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Reducing Our Ignorance about Monetary Policy Effects

Eric M. Leeper

The business pages of leading newspapers give the impression that the effects of monetary policy on the macroeconomy are well understood and predictable. Newspapers write with great certainty that when the Fed raises interest rates it "slows economic growth, and with it inflation" (Louis Uchitelle 1994), "bidding down stocks and bonds" (Anthony Ramirez 1994). With equal certainty, press accounts report that monetary policy responds to economic conditions: "The recent strength of the U.S. economy will continue in the first quarter, prompting the Federal Reserve to raise short-term interest rates as a preemptive strike against inflation" (Fred R. Bleakley 1994). With the economy responding to policy and policy responding to the economy, it is hard to tell what causes what. Far from the certainty with which economic journalists write, our knowledge is limited by these difficulties in sorting out causal factors in the data. Monetary policy effects are neither well understood nor easily predicted.

Evaluations of how monetary policy influences the economy differ, but particular elements are common to all. Each embodies particular views about (1) the current stance of monetary policy (whether it is "tight" or "loose"); (2) how the monetary authority behaves, including what it is trying to achieve and what it is doing to pursue its goals (its "reaction function"); and (3) how the private sector responds to current and expected future monetary policy (the "propagation mechanism of policy"). Pundits frequently blend these views to arrive at a Goldilocks-like assessment that policy is

This article was written while the author was a research officer in the macropolicy section of the Atlanta Fed's research department. He is currently on the faculty in the department of economics at Indiana University. The article draws heavily on work by David B. Gordon and the author (1993, 1994). The author thanks Jon Faust, Dave Gordon, and especially Will Roberds and Tao Zha for helpful discussions.

"too tight" or "too loose" or "just right"—though the last assessment is rare. For example, Jerry Jasinowski, president of the National Association of Manufacturers, declared in September 1994 that "one more rate increase by the Federal Reserve will drive the economy into a ditch, bringing on a recession" (quoted in Uchitelle 1994).

Putting these three things together, objective observers of monetary policy form a conclusion about the extent to which monetary policy has caused current economic conditions. These observers allocate some portion of the movements of variables to policy and the rest to nonpolicy factors. For example, if lower inflation and lower economic growth follow rising short-term interest rates, observers might conclude that the monetary authority wanted to slow down the economy (point 2 above), so it "tightened" policy by raising interest rates (point 1), causing economic activity to decline and easing upward pressure on prices (point 3).

Of course, during this period more than just monetary policy would have been impinging on the economy and affecting private decisions. Observers implicitly filter out the influences of other factors, however, leaving only the impacts of monetary policy. How can the plausibility of such an approach be evaluated? The process of attributing particular movements in variables to particular changes in economic behavior is called identification, a process applied—with varying degrees of sophistication and explicitness—whenever data are interpreted in terms of economic behavior. Identification can be a contentious matter because there is no single "correct" view of how the economy works.

This article illustrates the role that identification plays in policy analysis. Even though most economists agree on the qualitative effects of monetary policy, they disagree on its quantitative importance. The differences of opinion allow consensus and conflict to coexist, as the article explains. Despite the lack of consensus about monetary policy's quantitative impacts, monetary policy advisors must interpret economic developments and formulate policy advice. One approach is to specify and estimate a model of policy and private behavior. At a minimum such a model should include behavior in the market for bank reserves because monetary policy affects the economy initially through changes in the supply of reserves. Before turning to the data, therefore, the article discusses supply-and-demand behavior in the market for reserves.

A central theme of this article is that identifying monetary policy effects is a tricky business. Different but seemingly reasonable identifications can imply wildly different policy effects, including perverse ones, as is shown in the article's presentation of five models of private and monetary policy behavior in the United States. The models specified and estimated differ only in terms of their assumptions about how current economic decisions depend on current variables; dependence on past economic variables is the same across the models. Identical policy experiments—an unanticipated one-time monetary policy contraction—were performed in each model, with the results showing different qualitative and quantitative effects of policy from one model to the next. A policy advisor's interpretations of economic developments would therefore differ across models. In practice an advisor must rank the models according to their plausibility, and this article considers a variety of schemes for ranking them.

The diversity of results presented below might lead one to conclude that the impacts of monetary policy are largely unknown—and perhaps unknowable. However, by combining economic reasoning with careful data analysis it seems possible to reduce our ignorance about monetary policy effects.

Consensus and Conflict

A remarkably strong consensus exists among policymakers, business economists, and academic economists about many of the qualitative effects of a monetary policy expansion. To paraphrase Milton Friedman (1968), increasing the quantity of money at a faster rate than it had been increasing (a) initially lowers short-term nominal and real (inflation-adjusted) interest rates (the "liquidity effect"); (b) stimulates spending through the impact of lower interest rates on investment and other spending, which raises income; (c) increases production and lowers unemployment, at least temporarily; and (d) raises overall prices. As the demand for liquidity rises with incomes and as prices rise, the initial decline in interest rates will be reversed and rates will return to their initial levels. If money growth increases permanently, as people come to expect that prices will continue to rise, borrowers will be willing to pay and lenders will demand higher nominal interest rates. The higher rate of monetary growth will result in higher interest rates (the "expected inflation effect"). This synopsis of monetary policy effects, while credited to Friedman, accurately reflects the views held by economists of almost all stripes.

Economists disagree, however, about the quantitative importance of monetary policy. Some believe that "erratic" monetary policy plays a substantial role in generating business cycle fluctuations. Among writers before World War II, Irving Fisher (1931), R.G. Hawtrey (1934), Friedrich A. Hayek (1934), Ludwig von Mises ([1934] 1980), and Lionel Robbins (1934) were important contributors to this view. Since the war, prominent examples are Friedman (1960, 1968, 1970), Friedman and Anna J. Schwartz (1963), Friedman and David Meiselman (1963), Robert E. Lucas, Jr. (1987), and Christopher A. Sims (1972). Economists like James Tobin (1980) credit policy, including monetary policy, with reducing the amplitude of business cycle fluctuations since World War II. Both assessments embrace the view that monetary policy has powerful effects.[1]

Over the years other respected economists have staked out the opposite turf, arguing that monetary policy is all but impotent. During the Great Depression many believed that monetary policy was helpless. If at very low interest rates and high levels of unemployment the demand for liquidity is insensitive to changes in interest rates, then monetary policy cannot affect rates. If in addition consumption and investment demand are also insensitive to the interest rate, then even if monetary policy could change interest rates, it would do little good. As Friedman described it, this view held that "monetary policy was a string. You could pull on it to stop inflation but you could not push on it to halt recession" (1968, 1). In the 1950s and 1960s some theorists emphasized "real" causes of business cycles, relegating monetary policy to a purely passive role. (See examples in Robert Aaron Gordon and Lawrence R. Klein 1965.[2]) At the same time there was much debate about whether monetary or fiscal policy was the more potent tool. (See, for example, Albert Ando and Franco Modigliani 1965, Leonall C. Andersen and Jerry L. Jordan 1968, Friedman and Walter W. Heller 1969, and Bennett T. McCallum 1986.)

Many modern business cycle theorists, following Finn E. Kydland and Edward C. Prescott (1982), attribute the vast majority of output and employment fluctuations to shifts in technological innovation and productivity that are unrelated to monetary policy. Robert G. King and Charles I. Plosser (1984) identify correlations between money and economic activity as arising entirely from a passive response of the monetary sector to real economic activity. The view that unanticipated changes in monetary policy have had little influence on the macroeconomy has found a modern empirical voice in work by Sims (1980b, 1989) and Sims and Tao Zha (1994).

One reason that economists might agree on the qualitative effects of policy while they disagree on its quantitative importance is that they view economic data through very different economic lenses. Beliefs about qualitative effects stem largely from controlled monetary policy experiments conducted in theoretical models. A controlled experiment holds everything in the model fixed except monetary policy, which is changed in some known way. Policy effects are inferred by comparing the model's economy before and after the experiment. A wide variety of traditional theoretical models make similar predictions about policy effects, and a consensus of opinion has formed around those predictions.

To formulate a policy recommendation an advisor needs a model that both provides an unambiguous economic interpretation of past data and forecasts future data well.

Measuring quantitative effects is a trickier business as it involves the process of identification referred to earlier. A set of identifying assumptions amounts to using a model economy to interpret the actual economy. In the actual economy a number of things are changing simultaneously. To have data mimic the theoretical thought experiment, all kinds of identifying assumptions about behavior must be made, assumptions that serve to control for the fact that many things are changing at once. Because private-sector decisions depend on policy choices and vice versa, there is no universally accepted way to construct the empirical analog to the controlled policy experiment. With much room for differing views of how best to proceed, there is much room for differing beliefs about the quantitative importance of monetary policy.

Intellectual quagmires notwithstanding, policy decisions are made regularly. These decisions are likely to be most effective if they are based on some internally consistent view of how monetary policy choices will affect the economy. Toward that end, this article considers several different identifications of monetary policy and private-sector behavior. Because each identification, or model, makes different assumptions about behavior, each one conducts the empirical experiment of changing monetary policy, holding all else fixed, differently. And as a consequence, each identification carries different predictions about the effects of a monetary policy shift. The models are constructed with an eye toward developing tools that might be useful in advising monetary policymakers.

The Problem Facing a Policy Advisor

Consider the situation facing a monetary policy advisor in the United States in the beginning of the summer of 1995. Chart 1 reports recent data through May 1995 on reserves market variables and variables the Fed wants to influence. These are the data available to the advisor as of mid-June. The Fed raised the funds rate target from 3 percent to 6 percent between February 1994 and March 1995 and brought the annual growth of reserves from positive double digits to negative rates. Inflation hovered around 3 percent, as it did in 1992 and the first half of 1993. Output growth, as measured by industrial production, fell from its high level the previous year, and unemployment stopped the steady decline it experienced in 1993 and 1994.[3] These data, combined with other available information, may lead the advisor to believe real GDP growth in the second quarter of 1995 will be sluggish or possibly zero. There is also some risk that the sluggish growth will persist through the year. In light of this information, the advisor must decide whether to recommend that the Federal Open Market Committee vote to ease conditions in the reserves market and lower the federal funds rate.

Before arriving at a policy recommendation, several more fundamental questions should be answered:

- Why has the economy slowed?
- Was the slowdown predictable early last year when the Fed was considering raising the federal funds rate, or is the slowdown a surprise, resulting from unpredictable changes in private or policy behavior since the funds rate began rising?
- If the slowdown is a surprise, what unanticipated shifts in behavior account for it?
- Are unanticipated shifts in monetary policy partly responsible?
- How do surprises in monetary policy affect the economy?
- If the Fed were to lower the federal funds rate now, what would the effects be?
- What are the effects of not lowering the funds rate now?

To address these questions and formulate a policy recommendation the advisor needs a model that both provides an unambiguous economic interpretation of past data and forecasts future data well. The model should be able to predict the economic consequences of alternative current and future policy choices. Constructing such a model is difficult. Models with clear economic interpretations tend to fit the data poorly, and models that forecast well usually are consistent with a variety of economic interpretations with different policy implications. The dichotomy that some economists maintain between "policy evaluation" models and "forecasting" models seems false, however. This article emphasizes that for most purposes one would not be interested in the policy assessments of a model that forecasts poorly.

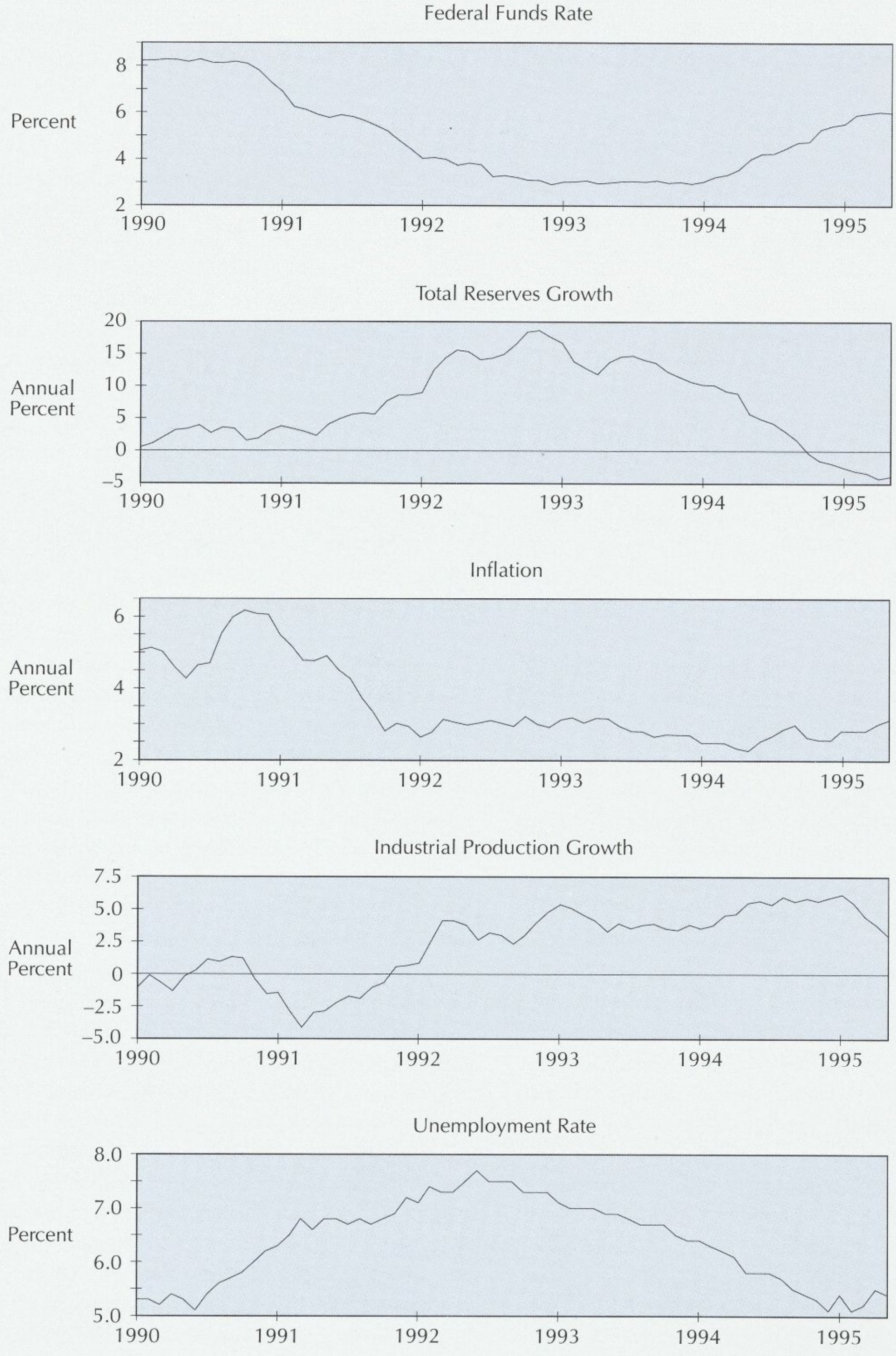
Forecasting and Policy Analysis

This article is an attempt to develop forecasting models for use in analyzing policy. The models adopt the perspective that economic time series are generated by shocks whose effects on economic decisions and, therefore, on data can be long-lasting. Shocks are unanticipated events that provide new information about the state of the economy—for example, bad (good) weather that produces crop failures (successes), rapid increases in oil or raw materials prices that drive up production costs, technological improvements that make workers more productive, or sudden changes in social attitudes toward government involvement in the economy. At each point in time a variety of different shocks impinge on the economy.

In interpreting data it is important to separate the shocks that hit the economy from the economic mechanisms that propagate the shocks. Private decisionmakers respond to shocks by altering their consumption, saving, production, and employment decisions. Policymakers also respond to shocks, changing taxes, government spending, regulations, the supply of money, or short-term interest rates. Social arrangements, like contracts, technological constraints such as the time it takes to build a new factory, and lags in implementing legislation or recognizing the need to change policy limit the ability of individuals and policymakers to adjust quickly to shocks. Since these factors evolve slowly over time, the propagation mechanisms will be fairly stable and predictable. Shocks are unpredictable by definition.

