 . The second is the dynamic equilibrium response of the reserve market variables to exogenous shocks in the gold price (u_{5t}). These measures are obtained by solving the structural model:

$$z_t = (D_0 + D_1L + D_2L^2 + \dots)u_t = D(L)u_t, \quad (2)$$

where $D_0 = A_0^{-1}$ is nonsingular, and $D(L) = (A_0 - A_1L - A_2L^2 - \dots - A_pL^p)^{-1}$. Thus, $D_k = \frac{\partial z_t}{\partial u_{t-k}}$. 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 uses the price of gold as an indicator for monetary policy, the reserve market should tighten in the face of exogenous positive gold price impulses. This would imply that $\frac{\partial tr_t}{\partial u_{5t-k}} < 0$ and $\frac{\partial fr_t}{\partial u_{5t-k}} > 0$ for some k . The dynamics of the policy response depend on how these multipliers vary with k .

The correspondence between $D(L)$ and the data generating process is not unique. The latter process is:

$$z_t = (I + C_1L + C_2L^2 + \dots)\epsilon_t = C(L)\epsilon_t \quad (3)$$

$$E\epsilon_t\epsilon_t' = \Sigma,$$

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

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

$$\epsilon_t = D_0 u_t.$$

To render the above mapping unique, so that A_0 and $D(L)$ can be identified, we have to impose further restrictions on our model. It is evident from (3) and (4) that

$$\Sigma = D_0 \Omega D_0'. \quad (5)$$

Because Σ is symmetric, there are 28 independent, nonlinear relations between the estimable elements in Σ and the 49 structural parameters in D_0 (and A_0) and Ω . 21 restrictions on the structure are needed to just-identify these parameters. Note again from (4) that knowledge of D_0 is sufficient to estimate $D(L)$.

We consider two models, each employing a somewhat different set of identifying restrictions. Model 1 employs restrictions on reserve supply and demand that are similar to those used by Gordon and Leeper (1994, Table 1, p. 1233):

$$A_0 = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & a_{17} \\ 0 & 1 & 0 & 0 & 0 & 0 & a_{27} \\ a_{31} & a_{32} & 1 & 0 & 0 & 0 & a_{37} \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 & a_{47} \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & 0 & a_{57} \\ a_{61} & a_{62} & 0 & 0 & 0 & 1 & a_{67} \\ 0 & 0 & a_{73} & a_{74} & a_{75} & a_{76} & 1 \end{pmatrix}. \quad (6)$$

In particular, output and the price level do not enter the contemporaneous reserve supply function, while commodity prices, gold and long-term yields do not enter the contemporaneous reserve demand equation. Unlike Gordon and Leeper, we do not restrict the contemporaneous response of the other variables in the system to the federal funds rate, which allows immediate responses to policy shocks.⁷

Model 2 serves to check the robustness of the results from the first model, and utilizes

⁷ Note that our system, unlike that used by Gordon and Leeper, is just-, rather than over-identified. Also, their model includes the unemployment rate, which we drop for parsimony. Including it in our system does not importantly alter our results. Finally, their model does not include the price of gold.

the following set of restrictions:

$$A_0 = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & 0 & a_{57} \\ a_{61} & a_{62} & a_{63} & 0 & 0 & 1 & a_{67} \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & 1 \end{pmatrix}. \quad (7)$$

As in Gordon and Leeper (1994), model 2 recursively orders the the first set of macro variables in the system (excluding gold). However, it imposes no restrictions at all on the Fed's policy reaction function, and thus allows for an *immediate* Fed response to changes in the CPI and real output. This model also allows for, but does not require, some relation between reserve demand and the long-term interest rate, and between the price level and output. Like model 1, model 2 is just-identified.

4. Data, estimation, results

We estimate both VAR models using monthly data from December 1982 to November 1995.⁸ A common lag of 6 is employed to whiten the residuals, and a constant and seasonal dummies are included to allow for a deterministic component. All variables are transformed into natural logs except the interest rate series. Because we estimate in levels, we do not have to examine the unit root and cointegration properties of the system.

Given the OLS estimates of the reduced form covariance matrix, the free parameters in A_0 and Ω are estimated by maximizing the log likelihood (see Hamilton 1994)

$$L(\hat{\Sigma}, A_0, \Omega) = -\frac{Tn}{2} \log 2\pi + \frac{T}{2} \log |A_0|^2 - \frac{T}{2} \log |\Omega| - \frac{T}{2} \text{trace}[(A_0' \Omega^{-1} A_0) \hat{\Sigma}]. \quad (8)$$

⁸ Output is proxied by the seasonally adjusted industrial production index, the price level is the consumer price index (all items, all urban), the interest rate is the 10-year treasury rate (constant maturity), commodity prices are proxied by the producer price index for all commodities, and total reserves are seasonally adjusted and adjusted for changes in reserve requirements. Gold prices and the federal funds rate are as defined above. We obtained all data except gold prices from the St. Louis Federal Reserve Bank's Electronic Data Base (<http://www.stls.frb.org/>).

The Berndt, Hall, Hall and Hausman algorithm is used to numerically optimize the function. Since the structural model is just-identified, global optimization is ensured by verifying that the value of the likelihood function after estimating A_0 and Ω is identical to that from the OLS estimation of the VAR.