An economic model that separates shocks from propagation mechanisms posits a set of behavioral

Chart 1
U.S. Data, January 1990-May 1995



Source: Board of Governors of the Federal Reserve System and U.S. Department of Labor, Bureau of Labor Statistics.

relationships for each type of decisionmaker in the economy—consumers, businesses, and governments. These relationships, which reflect the stable and predictable aspects of economic behavior, can be used to forecast the model's economic variables. The differences between actual data and the model's predictions are the shocks to behavioral relationships.[4] Forecasts of future economic variables may simply reflect the evolution of the propagation mechanism, assuming all future shocks are zero. Alternatively, forecasts may combine the propagation mechanism with assumptions about future shocks and the accompanying shifts in behavioral relationships.

One convenient way to decompose economic time series into anticipated and unanticipated components is the vector autoregression (VAR) model. This model's predictions are based on estimates of the historical dynamic correlations among variables in the model. Mechanically, the VAR consists of an equation for each variable. The equations are estimated by regressing each variable against lagged values of all the variables in the model. The regression error in each equation represents the change in that variable that cannot be forecast from past information on all the variables, so regression errors are forecast errors. Forecast errors average out to zero over time and, on the basis of information up to this period, are expected to be zero in the next and all future periods. In general, forecast errors are combinations of the shocks that shift behavioral relationships. An economic model allows the analyst to interpret statistical forecast errors in terms of the underlying economically meaningful changes in behavior.

There are several ways to use the estimated VAR to analyze data. As a pure forecasting model, the VAR can generate predictions of variables beyond the period for which data are available. This is the sort of exercise many commercial forecasters undertake. The VAR can also be used to break an observed data series into two parts: (1) its predicted value, given information on actual data up to some date T, and (2) its unpredictable value, which depends on the actual shocks hitting the economy after date T. The predicted value reports what would have happened to the variable after date T if the variable evolved according to the propagation mechanism alone.

This article has the modest goal of quantifying the effects of unanticipated shifts in monetary policy behavior, so the economic models will be correspondingly modest. All of the models' economic interpretations center on the behavior of demanders and suppliers in the market for reserves. No economic interpretation is attached to behavior in other markets. Before estimating the models, however, it is necessary to develop an understanding of reserves market behavior.

Supply and Demand in the Reserves Market

Any empirical analysis of monetary policy must first settle on a particular money market to study. The traditional analyses of Friedman and Schwartz (1963) or Phillip Cagan (1972) emphasized relatively broad monetary aggregates such as M1 or M2, which include currency in circulation, demand deposits, and other sorts of deposits held in financial institutions. To determine the role of money in the economy, it may be appropriate to focus on such broad aggregates. After all, households and businesses demand broad monetary aggregates to buy goods and services, so the demand for M1 or M2 is a "final demand" representing the portfolio behavior of only the private sector.

Unfortunately, the supply of broad aggregates has two influences—Federal Reserve policy and banking system behavior. When the Federal Reserve increases reserves through open market operations, it increases the banking system's ability to extend loans by "creating" deposits and increasing the private sector's liquidity. Of course, it is possible that an increase in the supply of reserves by the Federal Reserve would elicit no expansion of lending and deposits by the banking system, leaving the broader aggregates unchanged. On the other side, if banks have excess reserves they can extend additional loans and expand M1 or M2 without any change in behavior by the Fed. Consequently, the supply of broad aggregates combines the behavior of the Federal Reserve with the behavior of the banking system.

The purpose of this study is to isolate the effects of monetary policy per se rather than the effects of money, so it is essential to focus on a money market in which the Federal Reserve has control of the supply. All the results in this article stem from changes in behavior in the reserves market. In that market banks trade reserves and the federal funds rate adjusts to equate the quantity supplied to the quantity demanded.[5] (A more formal description of behavior in the reserves market and how that market is linked to a broader money market is contained in Appendix A.)

The Demand for Reserves. Because reserves on deposit at the Federal Reserve earn no interest, it is assumed that banks hold reserves largely because they are required to. For certain classes of deposits, banks are required to hold a specified fraction of deposits as reserves on deposit at the Fed or as vault cash. Consequently, the demand for reserves is a derived demand, rather than a final demand. One way to think of the derived demand is that reserves serve as an intermediate input in the "production" of loanable funds.

Demanders observe the cost of holding reserves (the federal funds rate), the prices of the goods they purchase, and their wealth when they make their demand decisions. The quantity demanded decreases as the funds rate rises, and it increases as either the price level or wealth increases. In principle the derived demand also depends on the prices of the banks' other factors of production, such as wages of employees and interest rates on bank assets. These other factor prices are assumed not to be important and are excluded from demand.[6] The derived demand for reserves can be represented as

$$TR^d = D(R, P, Y, I_{-1}) + e^d, \qquad (1)$$

where TR^d is the quantity of total reserves demanded. $D(R, P, Y, I_{-1})$ is notation that represents how the quantity demanded depends systematically on current and past economic variables. R is the current federal funds rate, P is a current aggregate price level like the consumer price index, and Y is current real income or wealth (in the empirical work industrial production serves as a proxy).[7] I_{-1} reflects past information upon which demand is also assumed to depend. The term e^d represents a shock that shifts the demand for reserves unexpectedly. By construction, the shock reflects changes in the demand for reserves that cannot be attributed to changes in R, P, Y, or past economic conditions.

Just as the supply of broad aggregates combines policy behavior and bank behavior, so too the demand for reserves combines the behavior of banks with that of final money demanders. The comingling of behavior would present a problem if the focus of this study were on isolating which shifts in demand for reserves arose from the two sources. To derive the effects of an unanticipated shift in supply, however, it is sufficient to estimate a demand for reserves that does not shift in the experiment of shifting the supply curve. To do so, all that is needed is a systematic relationship between the determinants of demand and the quantity of reserves.

The Supply of Reserves. The supply of total reserves is composed of borrowed reserves plus nonborrowed reserves.[8] To meet their level of required reserves, banks in the United States can borrow from the Federal Reserve's discount window, where they are charged the discount rate. Typically banks are instructed to try first to obtain reserves from sources other than the discount window, and each Reserve Bank discount officer must verify that loans are extended only for "appropriate" reasons.[9] A discount officer may pressure banks whose access to the window is deemed inappropriate to pursue other sources of reserves. Thus, discount window borrowing carries an additional implicit cost associated with moral suasion, making the actual cost to banks the discount rate plus such nonpecuniary costs.

Nonborrowed reserves are simply the portion of reserves provided to depository institutions through any means other than the discount window. The most important source of changes in nonborrowed reserves in the United States is open market operations conducted by the Fed. Open market operations are purchases or sales by the Fed of U.S. government securities. When the Fed buys securities it provides reserves to the banking system; when it sells securities it extracts reserves from the banking system.

Since the end of 1982 the Fed has followed a policy of indirectly targeting the federal funds rate, meaning that it adjusts the supply of reserves to achieve a targeted equilibrium interest rate in the reserves market.[10] The Fed changes the target level of the funds rate in response to its expectation about levels of output, unemployment, and inflation—the economic conditions it cares about. Future economic conditions are forecast using all available information. Although the Fed eventually sees data on current output, unemployment, and inflation, when it sets the target funds rate in a given month it knows the previous month's values of these variables but not the current month's. Bond, stock, commodity, and foreign exchange markets operate almost around the clock, and prices from these markets are available continuously. From current financial data and all past data, the Fed tries to glean information on the future values of the variables it cares about and hopes to influence.

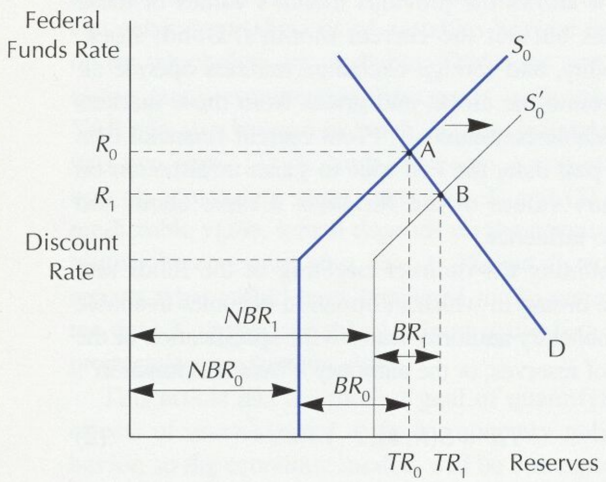
Combining the indirect targeting of the funds rate with the timing in which information becomes available to the monetary authority leads to the specification of the supply of reserves, or the authority's "reaction function":

$$TR^s = S(R, \Omega, I_{-1}) + e^s, \qquad (2)$$

where TR^s is the quantity supplied of total reserves. $S(R, \Omega, I_{-1})$ represents the systematic response of supply to past and currently observable economic conditions. R is the funds rate, Ω reflects the high-frequency information the monetary authority observes within the month, and I_{-1} is past information that influences the supply of reserves. e^s represents shifts in policy behavior that are unanticipated by the private sector. Monthly realizations of e^s are monetary policy shocks that shift the supply of reserves.

Equation (2) is an abstract representation of policy behavior. No monetary authority literally behaves as equation (2) depicts. The systematic part of the reaction function captures how policy responds on average to current and past economic conditions. When this month's funds rate begins to rise above its target level, the monetary authority injects reserves into the economy to bring it back to its target. Variables represented by Ω are informational rather than behavioral: they appear in the supply function because they contain information about current and expected future values of the variables the monetary authority responds to, not because the authority necessarily wants to influence or respond to the variables in Ω specifically. The monetary authority combines the information contained in current and past observable data—Ω combined with I_{-1}—to construct forecasts of the variables important to its decisions. The response of policy to current and past information, therefore, can be interpreted as a response to forecasts of the variables that concern the policy authority.

Chart 2
The Reserves Market—Open Market Purchase



NBR = Nonborrowed Reserves
BR = Borrowed Reserves
TR = Total Reserves

Treating the policy reaction function as composed of a regular, predictable part, $S(R,\Omega,I_{-1})$, and a random, unpredictable part, e^s, is necessary to conduct a thought experiment that shifts supply, holding all else constant. Along with the specification of private and policy behavior in the model comes a specification of the information upon which the economic players base their decisions. Equation (2) introduces the random term in policy behavior as a tool for describing an environment in which private decisionmakers and policymakers interact without certain knowledge of the information and incentives facing each other.[11]

Equilibrium in the Reserves Market. Banks can be either net suppliers or net demanders of reserves. Overnight loans of reserves from one bank to another are called federal funds and bear the overnight federal funds rate. Arbitrage implies that borrowed and nonborrowed reserves must be perfect substitutes from the perspective of demanders, so the federal funds rate must equal the discount rate plus the nonpecuniary costs of borrowing at the discount window. One implication of the assumption that rate-of-return differences between borrowed and nonborrowed reserves are arbitraged away is that the federal funds rate changes if and only if total reserves change: the composition of total reserves between the two components is irrelevant.

The interaction of supply and demand in the reserves market is summarized in Chart 2.[12] An open market purchase of securities increases the supply of nonborrowed (and total) reserves, shifting the supply curve to the right from S_0 to S_0'. To induce banks to hold the higher level of reserves, the cost of doing so must fall from R_0 to R_1.[13] The decline in the short-term interest rate from a monetary policy expansion, dubbed "the liquidity effect," is the first step in the transmission of monetary policy to the macroeconomy.

Empirical work that seeks to quantify the effects of monetary policy must find an empirical analog to the textbook exercise depicted in Chart 2. The thought experiment shifts the supply of reserves, holding the demand curve fixed. In the economy both curves are shifting around, so actual monthly data on the funds rate and total reserves combine instances in which the supply curve shifts with ones in which the demand curve shifts. If, for example, the correlation between total reserves and the funds rate is close to zero at least three inferences are possible: (1) demand is either very sensitive to interest rates (nearly flat) or very insensitive (nearly vertical), and supply shifts around a stable demand; (2) supply is very responsive or unresponsive to interest rates, and demand shifts around a stable supply; (3) supply and demand shifts by approximately equal amounts, and the negative correlations induced by supply shifts canceled out the positive ones generated by demand shifts. Each of these inferences makes identifying assumptions about the behavior that generated the data. After describing the data used to estimate the models, the following section of this article looks at the data through the lenses of two different, simple assumptions about supply behavior. The discussion shows that the inferences drawn about the effects of monetary policy under the two behavioral assumptions seem to be inconsistent with widely held beliefs about the dynamic impacts of monetary policy.

The Data Series

Choosing the sample period requires an unpleasant trade-off. A longer sample period is likely to be more informative, as it reflects changes in policy and private behavior in the face of a wider variety of economic events. For example, data from 1960 to 1994 would report changes in behavior in response to large increases in military spending (the Vietnam War), big movements in relative prices (oil price increases), and dramatic swings in inflation. But the longer the period, the more likely it is that policy behavior itself displays discrete and unpredictable shifts. Following the steady rise in inflation during the 1970s, for example, in October 1979 the Fed shifted policy dramatically by focusing on monetary aggregates and allowing interest rates to fluctuate more. In late 1982 the Fed moved toward smoothing interest rates. When monetary policy operating procedures and policy objectives are shifting over time, it takes a while for the private sector to learn about policy. Economic models are not very good at capturing how people learn, and the models produce unreliable forecasts during the learning process.

This article trades the variety of economic experiences for a stable policy environment. All the results in the article come from estimating a vector autoregression (VAR) using monthly data from December 1982 to December 1994. This is a period over which the Fed indirectly targeted the funds rate (see Marvin Goodfriend 1991), the inflation process was stable, and financial markets had been deregulated, producing a fairly stable policy environment.

The variables to be included in the estimated model were chosen to represent the quantity and price in the reserves market (total reserves and the federal funds rate), the variables reflecting the goals of monetary policy (consumer prices, industrial production, and unemployment), and two variables that the Fed can observe daily that contain information about financial market participants' expectations of current and future economic conditions (the ten-year U.S. Treasury bond yield and a commodity price index).[14] The symbols used to represent variables in the charts and tables are reported in Box 1.

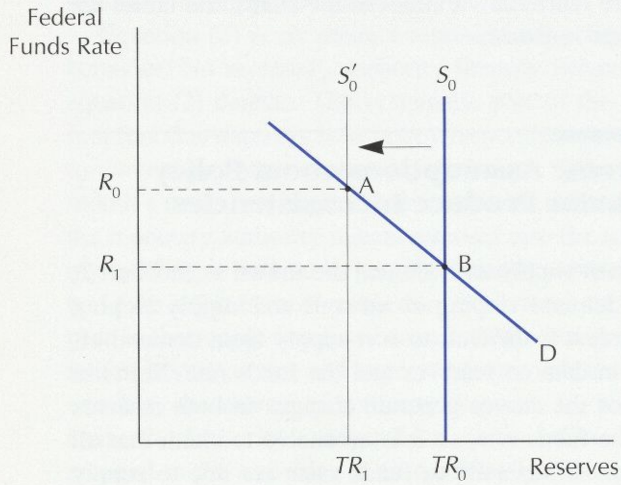
Extreme Assumptions about Policy Behavior Produce Inconsistencies

When supply and demand are drawn as in Chart 2, with demand sloping downward and supply sloping upward, it is difficult to sort supply from demand effects in data on reserves and the funds rate. Shifts in each of the curves generate changes in both reserves and the funds rate, so it is untenable to claim that all changes in reserves or funds rates are due to supply shifts or, alternatively, that all changes are due to demand shifts. Such straightforward interpretations of the data are possible only under extreme maintained assumptions about behavior. This section explores the implications of two sorts of extreme assumptions commonly made in analyses of monetary policy. The first is that the supply of reserves is perfectly inelastic with respect to the interest rate (Chart 3). In this case, the supply schedule is vertical and all changes in reserves must arise from shifts in the supply curve. Any correlation between the two variables necessarily occurs because a change in the supply of reserves causes the change in the funds rate along a fixed demand curve. The second sort of extreme assumption is that the supply curve is perfectly elastic with respect to the funds rate (Chart 4). A flat supply curve implies that all changes in the interest rate are due to shifts in the supply schedule. These shifts induce movements along the demand curve and changes in the quantity of reserves demanded.

Box 1
Notation

TR = total reserves
R = federal funds rate
P = consumer price index
Y = industrial production
U = unemployment
$R10$ = ten-year U.S. Treasury bond yield
CP = commodity price index denominated in U.S. dollars

Chart 3
The Reserves Market with Inelastic Supply—Open Market Sale



A shift in the supply of reserves is equivalent to a change in total reserves.