Tables 2 and 3 report coefficient estimates (with corresponding t-statistics and p-values) for the final row of A_0 for models 1 and 2 respectively. With one exception, the coefficients measure the response of the federal funds rate, in annualized basis points, to a one percent change in the explanatory variable, and so represent semi-elasticities of the reserve supply equation. (The exception is the coefficient for the long-term interest rate, which represents the basis point response of the federal funds rate to a ten basis point change in the long-term yield). In model 1, the estimated slope of the reserve supply equation (a_{76}) implies that a 74 basis point rise in the federal funds rate induces a one percent increase in the supply of total reserves, *ceteris paribus*, which is of the same order of magnitude as Gordon and Leeper's (1994) estimate. As for the gold price coefficient (a_{75}), it has a negative sign (as the hypothesized role of gold would suggest) but is small: a one percent rise in the gold price leads to a 1.7 basis point rise in the federal funds rate (holding the stock of reserves fixed). Finally, the commodity price and interest rate coefficients are also negative, the former being much larger in absolute value than the gold price coefficient. Only the coefficient on total reserves is statistically different from zero at typical levels of significance.

In model 2, the impact of gold on reserve supply is slightly smaller than in model 1, and does not appear to be statistically different from zero. The other coefficients generally are of the same order of magnitude as those in the first model, except possibly for the slope coefficient (a_{76}), but are more precisely estimated. Despite the counterintuitive sign on the CPI coefficient, the general inference from the contemporaneous elasticities is robust to the alternative specification.

Although the above findings imply at most only a small contemporaneous Fed response

to changes in gold's price, changes in the price of gold may nonetheless have an important delayed effect on monetary policy, as suggested in section 2. Figure 2 shows estimated dynamic response functions of the last four variables in model 1 to standard-deviation structural impulses to the commodity price index (u_4), the gold price (u_5), the demand for reserves (u_6) and the supply of reserves (u_7). Figure 3 shows the same response function estimates for model 2. Each figure includes standard error bands computed from a Monte Carlo simulation using antithetic acceleration techniques.⁹ Bear in mind that these are *equilibrium* responses to exogenous impulses.

Our principal concern is with the last two rows of the second column in each figure, which show the dynamic response of the monetary policy variables to equilibrium gold price shocks. The response functions are robust across the two models. A positive gold price shock that causes gold price to rise by 2 percent on impact causes a gradual increase in the federal funds rate of almost 10 basis points after about 12 months, and a gradual reduction in the stock of bank reserves. These delayed effects are significantly different from zero according to the simulated error bands. These findings imply that the Fed, on average, does in fact alter reserve supply in response to a change in the price of gold, albeit mainly after the change is seen to persist for several months. Also, the gold price tends to revert to its former level following a shock in the gold market (see figures 1 and 2, row 2, column 2), implying gold price stability in the face of these shocks.

The Fed's dynamic response to a commodity price shock is similar to its response to a gold price shock (column 1, rows 3 and 4 in the figures). However, the Fed's response to commodity price movements is both more substantial and more immediate.¹⁰ The relative importance of both kinds of price shocks in shaping Fed policy may be better gauged by

⁹ The simulations entail 500 replications. At each replication, A_0 and Ω are reestimated according to equation (8). Sims and Zha (1994) provide an alternative simulation procedure.

¹⁰ The lack of any immediate response of reserves to either a gold price or a commodity price shock suggests an inelastic short-run demand for reserves. See Strongin (1995).

looking at the forecast error variance decompositions shown in Tables 4 and 5. Commodity price shocks generally explain a larger part of variations in reserve market variables than do gold price shocks. Still, the latter shocks account for a far-from-trivial 10 to 13 percent of variations in total reserves and the federal funds rate at intermediate horizons.

Because the dynamic responses are equilibrium responses, the dynamic estimates noted above are consistent with the possibility that gold price shocks lead to a rise in the commodity price index, and the Fed reacts only to the commodity price index. That is, it might be that the measured response of policy to gold is an indirect effect, and that gold has no independent role in policy formation. However, note from the first row of the second column that commodity prices respond *negatively* in the short-run to gold shocks. It is also clear that gold's effect is not due primarily to shifts in the *demand* for reserves, since this would lead to a positive comovement between the equilibrium response of reserves and the federal funds rate. Our evidence, therefore, supports the claim that gold has played an independent role in formulating monetary policy.

Finally, as a check on proper identification, Figures 4 and 5 report the response functions, with simulated standard errors, of output, the price level and the long-term yield to money market shocks (u_6 and u_7), for models 1 and 2 respectively. For each model, output falls over intermediate horizons in response to an exogenous tightening in the reserve markets. The price level falls for model 1, but it is ambiguous under model 2. Counter-intuitively, the long-term yield *falls* initially for each model; however, Gordon and Leeper (1994) also find little evidence of such a liquidity effect for long-term rates. Overall, given especially the plausibility of the responses of model 1, these results do not contradict our claims regarding the response of monetary policy to gold price shocks.

5. Conclusion

Our findings suggest that, while the Fed may rely on other “sensitive” commodity prices as primary indicators of excess monetary liquidity, gold has played an independent

role in the formulation of monetary policy since the early 1980's. This conclusion is supported by anecdotal evidence as well as by evidence from a formal statistical model. This does not necessarily mean that the Fed "targets" the price of gold, or focuses solely on sensitive commodity prices to guide policy; still, Fed behavior does seem to have served to limit variations in the price of gold.

References

- Bernanke, Ben. "Alternative Explanations of the Money-income Correlation." *Carnegie-Rochester Conference Series on Public Policy*, 1986, 25, 49-100.
- Bernanke, Ben and Alan Blinder "The Federal Funds Rate and the Channels of Monetary Transmission," *American Economic Review*, September 1992, 82, 901-21.
- Bernanke, Ben and Ilian Mihov. "Measuring Monetary Policy," Working Paper No. 5145, National Bureau of Economic Research, June 1995.
- Blanchard, Olivier J., and Danny Quah. "The Dynamic Effects of Aggregate Demand and Supply Disturbances." *American Economic Review*, September 1989, 79, 655-73.
- Christiano, Lawrence J. and Martin Eichenbaum, "Identification and the Liquidity Effect of a Monetary Shock," in A. Cuikerman, L.Z. Hercowitz, and L. Leiderman, eds., *Business Cycles, Growth and Political Economy*, Cambridge, MA: MIT Press, 1992a.
- Christiano, Lawrence J. and Martin Eichenbaum, "Liquidity Effects and the Monetary Transmission Mechanism," *American Economic Review*, May 1992b, 82, 346-353.
- Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans. "The Effects of Monetary Policy Shocks: Evidence from the Flow of Funds," Federal Reserve Bank of Chicago Working Paper 94-2, March 1994.
- Cochrane, John H. "The Return of the Liquidity Effect: A Study of the Short-Run Relation Between Money Growth and Interest Rates," *Journal of Business and Economic Statistics*, January 1989, 7, 75-83.
- Cody, Brian J. and Leonard O. Mills. "The Role of Commodity Prices in Formulating Monetary Policy," *The Review of Economics and Statistics*, May 1991, 63, 358-65.
- Forbes, Malcolm S. Jr. "Is Gold Running the Fed?" *Forbes*, October 14, 1991, 25.
- Frank, Murray and Thanasis Stengos, "Measuring the Strangeness of Gold and Silver Rates of Return," *Review of Economic Studies*, 1989, 56, 553-67.
- Furlong, Frederick T. "Commodity Prices as a Guide for Monetary Policy," *Federal Reserve*

- Bank of San Francisco Economic Review*, Winter 1989, 21-38.
- Giannini, Carlo. *Topics in Structural VAR Econometrics*, Springer-Verlag, 1992.
- Gordon, Donald B. and Eric M. Leeper, “The Dynamic Impacts of Monetary Policy: An Exercise in Tentative Identification,” *Journal of Political Economy* December 1994, 1228-47.
- Hamilton, James D. *Time Series Analysis*, Princeton, NJ: Princeton University Press, 1994.
- Khoury, Salwa S. “The Federal Reserve Reaction Function: A Specification Search,” in Thomas Mayer (editor), *The Political Economy of American Monetary Policy*, Cambridge: Cambridge University Press, 1990.
- Lastrapes, William D., and George Selgin “The Liquidity Effect: Identifying Short-Run Interest Rate Dynamics using Long-Run Restrictions,” *Journal of Macroeconomics*, Summer 1995, 17, 387-404.
- Laurent, Robert D. “Is There a Role for Gold in Monetary Policy?” *Federal Reserve Bank of Chicago Economic Perspectives*, March/April 1994, 2-14.
- Moore, Geoffrey H. “Gold Prices and a Leading Index of Inflation,” *Challenge*, July/August 1990, 52-56.
- Sims, Christopher A., “Are Forecasting Models Usable for Policy Analysis?” *Federal Reserve Bank of Minneapolis Quarterly Review*, Winter 1986, 10, 2-24.
- Solt, Michael E. and Paul J. Swanson. “On the Efficiency of the Markets for Gold and Silver,” *Journal of Business*, 1981, 54, 453-78.
- Sims, Christopher A. and Tao Zha. “Does Monetary Policy Generate Recessions?: Using Less Aggregated Price Data to Identify Monetary Policy?” manuscript, December 1994.
- Strongin, Steven “The Identification of Monetary Policy Disturbances: Explaining the Liquidity Puzzle,” *Journal of Monetary Economics*, 35(3) August 1995, 463-97.
- Thornton, Daniel L. “The Borrowed-Reserves Operating Procedure: Theory and Evi-

dence,” *Federal Reserve Bank of St. Louis Review*, Jan/Feb 1988, 70 30-54.

Ullmann, Owen. “Why Greenspan Has a Touch of Gold Fever,” *Business Week*, March 7, 1994, 44.

Table 1. Estimated coefficients characterizing the relationship between the federal funds rate and gold

	coeff.	t-stat.	p
<i>Constant</i>	-0.067	-2.15	0.033
<i>Dummy</i>	0.1187	2.61	0.010
FFR_{t-1}	0.377	4.56	0.000
FFR_{t-2}	0.0297	0.34	0.735
FFR_{t-3}	0.0087	0.09	0.922
FFR_{t-4}	-0.1237	-1.42	0.158
FFR_{t-5}	0.131	1.49	0.137
FFR_{t-6}	-0.038	-0.47	0.637

	coeff.	t-stat.	p
<i>Constant</i>	-0.061	-1.42	0.157
<i>Dummy</i>	0.100	1.43	0.154
FFR_{t-1}	0.341	4.07	0.00
FFR_{t-2}	0.030	0.34	0.737
FFR_{t-3}	0.017	0.19	0.846
FFR_{t-4}	-0.123	-1.37	0.171
FFR_{t-5}	0.108	1.20	0.230
FFR_{t-6}	-0.081	-0.96	0.339
$(G - \overline{G})_t$	-0.331	-0.48	0.632
$(G - \overline{G})_{t-1}$	-0.378	-0.46	0.647
$(G - \overline{G})_{t-2}$	0.556	0.69	0.492
$(G - \overline{G})_{t-3}$	1.305	1.67	0.097
$(G - \overline{G})_{t-4}$	-0.749	-0.98	0.328
$(G - \overline{G})_{t-5}$	-0.387	-0.50	0.617
$(G - \overline{G})_{t-6}$	0.256	0.45	0.656

Notes: FFR_t denotes the federal funds rate at time t ; $(G - \overline{G})_t$ denotes the percentage deviation of the gold price from its sample mean. *Dummy* is zero when the price of gold exceeds its sample mean and one otherwise; p denotes the marginal significance level of the corresponding t-statistic.