Model TR: A Perfectly Inelastic Supply of Reserves. Much traditional empirical work regresses some variable of interest on current and lagged values of a money stock and interprets the coefficients as reporting the effects of money or monetary policy on that variable. Andersen and Jordan (1968) present one prominent example of this style of work. They regressed GNP against the money stock and the fiscal deficit and interpreted the estimated coefficients as meaning that the effects of monetary policy are bigger, more predictable, and faster than are the effects of fiscal policy. Cagan's (1972, chap. 7) classic work on the liquidity effect is another important example. He regressed an interest rate on current and past money and interpreted the coefficients as measuring the dynamic effects of money on interest rates.[15]

Empirical inferences based on such regressions assume that all changes in money arise from shifts in supply, rather than movements along a fixed supply curve induced by shifts in demand. In the context of the reserves market the inferences assume that changes in reserves are due entirely to shifts in monetary policy, with no role for changes in policy that accommodate movements in demand. In terms of equation (2) and the VAR model, an inelastic supply implies that the monetary authority does not respond to the funds rate or other current information, although it may respond to past information. The authority's reaction function can be expressed abstractly as

$$TR^s = S(I_{-1}) + e^s. \qquad \text{(2-TR)}$$

The assumption that supply is inelastic is simple and appealing. It is also one to which many economists are accustomed, as most textbooks about monetary economics also make the simplifying assumption (see, for example, Don Patinkin 1965, David E.W. Laidler 1985, or Frederic S. Mishkin 1992). It would be convenient if it could be assumed that supply is vertical, because the assumption implies that it is not necessary to model demand and supply: the quantity is fixed by policy and, given a quantity, the equilibrium interest rate is completely determined by demand.

Before proceeding with inferences based on the simplifying assumption about policy behavior it is important to check whether the assumption's implications are reasonable. In order to do so, equation (2-TR) is embedded in a VAR to form Model TR. The model can be used to estimate the dynamic impacts of an unanticipated decline in total reserves under the maintained assumption that the supply is inelastic. The reasonableness check is whether the results conform with consensus views about the qualitative effects of monetary policy that are summarized in points (a)-(d) earlier in the article (on page 2).

Model TR can be used to mimic the theoretical thought experiment of a one-time unanticipated monetary policy contraction. The model identifies the experiment with a one-period decline in e^s in equation (2-TR), holding all else fixed initially, which corresponds to the inward shift in the supply of reserves depicted in Chart 3. The qualitative effects of monetary policy, according to Model TR, are simply the model's predictions of the time paths of all the variables following the surprise contraction.

Chart 5 reports the dynamic responses of all seven variables over thirty-six months to an unanticipated 1 percent decline in reserves. In the absence of the decline in reserves, the variables would lie on the zero axis, so all movements in the variables are attributable to the unanticipated change in reserves. The solid lines are point estimates, and the dashed lines are one-standard-deviation bands. When both dashed lines fall above or below zero, the response of that variable is statistically significant.[16] Many of the responses look reasonable. Prices, output, and commodity prices fall throughout the horizon. Unemployment rises with a lag of six months, although it falls significantly for one month near the beginning. Other responses are less plausible.

At impact, the decline in reserves lowers the funds rate, so there is no liquidity effect. Rates do rise significantly after one month, consistent with a delayed liquidity effect. The brief increase in the long-term bond yield is consistent with the expected increase in the short-term interest rate over the subsequent several months.

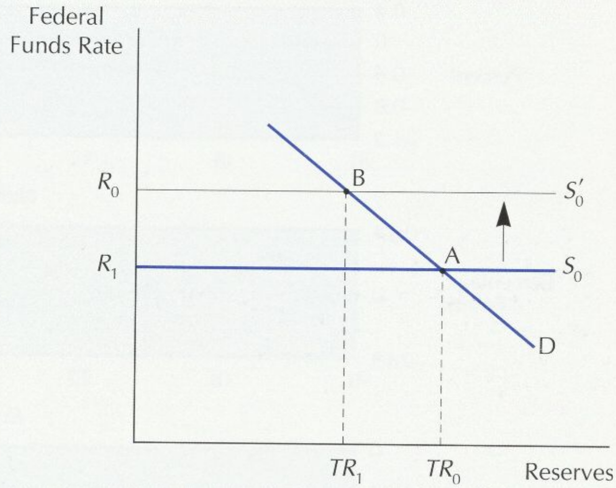
This pattern of responses raises doubts about the identifying assumption that the supply of reserves is perfectly inelastic. Most economists believe the funds rate adjusts immediately to clear the reserves market after a supply shock, with output and prices adjusting gradually to the lower level of reserves. The results make it seem that the demand curve is upward sloping. An immediate and significant drop in prices and output reduces the quantity of reserves demanded at any given funds rate, having the effect of shifting the demand curve in Chart 3 inward. For both the equilibrium funds rate and the level of reserves to decline, as they do in Chart 5, demand cannot be downward sloping. Although some responses seem to be consistent with common beliefs about monetary policy effects, the behavioral implications of the patterns of responses in this chart are implausible.

Model R: A Perfectly Elastic Supply of Reserves. Over the past twenty-five years it has been far more common for the Fed to target the federal funds rate than some measure of reserves.[17] If over a period of a month the monetary authority were to essentially provide reserves passively to accommodate shifts in demand, then the supply of reserves would be perfectly elastic. To accommodate shifts in demand the monetary authority makes the supply of reserves infinitely responsive to changes in current economic conditions. Doing so amounts to making the funds rate unresponsive to current information, and the authority's "reaction function," equation (2), becomes

$$R = S(I_{-1}) + e^s. \qquad \text{(2-R)}$$

Under this assumption about policy behavior, every unanticipated change in the funds rate represents a shift in the supply schedule. Among financial market observers and business journalists, this view is widespread, as implicitly every increase in the funds rate is treated as a monetary policy contraction. Many researchers have also assumed supply is elastic. Sims (1980b, 1992) and Ben S. Bernanke and Alan S. Blinder (1992), for example, interpret movements in macro variables following an unanticipated increase in the short-term interest rate as reflecting the dynamic impacts of a contractionary monetary policy shock.

Chart 4
The Reserves Market with Elastic Supply—Open Market Sale



A shift in the supply of reserves is equivalent to a change in the federal funds rate.

The abstract representation of policy behavior in equation (2-R) also comes close to reflecting the Fed's own views of its behavior. Policy debates are couched in terms of changes in the funds rate. Many of the models used in the Federal Reserve System to simulate the effects of alternative policy scenarios treat the funds rate as affecting current private behavior, but other variables do not affect the funds rate contemporaneously. This is precisely the assumption embedded in equation (2-R). With financial market participants, economic journalists, researchers, and the monetary authority all treating an equation like (2-R) as representing policy behavior, the identifying assumption that the supply of reserves is perfectly elastic is clearly important as well as widespread. Model R's implications for the dynamic impacts of unanticipated changes in monetary policy, therefore, are especially interesting.

Unfortunately, treating changes in the funds rate as shifts in the supply of reserves does not lead to reasonable results. Chart 6 reports responses to a surprise 25 basis point increase in the funds rate.[18] Interpreting the increase as an unanticipated monetary policy contraction implies some strange policy effects. The price level and output rise strongly for about six months, while unemployment is significantly lower for a year. Eventually, however, the interest rate increase affects the economy as most people would predict. The sharp rise

Chart 5
Responses to Unanticipated 1 Percent Decline in Reserves (Supply Perfectly Inelastic)

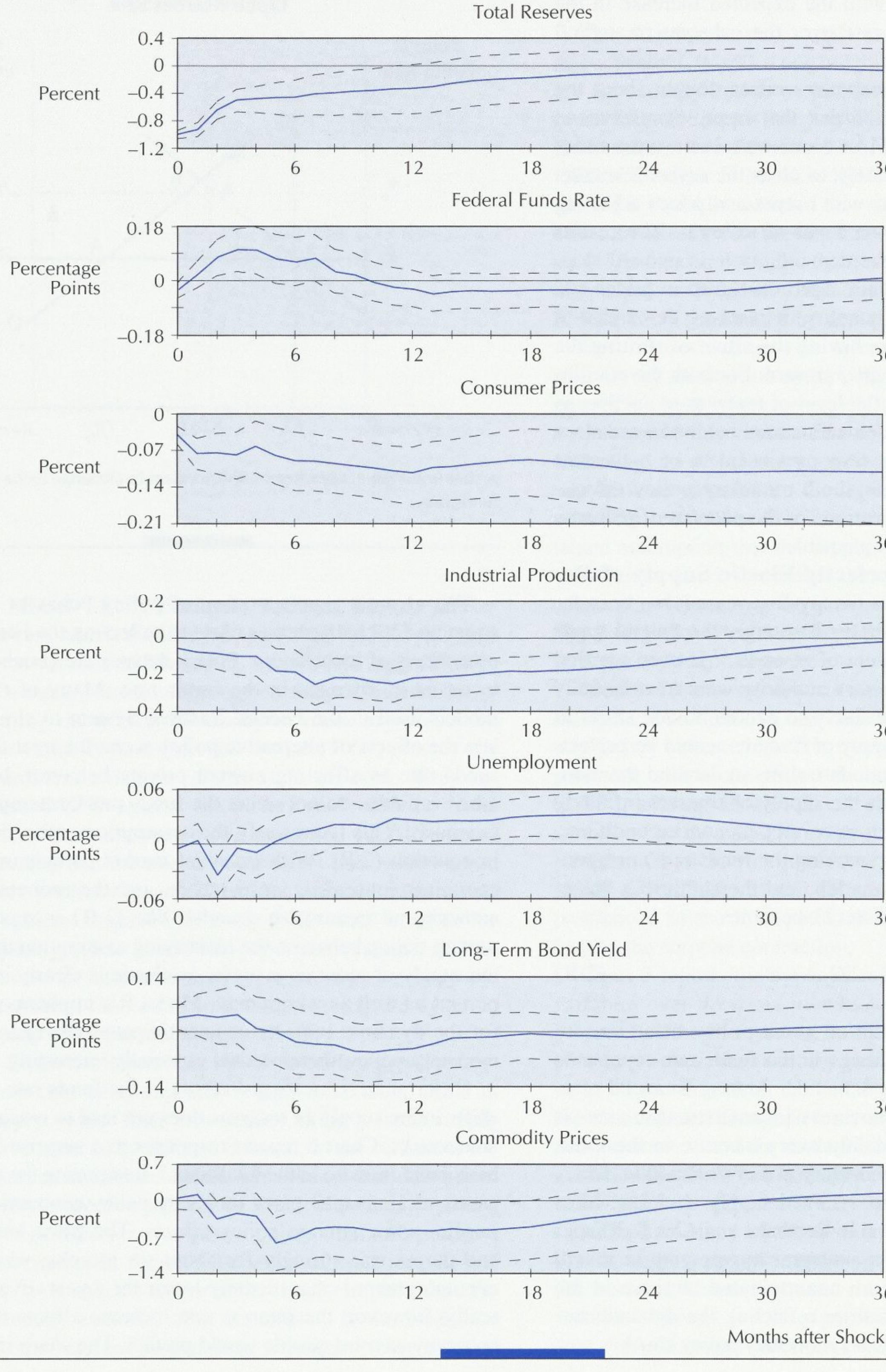
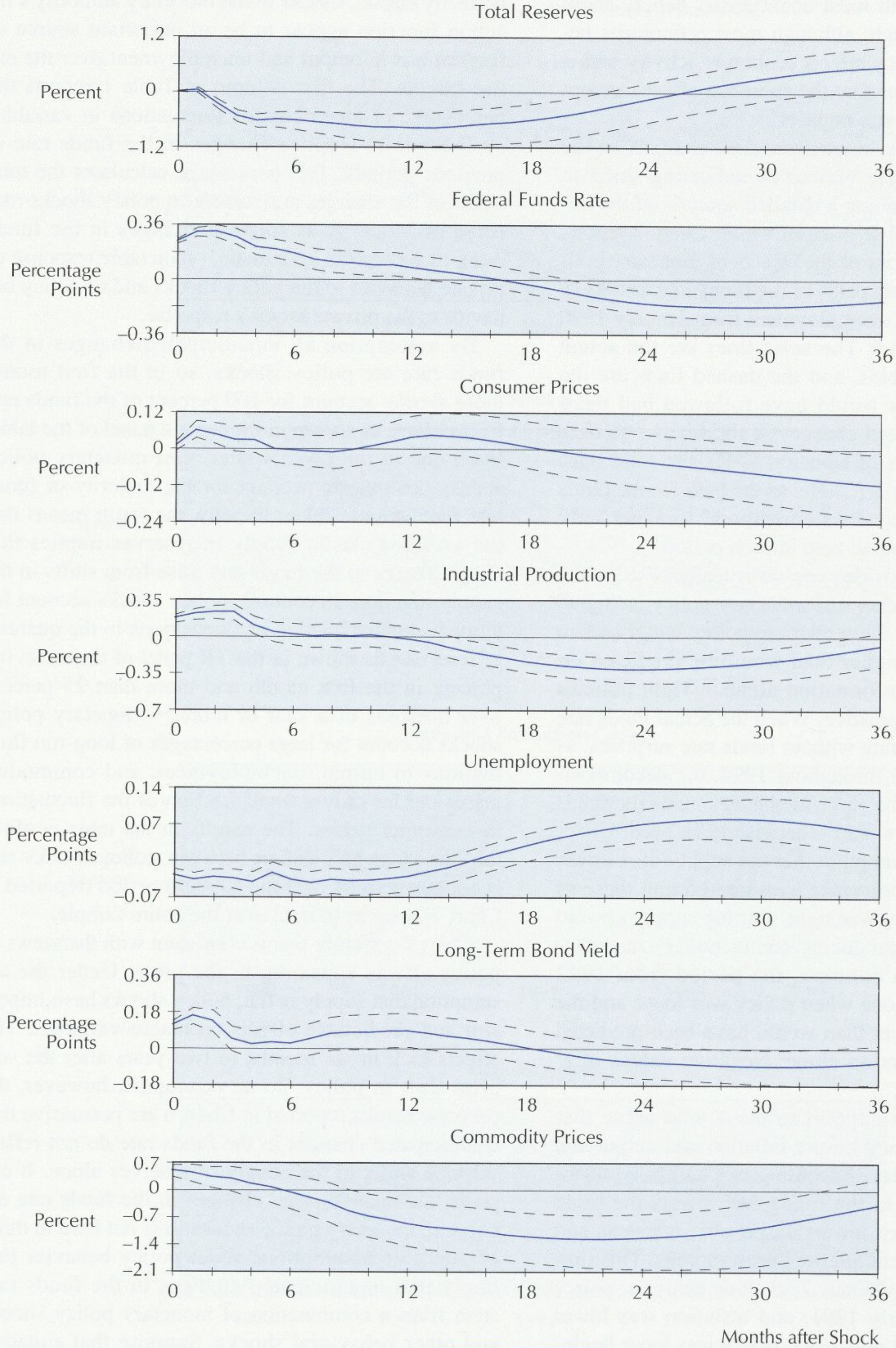


Chart 6
Responses to Unanticipated 25 Basis Point Increase in Funds Rate (Supply Perfectly Elastic)



in long-term interest rates for a few months is consistent with the financial press's view that the funds rate and bond prices move in opposite directions in the short run. The responses to a funds rate increase are sharply at odds with most economists' beliefs about policy effects, though: although most economists believe monetary policy affects economic activity with a lag, few would argue that the short-run effects are opposite to the longer-run impacts.

In spite of these inconsistencies, changes in the funds rate are widely viewed as indicating shifts in policy. Thus, conducting a detailed analysis of the implications of Model R is worthwhile. Chart 7 reports Model R's predictions of the effects of monetary policy shocks on the time paths of the funds rate, inflation, output growth, and unemployment from January 1990 to December 1994.[19] The solid lines are the actual paths of the variables, and the dashed lines are the paths the variables would have followed had there been no unanticipated changes in the funds rate over the period. In terms of equation (2-R), the solid lines correspond to using $S(I_{-1}) + e^s$ as the path for the funds rate and the dashed lines correspond to using only $S(I_{-1})$, setting e^s equal to zero in each period.

This exercise provides one statistically based interpretation of statements that monetary policy is "tight" or "loose." By this interpretation, policy is tight when the funds rate is higher than would be predicted on the basis of past information alone.[20] Tight policies emerge when e^s is positive. When the actual funds rate is greater than the rate without funds rate surprises, as it was in 1990 and throughout 1994, the decomposition suggests that the surprise changes made the funds rate higher than it would otherwise have been. Under the maintained assumption that the supply of reserves is flat, this result coincides with interpreting these as periods when policy was tight, shifting supply upward unexpectedly and producing contractionary monetary policy shocks. In contrast, the period from 1992 through 1993 was one when policy was loose and the funds rate was lower than would have been predicted using past information alone. Negative values of e^s imply loose policy.

The chart lends support to those who argue that tight monetary policy lowers inflation and output and raises unemployment. According to Chart 6, an unanticipated increase in the funds rate lowers the price level after two years, lowers output after one year, and raises unemployment after eighteen months. This timing is borne out by Chart 7. By this analysis, policy was tight until early 1991, and inflation was lower than expected until mid-1993; policy was loose beginning in 1992, and inflation was higher than expected in 1994. The patterns show up more strongly in output growth and unemployment.[21]

Under the maintained assumption that supply is perfectly elastic, shocks to the monetary authority's reaction function appear to be an important source of fluctuations in output and unemployment over the entire sample. The first column of Table 1 reports the percentage of unanticipated fluctuations in variables attributable to surprise changes in the funds rate in previous periods. This percentage calculates the total effect of the changes attributable to policy shocks (defined in Model R as surprise changes in the funds rate), including the systematic, predictable response of private behavior to the policy shocks and of policy behavior to the private sector's response.

By assumption all unanticipated changes in the funds rate are policy shocks, so in the first month those shocks account for 100 percent of the funds rate fluctuations, as shown in the second panel of the table. Even one to three years later, past monetary policy shocks continue to account for the majority of funds rate fluctuations. Taken literally, the result means that the assumed elastic supply of reserves implies that most changes in the funds rate arise from shifts in the supply function. In contrast, policy shocks account for a much smaller fraction of fluctuations in the quantity of reserves: as shown in the TR panel of the table, 0.8 percent in the first month and more than 25 percent over horizons of a year or more.[22] Monetary policy shocks account for large percentages of long-run fluctuations in output, unemployment, and commodity prices but for only a small fraction of the fluctuations in consumer prices. The results in the table confirm that the close association between policy shocks and economic activity over the 1990-94 period (reported in Chart 7) appears to hold over the entire sample.

Chart 7 certainly seems consistent with the views of policy effects appearing in the press. Under the assumption that supply is flat, policy shocks have important and predictable effects on macro variables. The effects kick in six months to two years after the surprise shift in policy. To an economist, however, the perverse results reported in Chart 6 are persuasive that unanticipated changes in the funds rate do not reflect surprise shifts in the supply of reserves alone. It appears that unanticipated changes in the funds rate are not pure monetary policy shocks. It is not hard to think of plausible assumptions about policy behavior that imply that unanticipated changes in the funds rate stem from a combination of monetary policy shocks and other behavioral shocks. Suppose that equation

Chart 7
Influence of Unanticipated Changes in Funds Rate

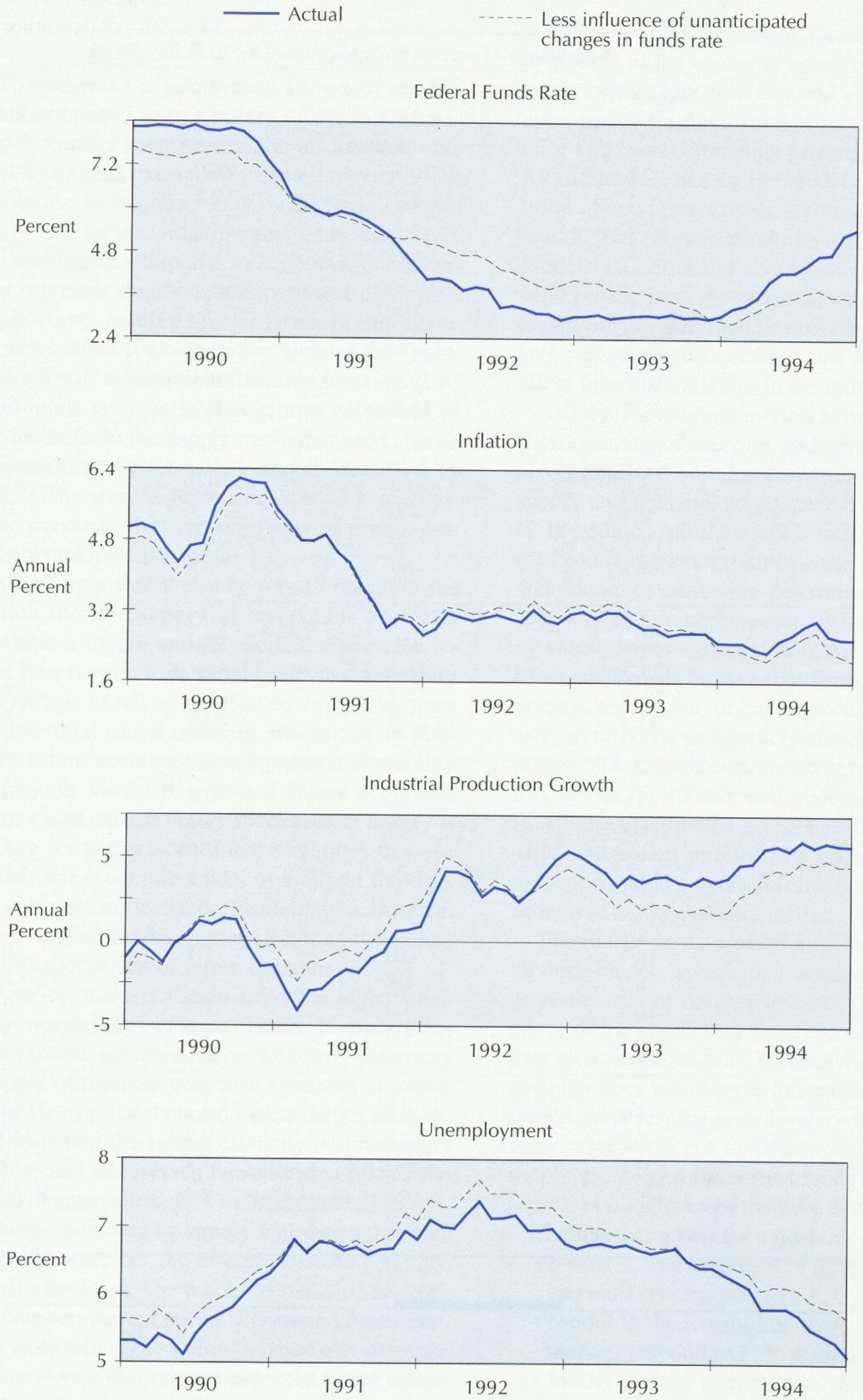


Table 1
The Role of Policy Shocks in Accounting for Fluctuations

Variable Explained		Percentage of Forecast Error Variance Due to Policy Shock: Impose TR^s Perfectly Elastic	Model 1	Model 2	Model 3
TR:	1st month	0.8	20.5	86.9	0.8
	1 year	26.1	8.2	17.2	0.9
	2 years	29.2	9.1	12.8	3.3
	3 years	27.9	7.7	10.3	4.4
R:	1st month	100.0	54.2	7.4	0.2
	1 year	58.4	24.9	11.3	4.1
	2 years	49.1	19.9	10.4	7.8
	3 years	51.7	18.0	9.6	5.8
P:	1st month	0.6	0.0	0.0	0.0
	1 year	2.4	4.8	5.3	2.7
	2 years	2.3	2.9	5.7	4.8
	3 years	5.5	3.9	8.1	5.4
Y:	1st month	14.6	0.0	0.0	0.0
	1 year	11.5	17.2	18.2	11.3
	2 years	26.9	23.3	24.2	7.9
	3 years	33.3	21.9	20.6	7.2
U:	1st month	3.9	0.0	0.0	0.0
	1 year	16.5	0.6	1.9	0.9
	2 years	19.6	4.7	7.6	1.4
	3 years	31.5	10.3	9.0	1.8
R10:	1st month	16.7	0.0	1.1	0.5
	1 year	8.9	4.9	1.4	5.1
	2 years	10.1	4.5	1.4	5.6
	3 years	14.8	4.4	1.4	5.0
CP:	1st month	7.4	0.0	0.5	88.5
	1 year	5.7	13.6	9.7	40.4
	2 years	21.6	15.2	11.4	25.3
	3 years	26.2	12.7	9.5	20.8

(2-R) understates the amount of information upon which the Fed bases its choice of the funds rate target. Then the correct specification of the reaction function is

$$R = S(I_{-1}, X) + e^s,$$

where X represents the information known by the Fed that is not contained in past values of the variables in the model. Further suppose that the information contained in X suggests that future inflation may rise. The Fed's response to the news in X might be to contract the supply of reserves and allow the funds rate to rise. Such an endogenous response to economic conditions does not represent the thought experiment of shifting the supply curve, holding all else fixed. In this example, the news about future inflation violates the "holding all else fixed" assumption. Reaction function (2-R) then confounds systematic endogenous responses of policy with shifts in the supply curve that hold all else fixed, contaminating the policy shock identified by Model R.[23] The story, however, may be able to rationalize the perverse short-run responses of prices, output, and unemployment in Chart 6.

The data imply that the only way to maintain the assumption that the supply of reserves is perfectly elastic within a month and reconcile the perverse results in Chart 6 with widely held views of monetary policy effects is to tell a complicated story. The story reverses the usual causal ordering, where current policy causes future economic developments. According to the story, in Model R expected future economic conditions cause current policy shocks. Such a story is unappealing for two reasons. First, it requires that one step outside the economic model to interpret the data. Second, it hinges critically on assumptions about unobservable and untestable notions such as the policy authority's expectations of future inflation.

Good policy analysis should strive for higher standards than storytelling can hope to meet. It appears that imposing extreme assumptions on the interest elasticity of the supply of reserves generates measures of monetary policy shocks that do not do what theory predicts. To avoid imposing the supply elasticity it is necessary to build a model of reserves behavior that allows the supply and demand elasticities to be estimated directly. With separate estimates of supply and demand it may be possible to trace out the effects of shifting supply, holding all else fixed. Once able to make direct connections between current policy actions and future economic developments, the policy advisor can dispense with telling stories that rely on expected future events causing current monetary policy.

Estimating Behavior in the Reserves Market

The rest of the article reports results from three other models of the economy based on different assumptions about policy behavior and about the information upon which financial market participants, who determine bond and commodity prices, base their decisions. All differences among the models stem from assumptions about interactions among variables within a month. The models make the same assumptions that Models TR and R did about how current variables depend on the past. As a consequence, the assumptions underlying all five models differ only in how a monetary policy shock is defined and how that shock can affect financial variables in the month.

All three remaining models assume that the equilibrium quantity of reserves and level of the funds rate are determined simultaneously by the interaction of supply and demand, an advance over Models TR and R. In addition, all the models build in the assumption that goods market variables—the price level, output, and unemployment—are determined in sectors of the economy that do not respond within the month to policy shocks. This assumption is not very controversial. Most economists believe that firms do not adjust their pricing, production, or employment decisions immediately in response to unanticipated changes in monetary policy. The models assume no response in these sectors within the month, and goods markets' responses in subsequent months are not restricted in any way. This assumption implies that all economic decision-makers respond to past information in ways that the economic model does not restrict.

In terms of the flow of information within the month, all three models assume that demanders of reserves observe the cost of holding reserves (the funds rate), the prices of the goods they purchase (the price level), and their own wealth (output). Within the month the monetary authority does not observe information about the goods market variables, the price level, output, and unemployment, which it hopes to influence. Instead, it bases its supply decision on the current funds rate and current information from financial markets, as assumed in equation (2). Differences across the models are summarized by

- Model 1: Fed responds to R, $R10$, and CP; financial markets respond to P, Y, U.
- Model 2: Fed responds to R and CP; financial markets respond to P, Y, U, and R.
- Model 3: Fed responds to R and CP; financial markets respond to P, Y, U, and R and TR.

Another way to summarize the differences across the models is that Model 1 treats reserves market variables as determined before financial market variables. Models 2 and 3 allow reserves market and financial market variables to be determined simultaneously, but in slightly different ways.

Each of the models freely estimates the interest elasticity of the supply of reserves. It is possible, therefore, for either of the two schemes that impose extreme elasticities—Models TR or R—to end up being estimated as the model of reserves market behavior. (Appendix B provides econometric details about how the models are estimated.)

Table 2
Model 1

Reserves Market

Demand: $137.88TR^d = -2.68R + 148.53P + 75.15Y + e^d$
(18.99) (.89) (66.79) (28.11)

Supply: $95.85TR^s = 4.91R - 1.93R10 - 13.02CP + e^s$
(25.82) (.57) (.42) (6.26)

Financial Market Variables

$4.67R10 = 89.26P + 36.66Y - .79U + e^{R10}$
(.28) (66.81) (24.69) (.79)

$71.56CP = -3.33P + 8.94Y - .69U + .96R10 + e^{CP}$
(4.29) (4.38) (25.56) (.79) (.40)

Goods Market Variables

$778.95P = .51Y - 1.25U + e^P$
(46.72) (6.66) (.74)

$290.05Y = -3.54U + e^Y$
(17.40) (.76)

$8.54U = e^U$
(.51)

Log likelihood value = 3283.673
LR test of overidentifying restrictions: $\chi^2(5) = 13.032$, significance level = .023
LR test with small-sample correction: $\chi^2(5) = 9.001$, significance level = .109
Akaike criterion = 3237.673
Schwarz criterion = 3170.180

*M*odel 1: A "Partial Equilibrium" View of the Economy

Standard textbook treatments of monetary policy adopt the view that a change in policy affects the rest of the economy only with a lag. In the context of the model, this perspective implies that within the month demanders take prices and output as given, while the Fed takes financial market variables as given. These assumptions underlie the partial equilibrium analyses of reserves market behavior that are taught in college economics courses.

Table 2 reports the estimated coefficients of the model.[24] The elasticity of demand with respect to the interest rate is negative, and the price and output elasticities are positive, as theory would predict. The estimated supply equation also has appealing properties. An unanticipated increase in the funds rate brings forth an increase in the supply of reserves to push the funds rate back down. This reaction is precisely what one would expect under a policy that targets the funds rate. In addition, surprise increases in long-term interest rates or commodity prices, which may portend increases in expected inflation, induce the Fed to contract the supply of reserves.

The estimated demand and supply curves are drawn in Chart 8. Demand is estimated to be fairly inelastic. To conduct the experiment of shifting the supply schedule along a fixed demand curve in Chart 8, the shock in the policy equation, e^s, is decreased for one month. The contractionary policy shock shifts supply to the left. Because monetary policy is assumed to affect the economy with a one-month lag, total reserves and the funds rate do not enter the equations for the remaining five variables. The partial equilibrium experiment, therefore, changes only reserves and the funds rate in the month the shock occurs.