**Table 2. Estimated coefficients of the reserve supply equation
Model 1**

	coeff.	t-stat.	p
a_{73} (r)	-1.50	-0.51	0.61
a_{74} (cp)	-18.93	-1.11	0.26
a_{75} (g)	-1.70	-0.89	0.37
a_{76} (tr)	-73.63	-4.19	0.00

Notes: For each coefficient except a_{73} , estimates are basis point response to one percent change in the independent variable. For a_{73} , the estimate is the basis point response of the federal funds rate to a ten basis point change in the long-term bond yield. p denotes the marginal significance level of the corresponding t-statistic.

**Table 3. Estimated coefficients of the reserve supply equation
Model 2**

	coeff.	t-stat.	p
a_{71} (y)	-7.55	-1.39	0.16
a_{72} (P)	44.13	1.54	0.13
a_{73} (r)	-2.22	-1.74	0.08
a_{74} (cp)	-17.66	-2.16	0.03
a_{75} (g)	-1.59	-0.75	0.45
a_{76} (tr)	-14.85	-1.34	0.18

Table 4. Variance decompositions (percent): Model 1

horizon	u_1	u_2	u_3	u_4^*	u_5^{**}	u_6	u_7
Total Reserves							
1	0.02	9.13	0.65	0.74	0.31	86.96	2.20
2	0.01	12.80	1.70	1.56	1.58	81.22	1.13
3	3.14	10.38	5.74	2.41	1.35	75.83	1.15
4	7.23	8.52	12.97	1.91	1.16	66.42	1.80
12	19.58	14.26	33.70	7.32	1.00	19.32	4.84
24	22.92	13.63	19.02	25.61	5.28	8.33	5.20
36	20.37	11.93	14.98	30.62	11.09	6.63	4.38
48	18.30	19.28	13.87	26.62	10.72	5.60	5.62
Federal Funds Rate							
1	0.84	43.97	8.88	10.11	4.29	1.72	30.20
2	3.04	44.40	15.20	9.97	2.06	0.66	24.66
3	5.47	42.46	19.59	11.37	1.51	0.54	19.07
4	8.19	42.09	21.02	11.98	1.72	0.57	14.43
12	34.25	19.23	13.50	17.95	7.60	2.33	5.14
24	37.90	13.03	9.12	23.21	11.39	1.83	3.53
36	35.24	16.86	9.86	21.68	10.95	2.00	3.40
48	34.24	18.74	8.44	23.58	9.77	1.98	3.24

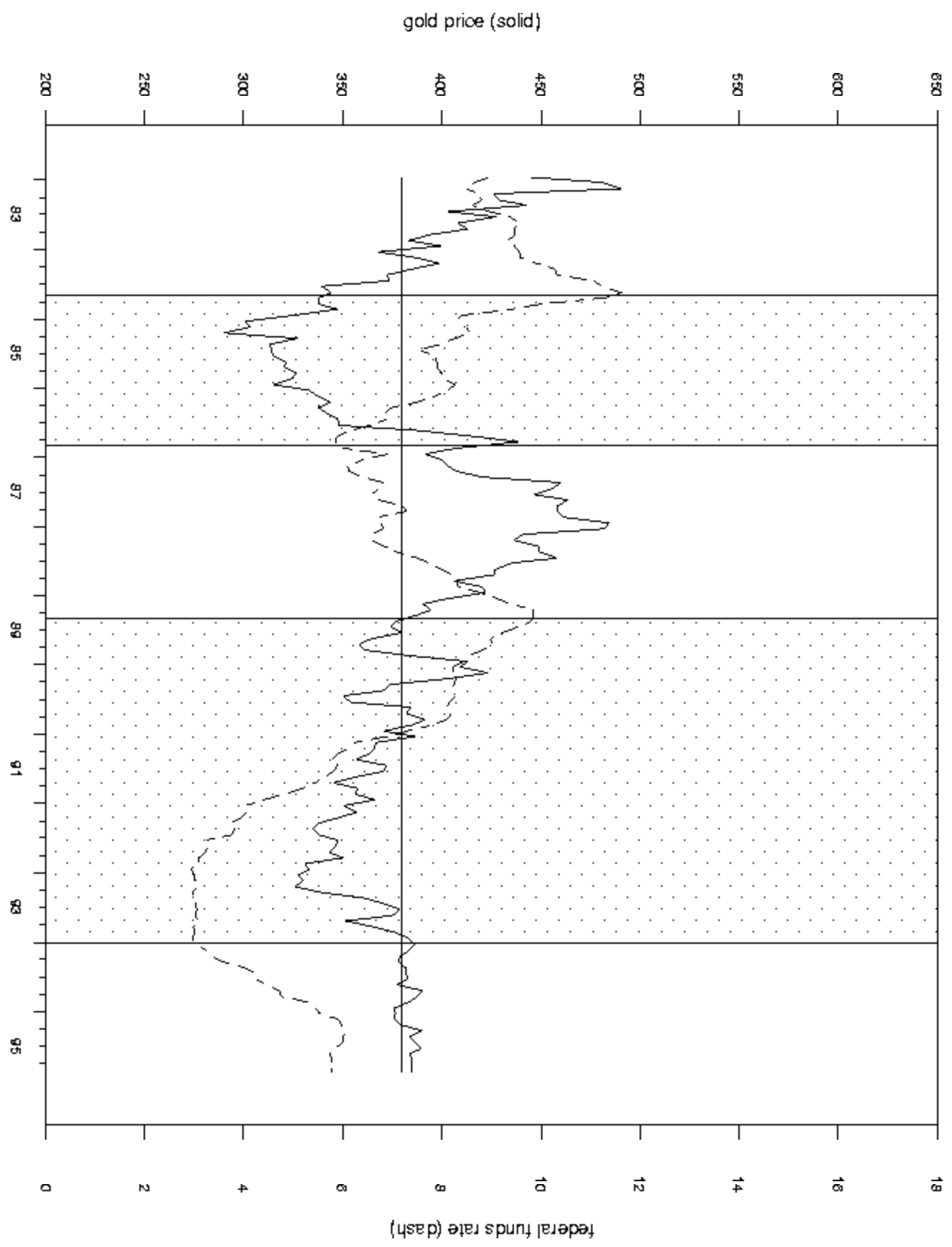
Notes: * commodity price shock; ** gold price shock.

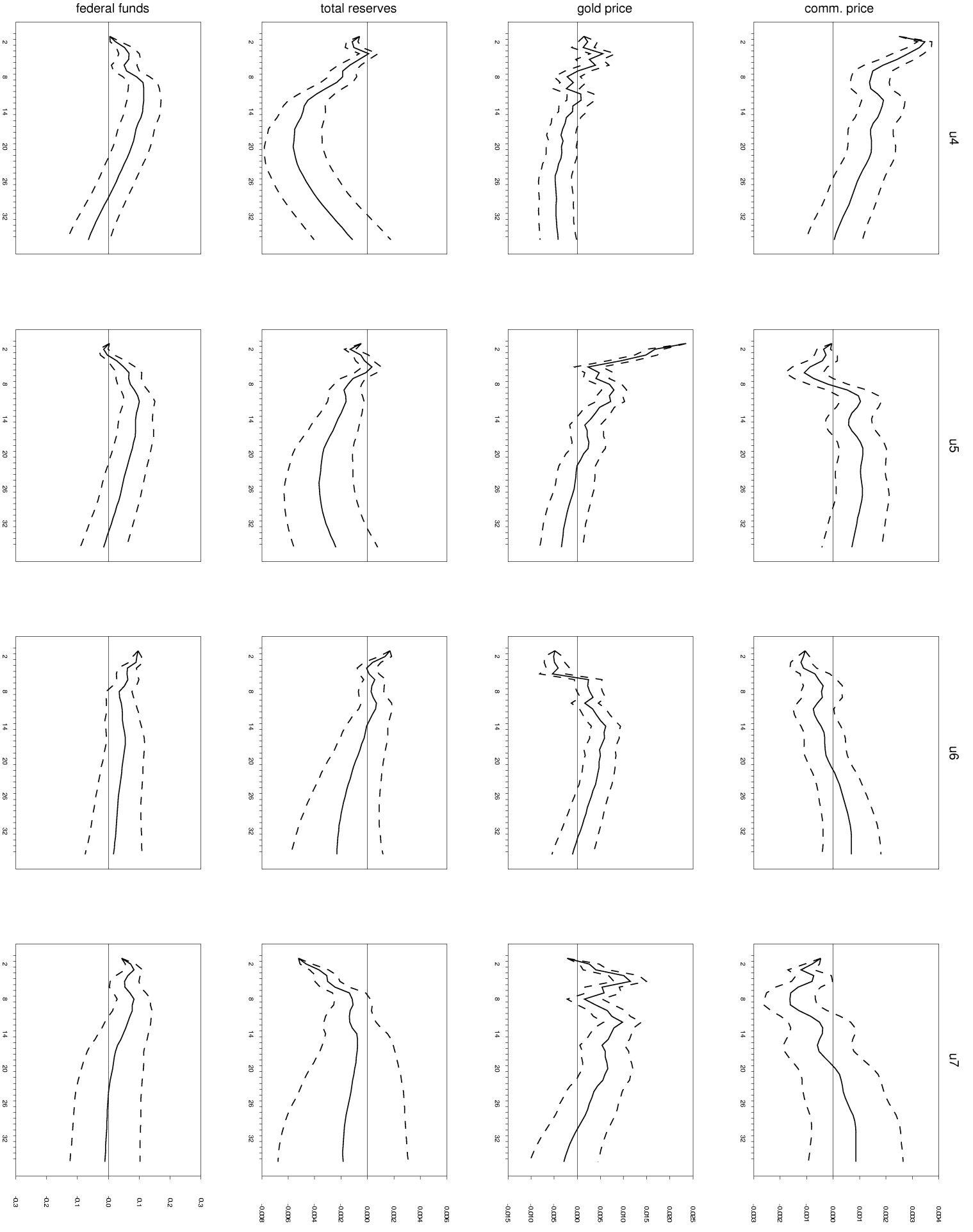
Table 5. Variance decompositions (percent): Model 2