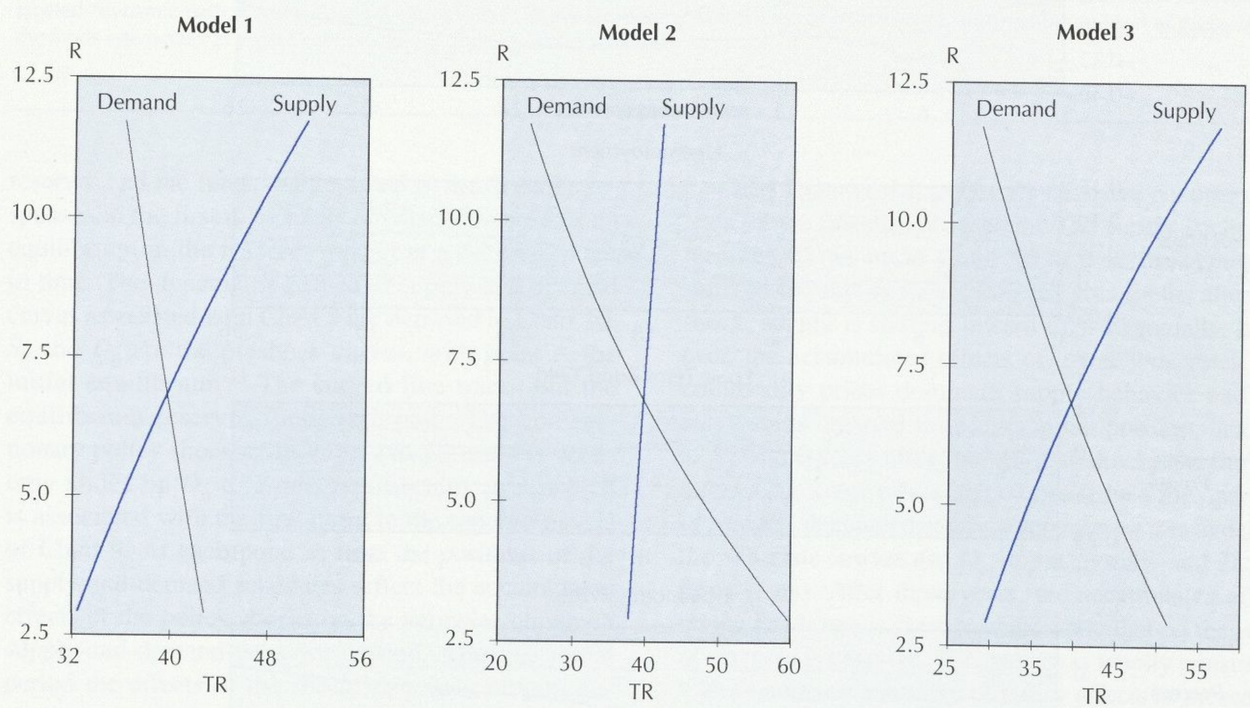
The Dynamic Impacts of Monetary Policy Shocks. The dynamic responses of all seven variables to a one-time unanticipated contraction in monetary policy that raises the funds rate initially by 25 basis points are reported in Chart 9.[25] Point estimates appear as solid lines and one-standard-deviation bands appear as dashed lines.[26] The leftward shift in supply has the immediate effect of moving the economy up the initial demand curve, raising the funds rate, and lowering the quantity of reserves. This liquidity effect lasts almost a year before the funds rate begins to fall significantly. The price level rises slightly initially, though the increase is substantially smaller and shorter-lived than it was under the assumption that the supply of reserves is perfectly elastic (Chart 6). After a couple of months prices begin to fall and continue to fall over the next few years.

Output displays none of the perverse responses appearing in Chart 6. It declines throughout the forecast horizon and is significantly lower after about three months. The sharpest drop in output occurs only five months after the contractionary policy shock. These results suggest that the lag effects of monetary policy are substantially shorter than many people believe.[27] It takes only a few months for policy shocks to affect prices and output measurably, whereas in Chart 6 unanticipated funds rate increases do not affect these variables in the expected ways for twelve to eighteen months. Thus, the identification of policy shocks influences inferences about the lags with which policy affects the economy. Unemployment is essentially unchanged for a little over a year after the policy shock, then it rises significantly. Financial variables, which are not permitted to react immediately to the policy shock, decline a month after the shock. These responses are interpretable as consistent with the decline in the price level and the eventual decline in short-term interest rates.

Past policy shocks have been an important source of unforecastable changes in output but a surprisingly unimportant source of movements in the price level (Table 1, column 2, panels 3 and 4), according to the model. Unanticipated shifts in monetary policy account for a fairly large percentage of fluctuations in commodity prices but not in long-term interest rates.

The model specifies supply-and-demand behavior in the reserves market only. Lacking a model of the rest of the economy, it is not possible to infer from the results exactly how the policy effects are transmitted into movements in prices, output, and unemployment. It is possible, however, to take a closer look at the dynamics of the reserves market. Each combination of

Chart 8
Estimated Supply and Demand Schedules in the Three Models



R = Federal Funds Rate (percent)
TR = Total Reserves (billions of dollars)

Chart 9

Responses to Unanticipated Monetary Policy Contraction in Model 1
(Policy shock raises funds rate initially by 25 basis points)

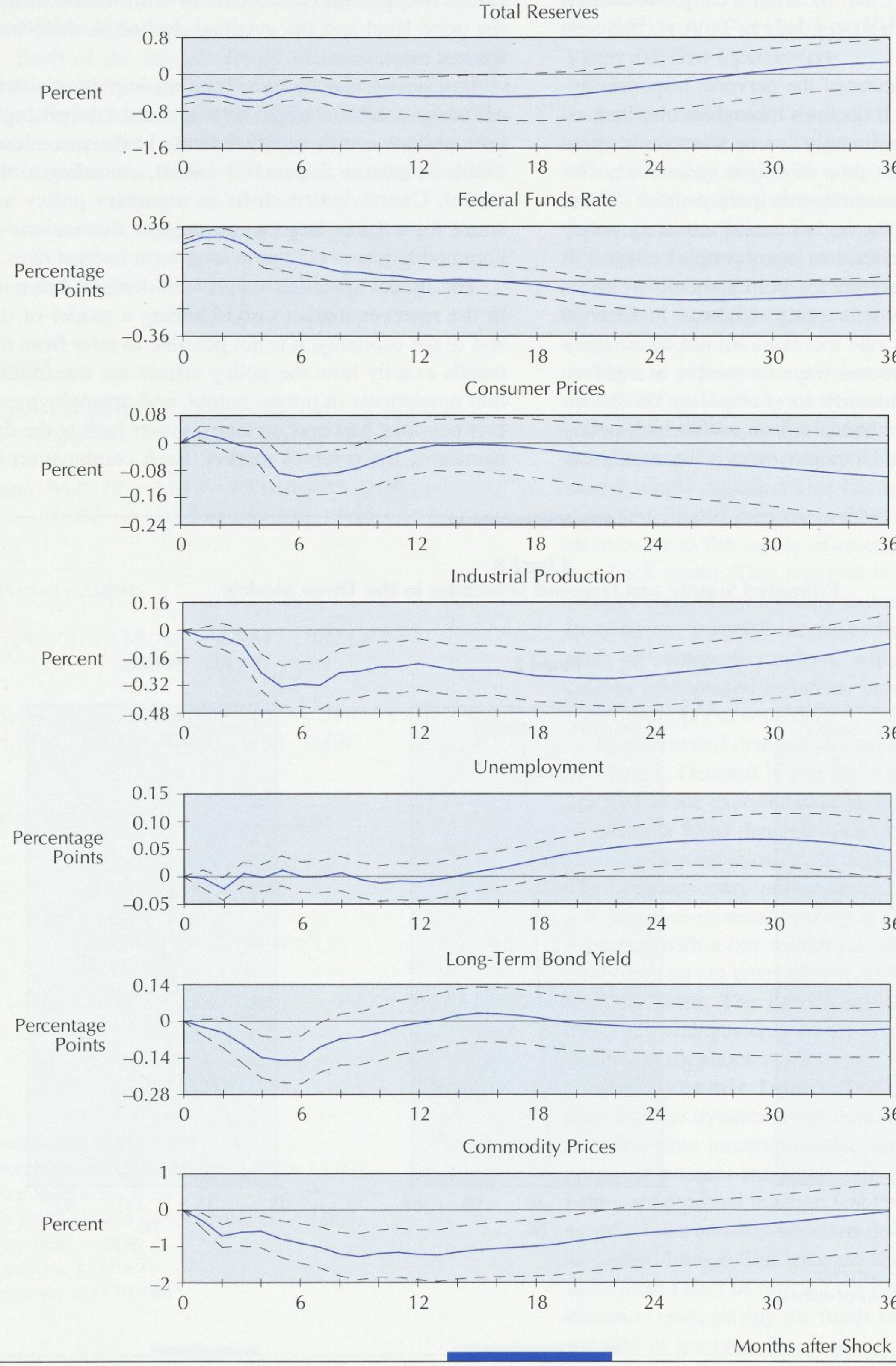
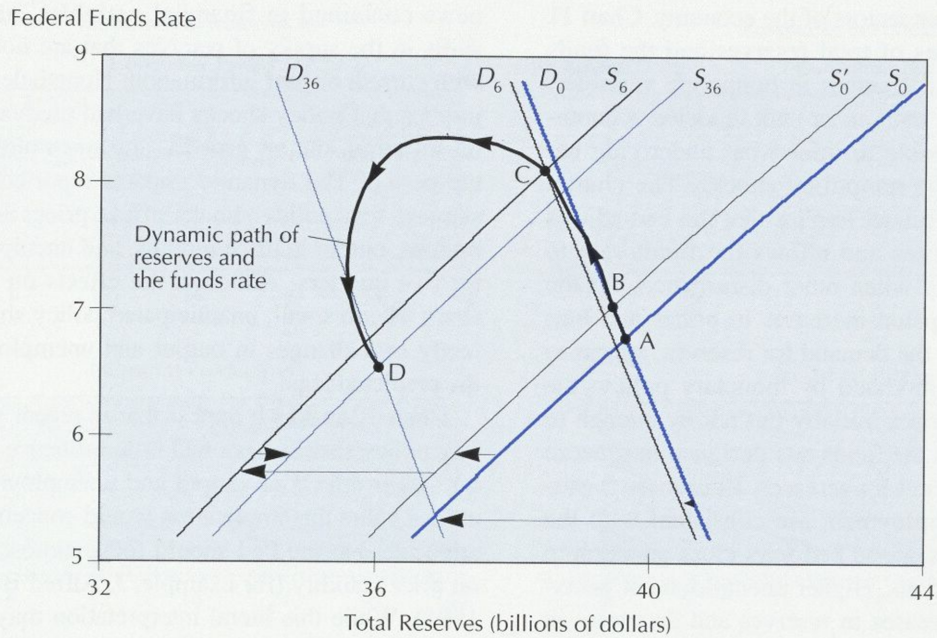


Chart 10
Dynamic Effects of Policy Shock on Reserves Market in Model 1



Initial monetary policy shock shifts supply from S_0 to S_0', moving the equilibrium from point A to point B along the initial demand curve, D_0. Six months later, the supply curve has shifted farther inward to S_6 and the demand curve has shifted inward to D_6, creating a new equilibrium at point C. Over time, the supply and demand curves continue to shift, with their intersections traced out by the curved black line labeled "dynamic path of reserves and the funds rate." Thirty-six months after the initial policy shock, the equlibrium level of reserves and the funds rate occurs at point D, where the S_{36} and D_{36} curves intersect.

reserves and the funds rate reported in the dynamic responses in the first two panels of Chart 9 represents an equilibrium in the reserves market at a different point in time. The dynamic sequence of supply and demand curves associated with Chart 9 are depicted in Chart 10. S_0 and D_0 are the preshock curves, with point A the initial equilibrium.[28] The curved line traces out the equilibrium reserves-funds rate path. The contractionary policy shock shifts supply to S_0', and the economy slides up D_0 to a new equilibrium at B, which is associated with the first point in the top two panels of Chart 9. At each point in time the positions of the supply-and-demand schedules reflect the accumulated effects of the policy shocks on the variables on which supply-and-demand behavior depend. After the initial period the effects of the shock on prices, output, unemployment, long-term interest rates, and commodity prices serve to shift both curves. Points C and D are the equilibria six months and three years after the supply shock.

Chart 9 shows that policy shocks have persistent effects on the quantity of reserves. The steady decline in reserves shows up in Chart 10 as a series of inward shifts in the supply schedule: even six months after the shock, supply is shifting inward (S_6). Eventually, however, the accumulated effects of lower long rates and commodity prices dominate supply behavior and the curve shifts outward toward its initial position, landing at S_{36} three years after the original shock. On the demand side, lower prices and output reduce the quantity of reserves demanded at any given interest rate and shift the schedule inward (to D_6 in six months and D_{36} in three years). After three years, the accumulated effect on the funds rate is close to zero, while that on the level of reserves is negative. This pattern is wholly consistent with Friedman's summary of policy effects as presented in the introduction of this article. After three years the level of total reserves has fallen but the growth rate is near zero. Consequently, the level of the funds rate ends up at the point at which it started. By showing how much policy responds to changes in the economy generated by policy itself, the chart emphasizes that monetary policy depends strongly on economic conditions.

Policy also responds over time to nonpolicy shocks emanating from other sectors of the economy. Chart 11 reports the responses of total reserves and the funds rate to unanticipated changes in nonpolicy variables. Because these other markets are not modeled economically, it is not possible to infer what underlying behavior generates the nonpolicy shocks. The chart's message is that the model implies that the Fed adjusts the supply of reserves and allows the funds rate to change substantially when other disturbances hit the economy. Unanticipated increases in prices and output, which increase the demand for reserves, appear to be partially accommodated by monetary policy: the supply of reserves rises initially but not by enough to avoid an increase in the funds rate designed to squeeze out the excess demand for reserves. Responses to surprise rises in unemployment are consistent with the casual observation that the Fed pays close attention to labor market conditions. Higher unemployment generates significant increases in reserves and decreases in the funds rate, which are consistent with common perceptions that monetary policy tries to offset shocks that raise unemployment.[29] Finally, the decline in reserves and the increase in the funds rate following unanticipated increases in the long rate and commodity prices are consistent with the view that the Fed may interpret financial variables as containing news about higher expected inflation.

These results are confirmed by the second column of Table 1. Monetary policy shocks in Model 1 account for only 20 percent of the variance of fluctuations in reserves and half of the variance of the funds rate within the month (see the first two panels of the second column). These percentages decline over time, making policy shocks a relatively unimportant source of unforecastable movements in reserves market variables two years out. Most of the fluctuations in these variables arise from endogenous responses of policy to nonpolicy shocks, underscoring the strong and consistent dependence of policy on the economy.

Interpreting Recent Economic History. What does this model tell a policy advisor about the recent slowdown in economic activity? Contrasting Charts 12 and 7, Model 1 implies that policy was less tight in 1990 and less loose in 1992-93 than it was according to Model R, which assumed the supply of reserves is perfectly elastic. The differences emerge for straightforward reasons. Chart 7 assumes that all unanticipated funds rate changes arise from shifts in the supply of reserves. Model 1 attributes some of these changes to shifts in demand that induce the Fed to adjust the quantity of reserves supplied along a fixed upward-sloping supply curve, some to changes in policy in response to news contained in financial variables, and some to shifts in the supply of reserves that are not associated with current or past information. Nonetheless, Model 1 implies that policy shocks have had predictable effects on inflation, output growth, and unemployment over the period. The dynamic impacts reported in Chart 9 suggest that policy shocks affect prices in about six months, output in three months, and unemployment after five quarters. Although the effects on inflation in Chart 12 are small, unanticipated policy shifts map directly into changes in output and unemployment with the predicted lags.

Chart 12 makes it appear that in recent years monetary policy shocks have had little influence on inflation but larger effects on output and unemployment. Taken at face value this implication would concern those who advocate that the Fed should focus almost exclusively on price stability (for example, J. Alfred Broaddus, Jr., 1995). While this literal interpretation may be mistaken, it highlights a pervasive and subtle problem with estimating the effects of policy. As an extreme example, suppose that the monetary authority seeks to achieve absolute price stability and that it has been successful in achieving this goal. To do so the authority must adjust the supply of reserves to offset any economic shocks that would otherwise cause the price level to adjust. Macroeconomic time series would exhibit large fluctuations in reserves market variables and in output and employment, but none in prices. Empirical work would find no effects of policy on prices but likely would find effects on real activity. Because policy has been so successful at controlling prices, an analyst without knowledge of the authority's objectives might mistakenly conclude that policy has only real effects.[30] By this interpretation, Model 1 implies that policy has been fairly successful at avoiding taking actions that generate price level fluctuations at the cost of producing fluctuations in output and unemployment.

The model may give cause for concern about economic developments in 1995. Policy shocks in 1994 were contractionary, according to the model. If the historic correlations between policy and macro variables continue to hold, the model predicts lower output, somewhat lower inflation, and, with a longer lag, higher unemployment in 1995.[31]

However, a model's predictions are only as good as its behavioral and statistical underpinnings. The assumption of Model 1 that financial market participants

Chart 11
Responses of Reserves Market Variables to Unanticipated Increases in Other Variables

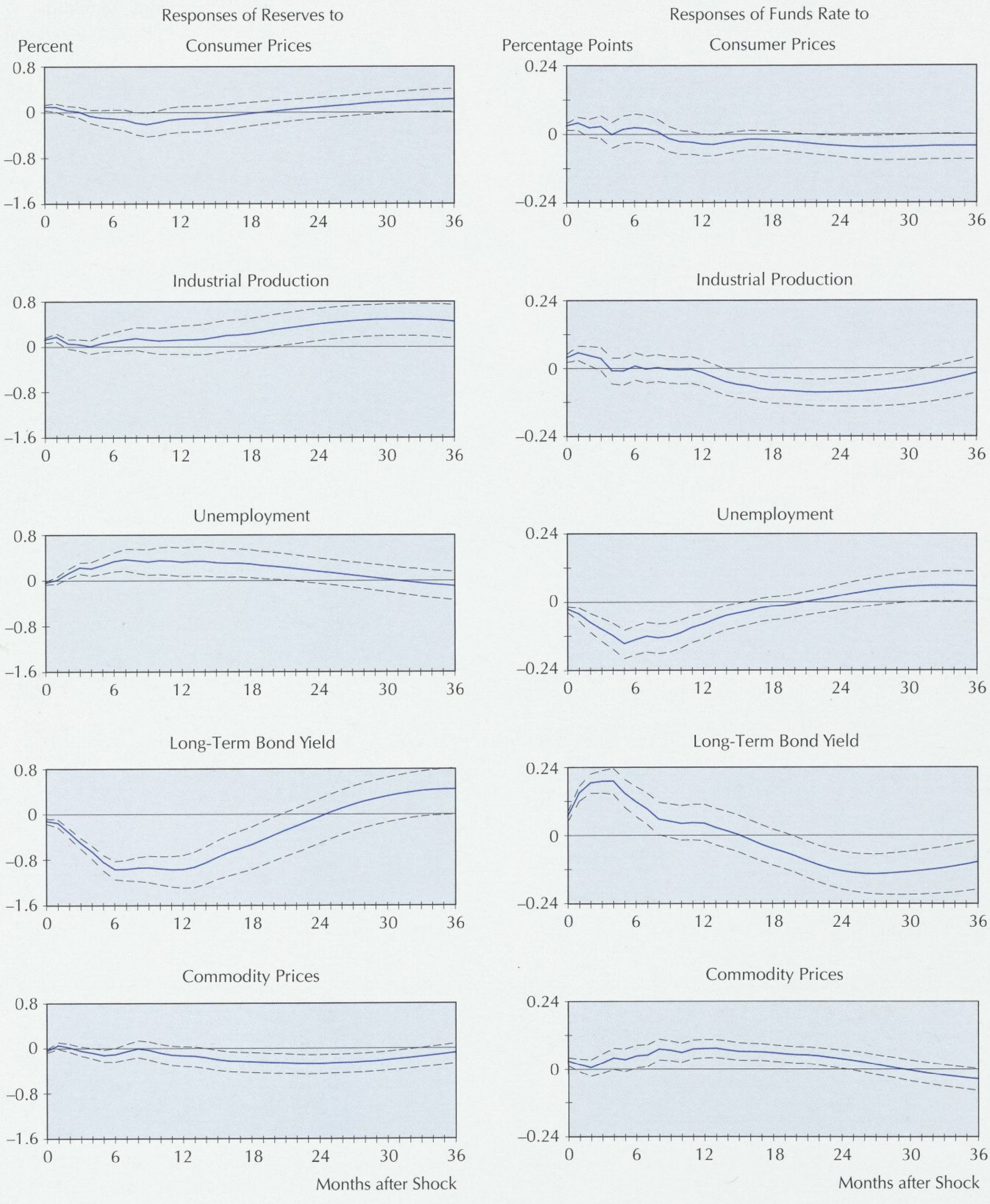
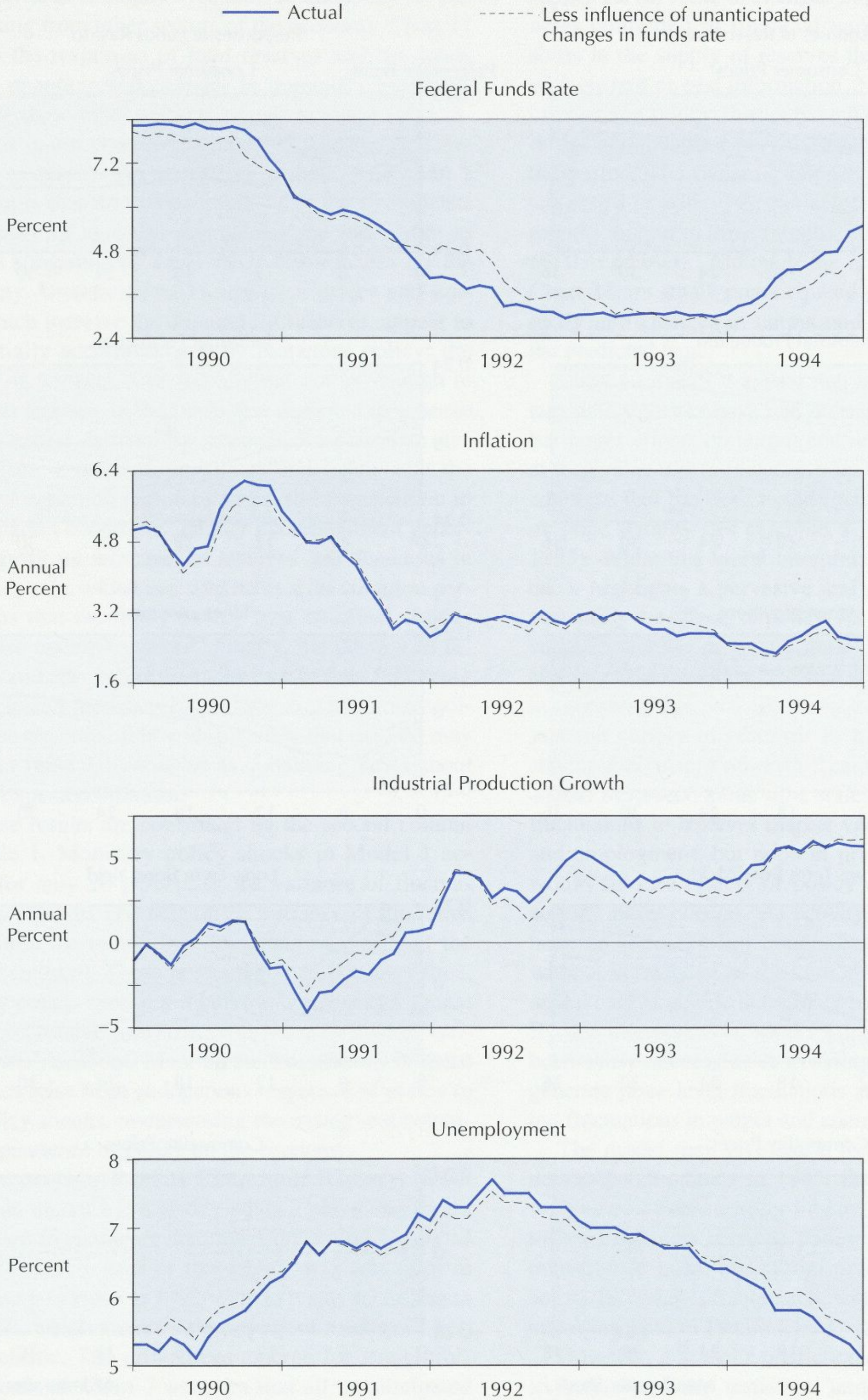


Chart 12
Influence of Monetary Policy Shocks on Model 1



do not react to policy actions within the month is grossly at odds with actual behavior.[32] Markets actually react immediately and often strongly to news about monetary policy. The next two models attempt to address this weakness by allowing reserves market variables and financial market variables to be determined simultaneously.

Model 2: The Funds Rate Affects Financial Variables Contemporaneously

Model 2 modifies Model 1 by allowing reserves market behavior to affect financial variables within the month. Whereas Model 1 imposed the rule that financial variables affected the reserves market immediately but not vice versa, Model 2 determines all reserves market and financial market variables simultaneously. The model assumes that within the month the Fed responds only to the funds rate and commodity prices when it sets the supply of reserves. Model 2 also assumes that the behavior of financial market participants depends on the current funds rate as well as goods market variables.

The model and its estimated parameters are reported in Table 3. The qualitative features of demand-and-supply behavior in the reserves market are similar across Models 1 and 2. Demand for reserves continues to depend negatively on the funds rate and positively on the price level and output. Supply still rises with the funds rate and falls with commodity prices. As seen in Chart 8, the estimated supply of reserves is fairly inelastic with respect to the funds rate. A policy shock in Model 2, therefore, is defined very much as it was in Model TR, where the maintained assumption was that supply was perfectly inelastic and every unanticipated change in reserves was interpreted as a monetary policy shock.

With the funds rate and financial variables determined simultaneously, it is possible from the coefficients reported in Table 3 to infer immediately how some of the dynamic responses to policy shocks in Model 2 will differ from those reported for Model 1. A contractionary monetary policy shock shifts the supply of reserves inward and raises the funds rate initially. The higher funds rate in Model 2 immediately increases both the long-term interest rate and commodity prices. The higher commodity prices feed back into the supply equation, shifting it inward and reinforcing the original contraction. By making monetary policy depend on commodity prices at the same time that it affects commodity prices, Model 2 changes the amount by which a given-sized policy shock shifts the supply schedule.

Chart 13 records the dynamic responses in Model 2 to an unanticipated monetary policy contraction that raises the funds rate by 25 basis points initially.[33] Policy shocks continue to have statistically significant effects on all the variables. Contractionary policy increases the funds rate in the short run and decreases it in the long run. The price level no longer increases initially, and it falls more persistently than in Model 1. Output also falls for three years after the shock. After a strange one-month decline, unemployment rises more quickly than it did in the first model. Long rates rise at impact, consistent

Table 3
Model 2

Reserves Market

Demand: $$\underset{(36.57)}{47.76}TR^d = -\underset{(.51)}{5.01}R + \underset{(72.09)}{88.37}P + \underset{(23.96)}{110.59}Y + e^d$$

Supply: $$\underset{(13.77)}{155.32}TR^s = \underset{(1.08)}{1.83}R - \underset{(6.46)}{3.25}CP + e^s$$

Financial Market Variables

$$\underset{(.30)}{5.02}R10 = \underset{(.45)}{2.10}R + \underset{(66.35)}{80.55}P - \underset{(17.04)}{1.79}Y - \underset{(.76)}{.66}U + e^{R10}$$

$$\underset{(4.38)}{72.94}CP = \underset{(.51)}{1.06}R - \underset{(42.65)}{4.63}P - \underset{(26.69)}{8.86}Y - \underset{(.79)}{.67}U + \underset{(.42)}{.61}R10 + e^{CP}$$

Goods Market Variables

$$\underset{(46.72)}{778.95}P = \underset{(2.30)}{.52}Y - \underset{(.73)}{1.26}U + e^P$$

$$\underset{(17.40)}{290.06}Y = -\underset{(.76)}{3.54}U + e^Y$$

$$\underset{(.51)}{8.54}U = e^U$$

Log likelihood value = 3285.351
LR test of overidentifying restrictions: $\chi^2(4) = 9.676$, significance level = .046
LR test with small-sample correction: $\chi^2(4) = 6.682$, significance level = .154
Akaike criterion = 3237.351
Schwarz criterion = 3166.924

with press accounts of bond market reactions to policy. In contrast to Model 1, however, long rates never fall significantly in spite of a steady decline in the price level and lower short-term interest rates in the future. This is a questionable implication of the model.[34]

Returning to Table 1, policy shocks in Model 2 are the primary source of short-run fluctuations in reserves. This is exactly what the estimated highly inelastic supply of reserves implies. Policy shocks account for relatively small percentages of fluctuations in all the remaining variables except output. In Model 2, policy shocks influence output as strongly as they did in Model 1.

Model 2 supports an interpretation of the 1990-94 period that is qualitatively very similar to that of Model 1 except that unanticipated shifts in policy are quantitatively less important. This point will be discussed later.

Model 2 can be criticized for implicitly assuming that financial markets view all changes in the funds rate as created equal. The model forces all changes in the funds rate, whether from supply shocks, demand shocks, or endogenous responses of policy to other behavioral disturbances, to affect financial variables in the same way. But it is likely to be important to financial market participants to know why the funds rate changed. For example, if the impacts of demand shocks tend to be short-lived, the shocks may affect the funds rate this month but not contain much useful information about the funds rate six months from now. Supply shocks, on the other hand, may have more persistent effects on interest rates, as the Fed has tended to move the funds rate in the same direction for some time. This article has argued that to isolate monetary policy shocks it is essential to construct a model that determines equilibrium price and quantity in the reserves market simultaneously, so treating all changes in the funds rate as stemming from the same source (for example, shifts in monetary policy, as Model R does) is misleading. Logically it seems that financial market participants may need to observe the funds rate and reserves in order to distinguish the source of the change in the short-term interest rates. The final model addresses this concern.

Model 3: Reserves and the Funds Rate Affect Financial Variables Contemporaneously

The final model is identical to Model 2 except that total reserves and the funds rate are allowed to affect long-term interest rates and commodity prices within the month. This model assumes that financial market participants base their decisions on information about the current levels of both reserves and the funds rate.

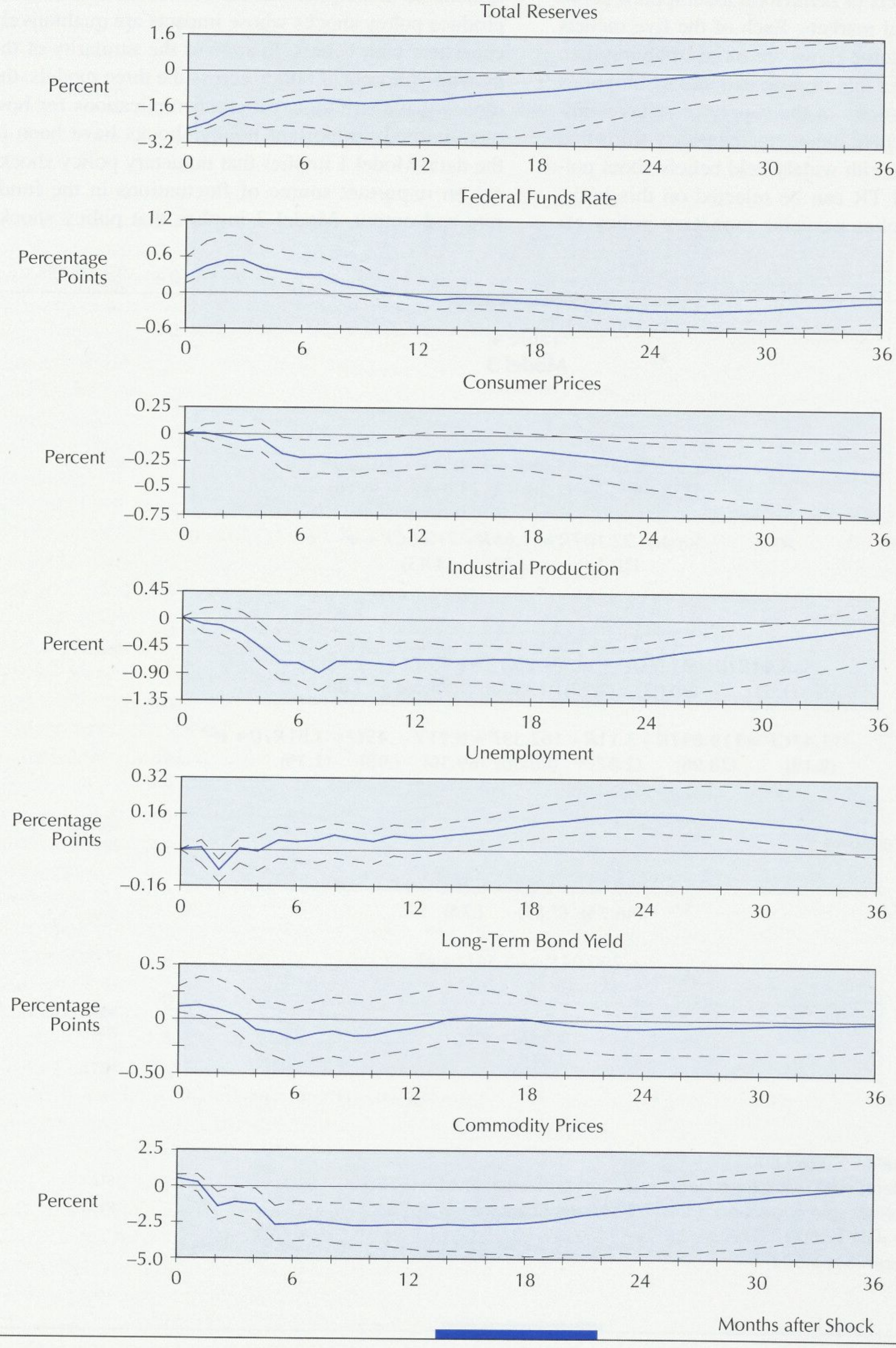
Table 4 presents the model's estimated parameters. The critical differences between Models 2 and 3 are apparent immediately. Model 3 implies a huge monetary policy response to commodity prices. The responsiveness of the supply of reserves to changes in commodity prices is more than 150 times larger in the third model.[35] The simultaneous determination of financial variables, total reserves, and the funds rate implies that an unanticipated contraction in policy generates the following sequence of responses within the month: the inward shift in the supply of reserves raises the funds rate; the lower level of reserves and higher funds rate have reinforcing effects that raise commodity prices; the higher commodity prices shift the supply of reserves outward, counteracting the initial contraction. This chain of events eventually implies that the ultimate shift in reserves due to a reasonably sized policy shock is minuscule.