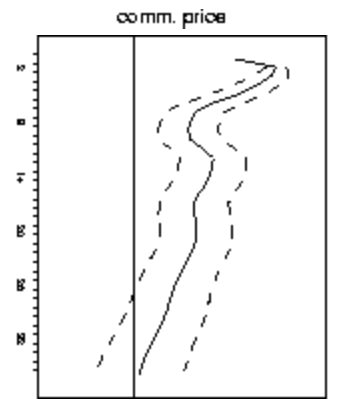
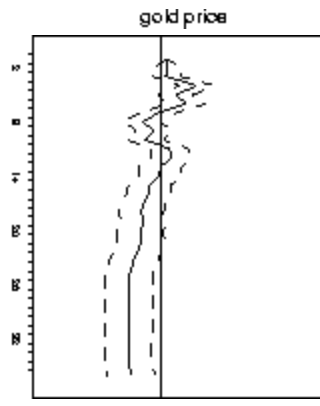
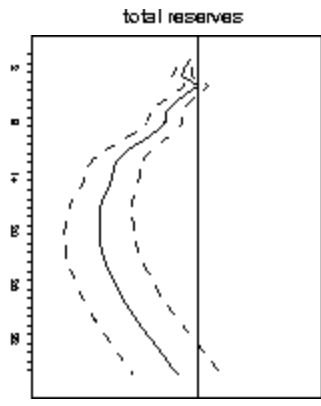
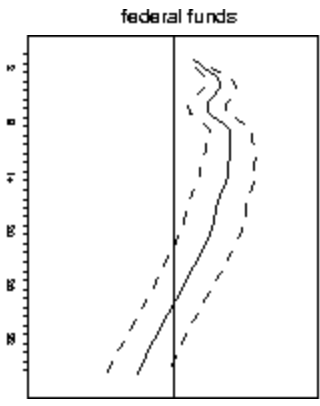
horizon	u_1	u_2	u_3	u_4^*	u_5^{**}	u_6	u_7
Total Reserves							
1	0.19	7.13	0.11	0.37	0.22	86.55	5.42
2	0.15	9.86	0.64	1.12	1.63	83.54	3.06
3	3.35	9.34	3.66	1.81	1.39	76.94	3.50
4	8.39	7.61	10.32	1.44	1.17	65.89	5.19
12	24.59	5.41	36.38	12.05	3.03	16.27	2.27
24	29.06	3.66	20.09	30.42	9.23	6.28	1.27
36	25.77	6.29	16.76	31.22	13.73	4.92	1.31
48	23.41	13.81	17.17	27.99	12.17	4.25	1.20
Federal Funds Rate							
1	6.42	1.78	6.46	4.44	2.58	14.02	64.30
2	10.56	2.56	12.87	5.56	1.22	8.56	58.67
3	14.19	2.69	17.31	7.71	1.05	5.81	51.25
4	17.72	3.53	19.32	9.31	1.70	4.45	43.98
12	42.76	2.09	11.77	14.25	8.07	2.83	18.22
24	44.90	3.06	8.28	17.72	11.63	2.14	12.27
36	42.10	6.12	10.16	17.27	10.91	1.94	11.49
48	41.54	6.57	8.85	21.33	10.74	1.50	9.47

Notes: * commodity price shock; ** gold price shock.

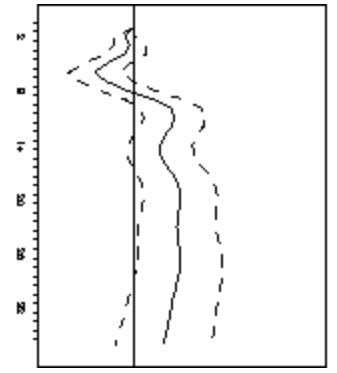
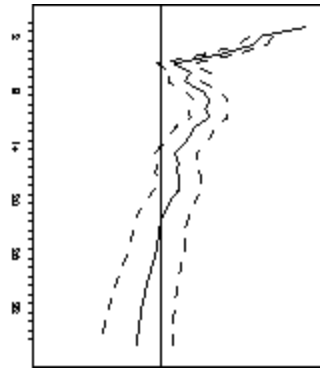
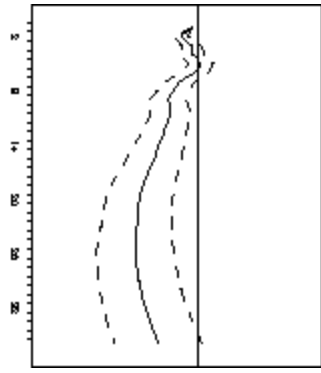
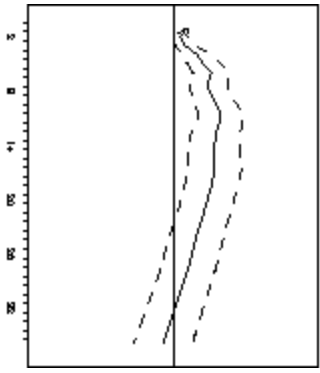
Figure 1. Gold price and federal funds rate



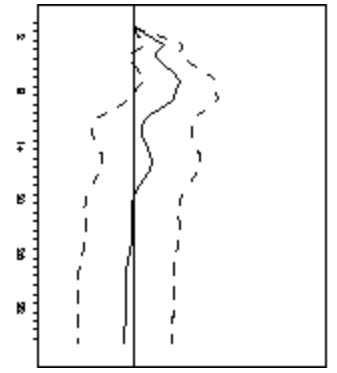
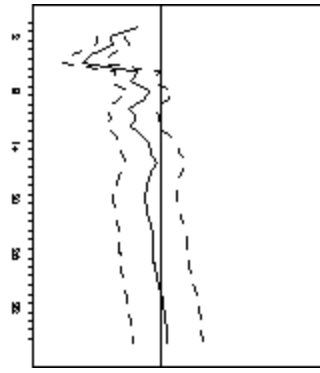
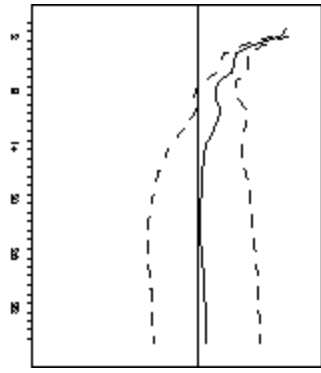
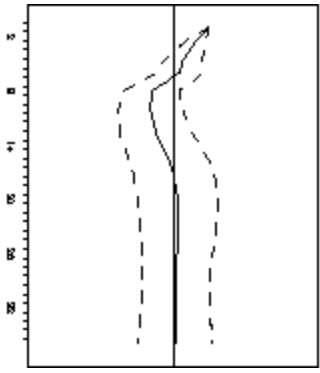




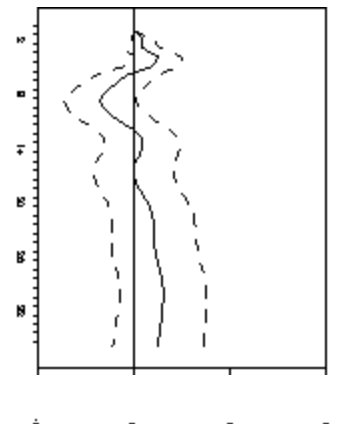
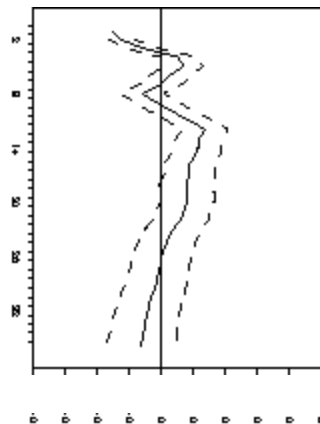
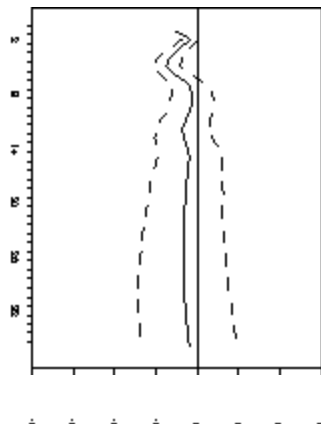
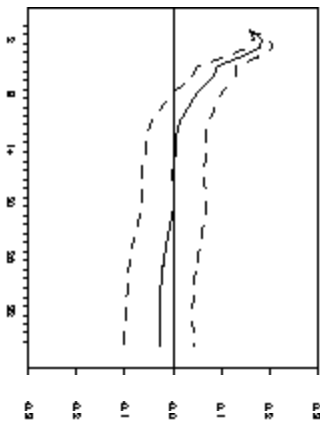
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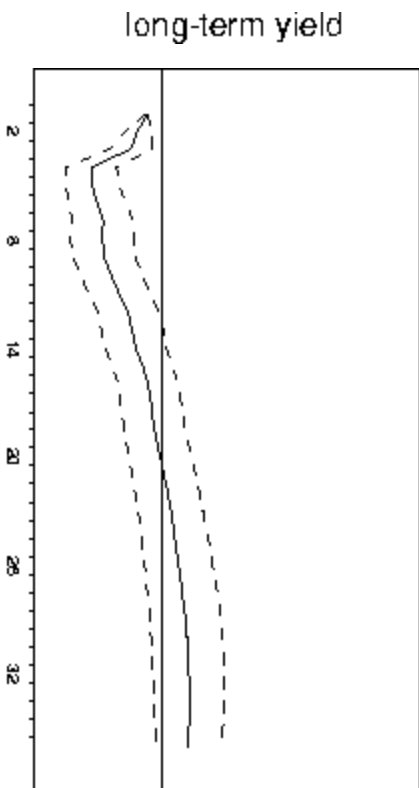
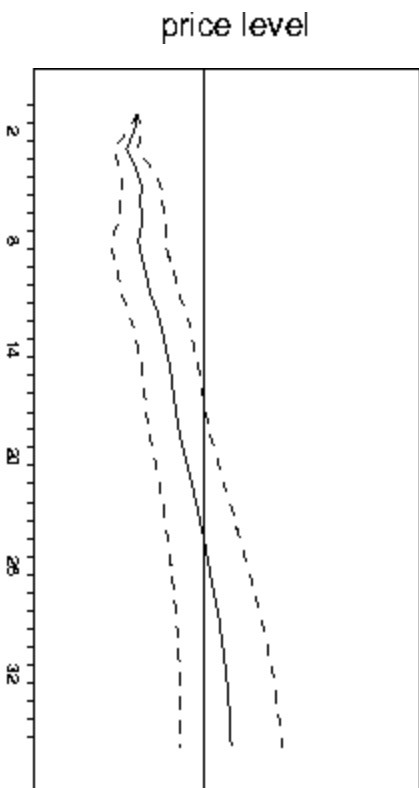
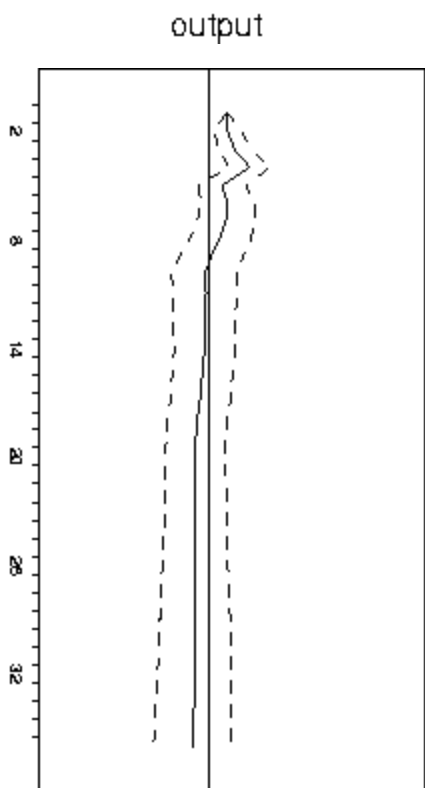