Qualitatively the dynamic impacts of a policy shock from Model 3 on goods market variables, shown in Chart 14, are similar to those from Model 2.[36] An unanticipated policy contraction significantly lowers prices and output and raises unemployment with somewhat shorter lags than in previous models. As Table 4 reveals, with the funds rate rising and reserves falling initially, long-term interest rates fall significantly. Long rates continue to fall through most of the next three years. Commodity prices drop sharply at the time of the policy shock. The initial drop seems implausibly large.

The most substantive difference between Models 2 and 3 comes from the models' predictions of future policy following an unanticipated contraction. Chart 14 shows that in Model 3 the contraction lasts only a few months before being reversed. Four months after the contraction, reserves have begun to grow and the funds rate has begun to decline. This reversal in policy is strong enough that by the end of three years output is growing and unemployment is falling. Neither Model 1 nor Model 2 display such a rapid turnaround in policy behavior.

Table 1 reports that policy shocks in Model 3 have been a trivial source of fluctuations in all economic variables except commodity prices. In the short run, policy disturbances have been the single most important reason that commodity prices moved in unpredictable ways. This implication, coupled with the model's implied rapid reversal of the direction in policy, make Model 3 of dubious usefulness.

Chart 13
Responses to Unanticipated Monetary Policy Contraction in Model 2
(Policy shock raises funds rate initially by 25 basis points)



Are the Models Believable?

The article has reviewed the monetary policy implications from five sets of behavioral assumptions about policy and financial markets. Each of the five models has its flaws, but some flaws are more troubling than others. The schemes that impose extreme assumptions on the interest elasticity of the supply of reserves imply dynamic impacts of unanticipated policy shifts that are sharply at odds with widely held beliefs about policy effects. Model TR can be rejected on this basis. Model R also implies perverse monetary policy effects, but because it comes close to the way many people identify monetary policy, it deserves closer scrutiny.

Models 1 through 3, which directly estimate supply-and-demand behavior in the reserves market, all make reasonable assumptions about economic behavior and produce policy shocks whose impacts are qualitatively consistent with beliefs. In spite of the similarity of the dynamic impacts of policy across the three models, the models have strikingly different implications for how quantitatively important policy shocks have been in the data. Model 1 implies that monetary policy shocks are an important source of fluctuations in the funds rate and output, Model 2 implies that policy shocks

Table 4
Model 3

Reserves Market

$$\textit{Demand}: 70.76TR^d = -4.68R + 104.31P + 107.20Y + e^d$$
(133.69) (2.28) (123.05) (36.16)

$$\textit{Supply}: 22.10TR^s = 1.65R - 71.85CP + e^s$$
(20.54) (.70) (4.43)

Financial Market Variables

$$3.44R10 = 91.09TR - .40R - 20.15P + 15.71Y - 1.13U + e^{R10}$$
(1.51) (90.03) (2.27) (135.68) (74.15) (.80)

$$11.47CP = 119.89TR - 3.11R - 162.39P + 8.91Y - .45U + 3.81R10 + e^{CP}$$
(9.18) (28.96) (2.87) (88.80) (69.36) (.98) (1.39)

Goods Market Variables

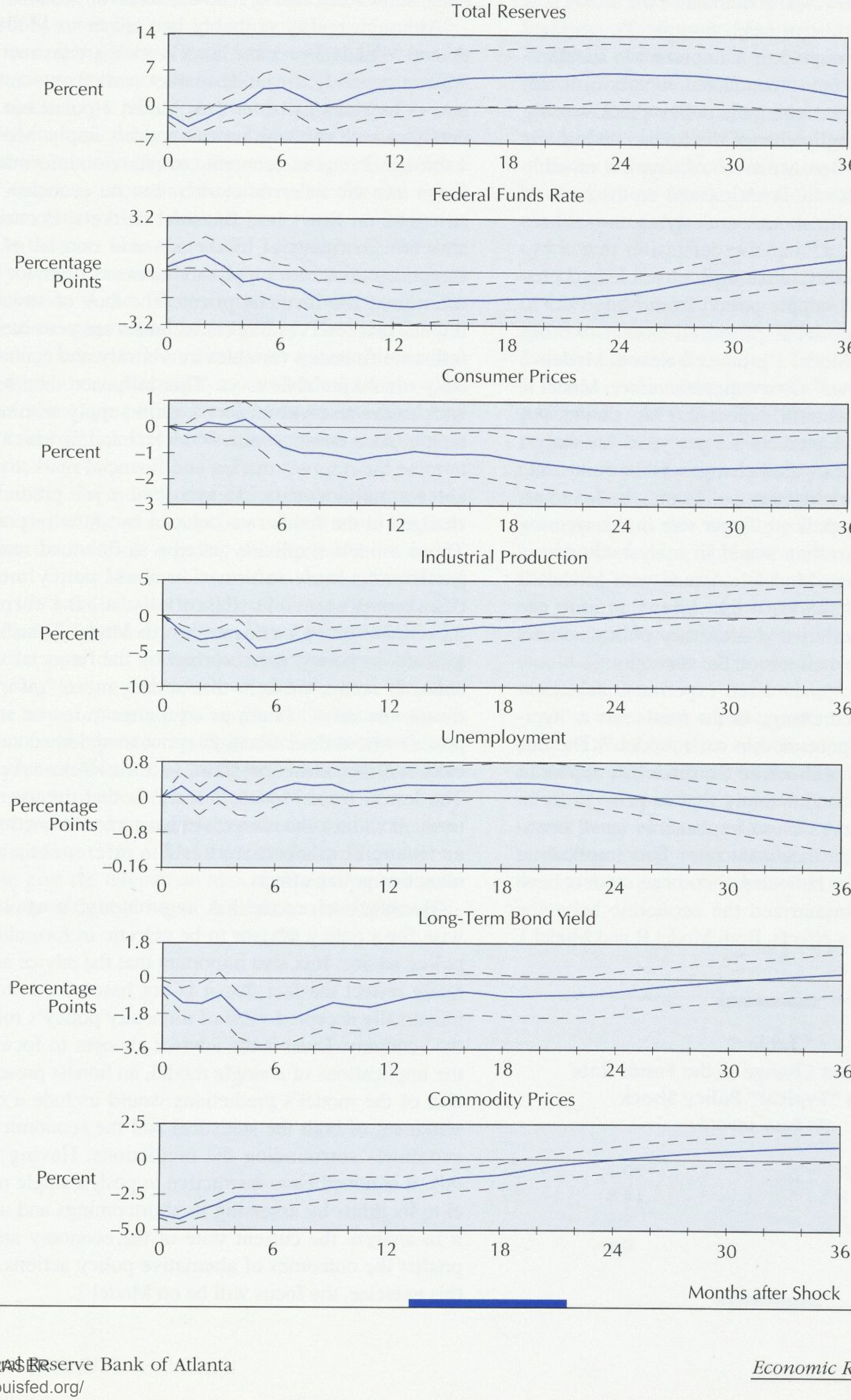
$$779.02P = .52Y - 1.26U + e^P$$
(46.73) (7.57) (.74)

$$290.04Y = -3.54U + e^Y$$
(17.40) (.76)

$$8.54U = e^U$$
(.51)

Log likelihood value = 3289.800
LR test of overidentifying restrictions: $\chi^2(2) = .779$, significance level = .678
LR test with small-sample correction: $\chi^2(4) = .538$, significance level = .764
Akaike criterion = 3237.800
Schwarz criterion = 3161.503

Chart 14
Responses to Unanticipated Monetary Policy Contraction in Model 3 (Policy shock raises funds rate initially by 25 basis points)



influence reserves and output, and Model 3 says that policy shocks affect only commodity prices.

There is no sensible mechanical way to choose among the three models. Purely statistical criteria do not imply that one model clearly dominates the others.[37] A little common sense can help, though. To evaluate Models R and 1 through 3, it is important to standardize the experiment being conducted. Charts 6, 9, 13, and 14 were drawn assuming the policy shock was big enough to unexpectedly change the funds rate initially by 25 basis points. Because much of a typical monthly change in the funds rate is anticipated on the basis of past information, the shocks underlying those three charts were "big." Using the definition that a big shock raises the funds rate on impact by at least 25 basis points, over the sample period from May 1983 to December 1994 Model R produced twenty-two big policy shocks and Model 1 produced eleven. Models 2 and 3 produced none.[38] On average, therefore, Model R suggests that one should expect 2.6 big shocks per year, while Model 1 predicts 1.1 per year. An analyst who treats all unanticipated changes in the funds rate as surprise shifts in monetary policy may be led to attribute to monetary policy a larger role in determining economic conditions than would an analyst who views the economy through Model 1. Armed with Models 2 or 3, however, an analyst might infer that only extremely large unanticipated monetary policy actions will have discernible effects on the economy.

A twist on this standardized experiment asks how big an unanticipated change in the funds rate a "typical" policy shock generated in each model.[39] The initial impacts of such a shock on the funds rate appear in Table 5. Models 2 and 3 imply that surprise shifts in the supply of reserves cause implausibly small unanticipated changes in the funds rate. This implication alone is grounds for believing that those models have not adequately summarized the economic behavior that generates policy effects. Both Model R and Model 1 seem reasonable along this dimension. The choice between Models R and 1, therefore, comes down to how plausible the models' implications are for policy effects. The strange policy impacts that Model R implies, shown in Chart 6, lead one to favor Model 1.

Although reality probably lies closer to Model 1 than to Models 2 or 3, the latter models are instructive. Almost certainly, financial market participants anticipate policy actions better than Model 1 posits but not nearly as well as the other two models imply. Models 1 through 3 impose economic structure on information flows into the reserves markets but no economic restrictions on flows into financial markets. Economic structure in financial markets would consist of assumptions about the supply-and-demand behavior that determines the financial prices. The lack of structure implies that reserves market variables are permitted to influence financial variables in arbitrary and economically uninterpretable ways. This influence then feeds back to the reserves market to shift supply within the month. As a consequence, Models 2 and 3, which determine the reserves market and financial market variables simultaneously, do too good a job predicting changes in the funds rate induced by shifts in policy. Those models implicitly ascribe to financial market participants more information about policy moves than seems plausible. Essentially, all the surprise movements in the funds rate, which Model 1 attributes to shifts in policy, get absorbed by the financial variables. It seems unlikely that adding more "informational variables" (such as exchange rates or stock prices) whose determination is not modeled economically will solve this problem, so there is no easy fix. The lesson from Models 2 and 3 is that the assumptions about how the reserves market interacts with other financial markets matter for inferences about monetary policy effects.

Because each model has its problems, it would be wise for a policy advisor to be eclectic in formulating policy advice. It is also important that the advice accurately reflect the fact that it is not based on a single, universally accepted view of monetary policy's role in the economy. Even if the advisor chooses to focus on the implications of a single model, an honest presentation of the model's predictions would include a clear statement of both the statistical and the economic uncertainties surrounding the predictions. Having said this, it is nonetheless instructive to push a single model to its limits by assessing its shortcomings and using it to analyze the current state of the economy and to predict the outcomes of alternative policy actions. For this exercise, the focus will be on Model 1.

Table 5
Unanticipated Change in the Funds Rate from a "Typical" Policy Shock
(In basis points)

Model R	20.3
Model 1	14.8
Model 2	5.5
Model 3	0.9

Where Does All This Leave the Policy Advisor?

For all of its warts, Model 1 seems fairly reasonable as a first cut at the problem of isolating and quantifying monetary policy effects. Like any model it has its limitations. It cannot be used to predict financial market reactions to policy shocks. It is estimated over a period that was fairly quiescent in terms of shocks that hit the economy. During the estimation period there was only one economic downturn, limiting the information content of the data.

On the plus side, the model appears to fit the data fairly well. It provides a straightforward interpretation of behavior in the reserves market, where the Fed intervenes to conduct monetary policy. The specification of policy behavior is in terms of a quantity (reserves) that the Fed can potentially control. Model 1 also produces monetary policy shocks whose estimated impacts conform closely to consensus views about policy effects.

Finally, the model provides at least first-pass answers to the questions a policy advisor must confront before formulating a policy recommendation to the Federal Open Market Committee. In the middle of June 1995 the advisor could have used the model to forecast the economy given data through May. The forecast provides one prediction of how severe and how long-lasting the slowdown will be. One measure of the role of monetary policy shocks in the slowdown comes from reproducing Chart 12 for the period, say, from June 1994 to May 1995. This calculation reports how much of the unpredicted slowdown in activity can be attributed to unanticipated contractions in monetary policy. The model's estimated policy shocks would give the advisor an idea of whether recent policy has been tight or loose. A sequence of sizable tightening shocks would lead the advisor to infer that recent monetary policy actions will tend to make future output and inflation lower and unemployment higher, based on the results in Chart 9. In that situation a decision not to lower the funds rate would likely generate further contractions and exacerbate the slowdown.

This is about as far as a policy advisor can go in extracting information from the model. The model is silent on the question of whether contractionary shocks are "good" or "bad." The model generates predictions of future economic conditions and economic interpretations of past developments. It can, in principle, be used to forecast outcomes of contemplated future policy choices. It cannot evaluate the desirability of the outcomes. Like the Goldilocks assessments that policy is too tight, an evaluation of the desirability of outcomes carries an implicit statement about preferences over the outcomes.

There is one further potential use for the model. If a policymaker feels that Fed behavior over the 1983-94 period has largely achieved the policymaker's objectives, the model can be used to automate the policymaker's decisions. The model produces a prediction of what the funds rate would be if there were no shocks to policy behavior. This path of the funds rate embodies policy's usual response to economic conditions. If the policymaker seeks to minimize the economic shocks introduced by policy behavior, the policymaker would simply vote to implement the model's funds rate prediction.

Of course, such a policymaker is rare. More often policymakers hope to improve upon past policy and economic performance. In that case the model remains informative about past economic developments. The model must be used with great caution, however, in predicting longer-run outcomes of policy actions that deviate from past policy behavior.