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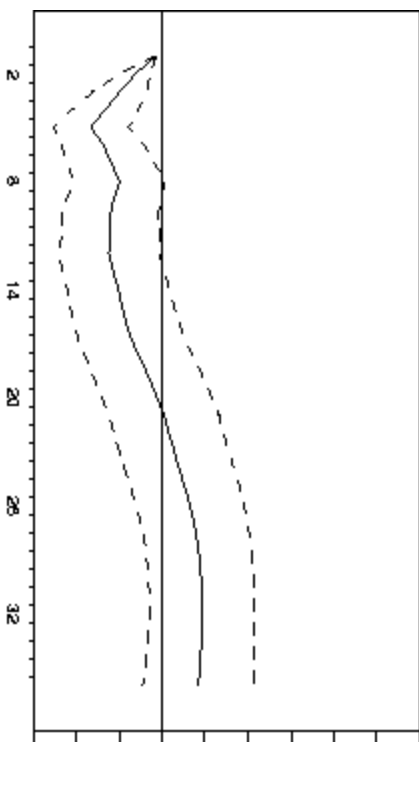
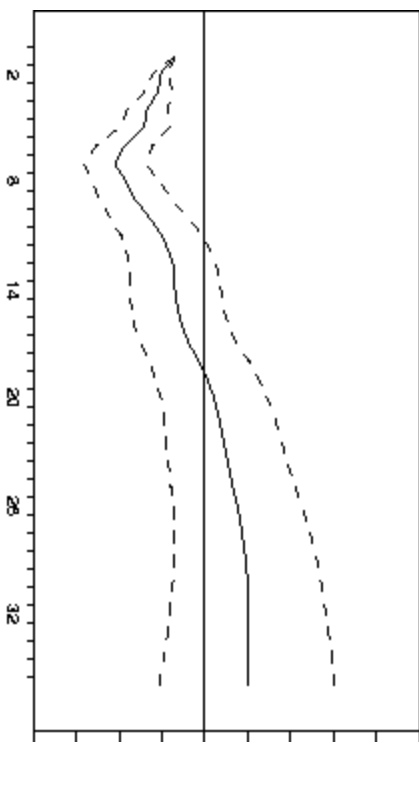
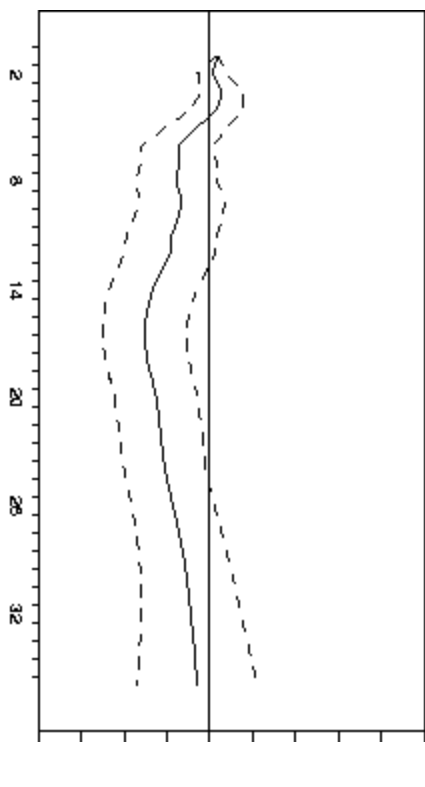


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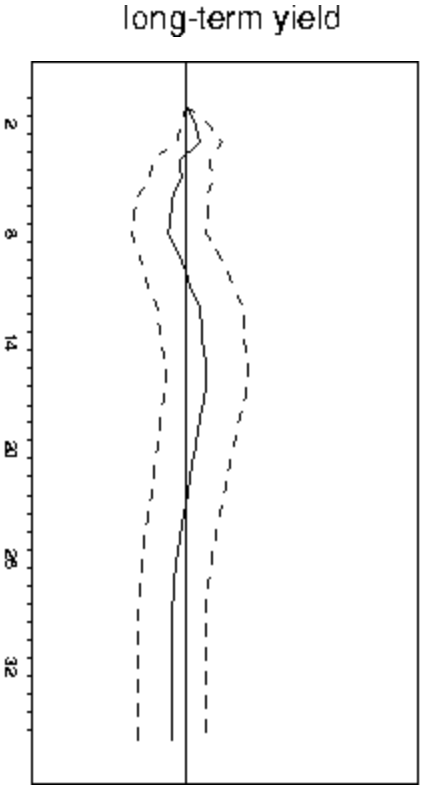
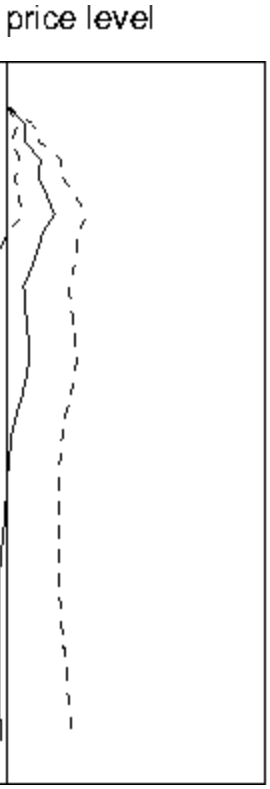
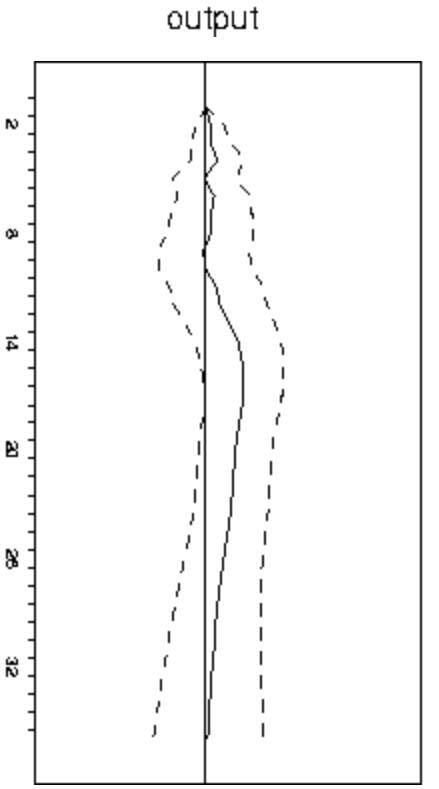


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