Appendix A
Demand and Supply Analysis of the Reserves Market

This appendix derives the demand and supply functions for reserves and links these behavioral relationships to a broader monetary aggregate like M2. The linchpin of the models reported in the text is the existence of an integrated market for reserves: the federal funds market. As a result of this market, demanders of reserves face a common opportunity cost of both borrowed and nonborrowed reserves, so demanders perceive borrowed and nonborrowed reserves to be perfect substitutes. The opportunity cost of reserves is the funds rate. More precisely, the funds rate equals the interest cost plus the costs of reserves' transactions in the federal funds market and must equal the discount rate plus any nonpecuniary costs of borrowing from the discount window.[1]

Assuming that the demand for reserves is not completely interest inelastic—an assumption that appears to be innocuous as long as excess reserves are positive—the opportunity cost is a function of the total supply of reserves and is independent of the composition of total reserves between borrowed and nonborrowed reserves. Thus, for the purpose of identifying monetary policy shocks, no distinction is required among open market operations and discount window operations.[2]

As is implicit in much of the earlier work on the reserves market, reserves are treated as a factor of production in intermediating between the M2 market and a market for less liquid assets.[3] A demand relation is assumed for M2 of the form

$$M^d = D(R, P, W), \qquad \text{(A.1)}$$

where R is the cost of holding M2, P is the price level, and W is a scaling variable. The demand for M2 is the demand for a joint product comprising a portion that pays a positive own rate of return and a portion that provides transactions services. Because the interest-bearing portion is a perfect substitute for other interest-bearing assets, its demand is infinitely elastic. Demand for the transactions services provided by M2 is a decreasing function of the price of the services. The return determined in the M2 market is the unobserved sum of the own rate and the marginal value of transactions services. In equilibrium, the total return to holding M2 must equal the rate on the alternative asset.

M2 supply is given by

$$M^s = S(R, R_f, R_L, \ldots), \qquad \text{(A.2)}$$

where R_f is the fed funds rate, R_L is the nominal interest rate on bank assets, and the additional variables reflect other costs of intermediation.

$S(\bullet)$ is determined by a group of intermediaries viewed as "producing" loanable funds, L, which earn the rate of return R_L, by using the technology

$$f(L, TR, M^s, \ldots) = 0. \qquad \text{(A.3)}$$

Implicitly, the intermediaries are viewed as using the liabilities, M, as an input to the process of producing the assets, L.

The cost function $C(\bullet)$ of the intermediaries is the solution to

$$C(\bullet) = \min_{\{TR, M^s\}} R_f \bullet TR + R \bullet M^s + \textit{other costs}, \qquad \text{(A.4)}$$

subject to the technology (A.3), taking L, R_f, and R as given.

The first-order conditions for the cost-minimization problem yield the implicit derived demand for total reserves:

$$R_f = R \bullet \frac{f_{TR}}{f_{M^s}}, \qquad \text{(A.5)}$$

where f_x denotes the partial derivative of the production function with respect to x.

The M2 supply results from solving:

$$\max_{\{L\}} L \bullet R_L - C(L, R, R_f, \ldots), \qquad \text{(A.6)}$$

which yields the inverse supply function for loans:

$$R_L = C_L(L, R, R_f, \ldots). \qquad \text{(A.7)}$$

The demand for reserves can be expressed in terms of the variables R_f, P, and W by using the M2 demand function (A.1), the supply function for loans (A.7), and the production function (A.3) to eliminate M, L, and R. Substituting these results into the derived demand for reserves (A.5), yields a transformed demand for reserves of the form:

$$TR = TR^{d*}(R_f, P, W, R_L, \ldots). \qquad \text{(A.8)}$$

The specification of reserves supply abstracts from any distinctions between open market operations and borrowing at the discount window. The Federal Reserve is assumed to respond to the current federal funds rate and other available information in determining the supply of reserves:

$$TR^s = G(R_f, \Omega_G), \qquad \text{(A.9)}$$

where Ω_G is the information set available to the policy authority.

In a symmetric fashion, the supply of M2 can be expressed as a function of the variables in the policy rule (A.9) rather than of the funds rate. The reserves supply function (A.9), the derived demand for reserves (A.5), and the production function (A.3) are solved for TR, R_f, and L. Substituting the results into the money supply function (A.2) yields a transformed M2 supply function:

$$M^s = M^{s*}(R, R_L, I_G, \ldots). \qquad \text{(A.10)}$$

The derived demand for reserves, equation (A.8), is obtained by combining the behavior of M2 demanders with the behavior of the financial intermediaries that are issuing loans. Thus, shifts in this function may arise from either of these two behavioral sources. Similarly, the M2 supply function, equation (A.10), blends the behavior of the policy authority that is supplying reserves with the behavior of intermediaries that are issuing the liabilities that make up M2. Changes in the behavior of either the policy authority or intermediaries can cause shifts in the M2 supply function.

The empirical work focuses on the equilibrium relationship:

$$TR^{d*}(R_f, P, W, R_L, \ldots) = TR^s = G(R_f, \Omega_G). \qquad \text{(A.11)}$$

Notes

1. The discount rate can exceed the funds rate either because discount loans are longer term than federal funds or because the only holders of discount loans face prohibitive risk premiums in the federal funds market.
2. For questions beyond the identification of monetary policy shocks, the distinction between borrowed and nonborrowed reserves is of interest. For example, Tinsley and others (1981) and Bryant (1983) focus on questions about monetary policy operating procedures and the interaction of the discount window and open market operations.
3. See, for example, Meigs (1962), Morrison (1966), or Goldfeld and Kane (1966).

Appendix B
Estimating an Identified VAR

This appendix provides the econometric details for the estimated models reported in the text. The procedure follows the work of Bernanke (1986), Olivier J. Blanchard and Mark W. Watson (1986), and Sims (1986). Let e_t be an $(n \times 1)$ vector of behavioral disturbances and x_t be an $(n \times 1)$ vector of data observed over periods $t = 1,2, \ldots T$. The structural model is given by

$$A(L)x_t = e_t, \; Var(e_t) = \Omega = I_n. \qquad \text{(B.1)}$$

The VAR for this structure is

$$C(L)x_t = v_t, \; C_0 = I, \; Var(v_t) = \Sigma. \qquad \text{(B.2)}$$

Assume that (B.1) is complete in the sense that current x's are determined by current and past e's. Then

$$x_t = A^{-1}(L)e_t, \qquad \text{(B.3)}$$

when the right-hand side of (B.3) is one-sided and convergent, implying that stationary e's imply stationary x's.

The VAR in (B.2) can be solved to yield the impulse response matrices for x, G_s:

$$x_t = \sum_{s=0}^{m} G_s v_{t-s} + H_m(L)x_{t-m}, \qquad \text{(B.4)}$$

where the impulse response matrices do not depend on m.

Writing out (B.1) and (B.2) as

$$A_0 x_t = I_n e_t + \sum_{s=1}^{\infty} I_n e_{t-s} - \sum_{s=1}^{\infty} A_s x_{t-s}$$

and

$$x_t = v_t - \sum_{s=1}^{\infty} C_s x_{t-s},$$

it is clear that if current and past e's and x's span the same space and the e process is serially independent, then

$$A_0 v_t = e_t; \qquad \text{(B.5)}$$

hence,

$$v_t = A_0^{-1} e_t. \qquad \text{(B.6)}$$

Substituting (B.5) into (B.4) implies the impulse response matrices of the identified VAR, $G_s A_0^{-1}$ for all s's.

Equation (B.6) is a mapping from the VAR innovations to the behavioral disturbances. The identification takes the form of assuming that some of the elements of A_0 are zero. An identity covariance matrix for the behavioral disturbances combines a normalization with the identifying assumption that each shock is associated with a behaviorally distinct sector of the economy. The zero restrictions on A_0 limit the contemporaneous interactions among variables. Importantly, if the identifying assumptions restrict only A_0 and Ω, then they may restrict Σ , but they will not restrict the C and G_s matrices. Hence, the reduced form for x_t is not affected by identifying assumptions of this form. When the model is just identified, no restrictions are imposed on Σ and the model is one of many observationally equivalent rotations of the covariance matrix of the unrestricted VAR. Among these observationally equivalent rotations are those orthogonalized using a Choleski decomposition.

The model is fit by treating the estimate of Σ as data and performing maximum likelihood with respect to the free parameters in A_0. The log likelihood function of the sample in terms of the VAR innovations is

$$\log L \propto -\frac{T}{2}\log|\Sigma| - \frac{1}{2}\sum_{t=1}^{T} v_t' \Sigma^{-1} v_t. \tag{B.7}$$

Assuming a flat prior distribution over the VAR parameters, and parameterizing Σ by $A_0^{-1}\Omega A_0^{-1\prime}$, the posterior density for A_0 and the C matrices is given by

$$\log L \propto -\frac{T}{2}\log\left|A_0^{-1}\Omega A_0^{-1\prime}\right| - \frac{1}{2}\sum_{t=1}^{T} v_t' A_0' \Omega^{-1} A_0 v_t. \tag{B.8}$$

Integrating out the VAR parameters produces the marginal posterior density for A_0:

$$\log L \propto T \bullet \log|A_0| - \log|\Omega| - \frac{1}{2} tr\,\Omega^{-1} A_0 \hat{\Sigma} A_0'$$
$$\propto T \bullet \log|A_0| - \frac{T}{2} tr A_0 \hat{\Sigma} A_0', \tag{B.9}$$

where the last line of (B.9) is obtained by imposing the normalization and the identifying restrictions that $\Omega = I_n$.

There are $n(n+1)/2$ distinct elements in $\hat{\Sigma}$. From these it is possible to estimate up to $n(n+1)/2$ elements in A_0. When more than $n(n-1)/2$ restrictions are imposed on A_0, the model is overidentified. In this case, estimates obtained by maximizing (B.9) are consistent but not fully efficient.

Four methods of evaluating the models' goodness of fit are presented in the text. Classical tests of overidentifying restrictions are computed in two ways as follows. Let k be the number of parameters estimated in A_0 so that $r = n(n+1)/2 - k$ is the number of overidentifying restrictions. Evaluated at the maximum likelihood estimates, the likelihood value for the unrestricted model is

$$L_u = -\frac{T}{2}\log\left|\hat{\Sigma}\right| - \frac{Tn}{2}, \tag{B.10}$$

and the value for the restricted model is

$$L_r = -\frac{T}{2}\log\left|\hat{A}_0^{-1}\hat{A}_0^{-1\prime}\right| - \frac{T}{2} tr\left(\hat{A}_0 \hat{\Sigma} \hat{A}_0'\right). \tag{B.11}$$

The statistic

$$W_r = 2(L_u - L_r) = T\left(\log\left|\hat{A}_0^{-1}\hat{A}_0^{-1\prime}\right| + tr\left(\hat{A}_0 \hat{\Sigma} \hat{A}_0\right)\right.$$
$$\left. - \log\left|\hat{\Sigma}\right| - n\right) \tag{B.12}$$

is distributed as central χ_r^2. To improve the small-sample properties of the test statistic, Sims (1980a) has suggested using the statistic

$$W_r^* = (T - nl - 1)\left(\log\left|\hat{A}_0^{-1}\hat{A}_0^{-1\prime}\right| + tr\left(\hat{A}_0 \hat{\Sigma} \hat{A}_0\right)\right.$$
$$\left. - \log\left|\hat{\Sigma}\right| - n\right), \tag{B.13}$$

where l is the number of lags in the estimated VAR.

The other two fit criteria applied to the estimated models are Bayesian. Letting L^* denote the value of the maximized likelihood function for a given model, the Akaike criterion is computed as

$$AC = L^* - 2 \bullet k, \tag{B.14}$$

and the Schwarz criterion is computed as

$$SC = L^* - k \bullet \log(T). \tag{B.15}$$

Notes

1. Gottfried Haberler (1965) traces the rise and fall of monetary explanations of economic fluctuations that were put forth in the first half of this century.
2. The work of Gottfried von Haberler (1938) is an early example of a theory of business cycles in which money plays no active role.
3. In the chart all growth rates are calculated month-over-month a year ago.
4. Another way to view the shocks is as movements in economic variables that the posited economic behavior in the model cannot explain.
5. It may seem more natural to study supply and demand for the monetary base, which is also under the control of the Fed. The base is the sum of the Fed's monetary liabilities (currency in circulation and reserves) and the U.S. Treasury's monetary liabilities (Treasury currency in circulation), with currency making up the vast majority. There are three reasons not to concentrate on the base. First, much U.S. currency is held outside the United States and does not influence American economic conditions directly. Second, because open market operations affect reserves, the Fed's policy directive is couched in terms of reserves rather than the base. Finally, the Federal Reserve has for a long time maintained a policy of elastically supplying currency, so changes in the base that are not associated with changes in reserves are not likely to represent the desired policy experiment.
6. For example, long-term interest rates are excluded from the demand for reserves, leaving short-term rates, prices, and output to distinguish between changes in expected inflation and changes in expected real interest rates. When real rates are easy to forecast, this exclusion is unlikely to be a bad approximation. However, when there is much uncertainty about inflation and real rates, omitting other factor prices from the derived demand may be overly restrictive.
7. Industrial production is an imperfect proxy for the income or wealth concept that influences money demand. It is also an imperfect measure of output, as it ignores the large fraction of output associated with the service sectors of the economy.
8. Meulendyke (1989) offers an excellent and thorough introduction to the Fed's operating procedures and the reserves market.
9. See Mengle (1993) for further discussion of the discount window.
10. See Goodfriend (1991) for a discussion of the operating procedure.
11. Randomness in policy need not reflect capriciousness or mistakes in policy choices. Without a detailed model of policy behavior, however, it is not possible to distinguish among several potential sources of the randomness. Sources may be imperfect understanding of economic conditions stemming from preliminary data releases or errors in forecasting or they may be unpredictable shifts in the preferences of policymakers.
12. The graph is from Goodfriend (1982), which gives a detailed description of how various monetary policy operating procedures influence the supply of reserves and of broader monetary aggregates.
13. The chart also shows that the open market purchase, holding the discount rate fixed, decreases the spread between the funds rate and the discount rate. A smaller spread decreases the incentive to borrow at the window, so borrowed reserves fall, but by less than the increase in nonborrowed reserves, leaving total reserves higher.
14. The VAR was estimated with six lags and a constant term. Data from December 1982 to May 1983 were used as initial conditions. Total reserves, the price level, output, and commodity prices are measured in logs; the federal funds rate, unemployment, and the long-term bond yield are measured in percentages. The data were TR = total reserves, seasonally adjusted and adjusted for reserve requirement changes; R = federal funds rate, average of business day figures; P = consumer price index, seasonally adjusted; Y = total industrial production, seasonally adjusted; U = civilian unemployment rate, seasonally adjusted, adjusted in 1994 by –0.3 percentage points to account for changes in survey methods; $R10$ = yield on ten-year U.S. Treasury bond, constant maturity, average of business day figures; CP = industrial country commodity price index from the International Monetary Fund *International Financial Statistics*, line 110, denominated in or converted to U.S. dollars.
15. Leeper (1992) and Leeper and Gordon (1992) explore Cagan's results in the context of modern time series models. Recently Pagan and Robertson (1995a, 1995b) have executed careful statistical analyses of existing work on the liquidity effect.
16. The bands are produced using the Bayesian Monte Carlo procedures in RATS and are based on 10,000 draws from the posterior distribution of the VAR coefficients.
17. A notable exception was from October 1979 to November 1982 when the Fed targeted nonborrowed reserves.
18. The unanticipated increase in the funds rate holds the level of reserves fixed in the month, so the positive contemporaneous correlation between the two variables that appears in Chart 5 is forced to be zero in Chart 6. Because the correlation is small, holding reserves fixed for this experiment does not alter the results.
19. To compute the historical decompositions, the VAR is estimated over the entire sample period and the model is used to generate a forecast conditional only on the model's initial conditions, meaning on actual data available through May 1983.
20. This definition of tight and loose policy emphasizes that these are relative terms. It employs an information-based metric of policy that may differ from the basis of comparison others employ.
21. Chart 6 also points to one interpretation of the "overheating" view that "too rapid" output growth pushes up inflation. Because output tends to respond to interest rate surprises more

quickly than does inflation, the timing makes it appear that higher output leads to higher inflation. Of course, in this case there is no causal relationship between the two, as the cause of movements in both was the change in the funds rate.

22. For these calculations, reserves are not held fixed to compute the correlations of funds rate surprises with other variables.
23. To word it differently, the unanticipated change in the funds rate, which Model R identifies as a monetary policy shock, is not a shock at all because it must be partially predictable from data outside past values of the seven variables in the VAR.
24. The model is normalized to have an identity covariance matrix. The standard errors, reported in parentheses, were computed from a numerical estimate of the inverse of the second derivative matrix of the likelihood function evaluated at the maximum likelihood estimates of the parameters.
25. The full moving average representations for the models are available from the author.
26. The errors bands are estimated using the Bayesian Monte Carlo procedure developed by Sims and Zha (1995). The method draws directly from the asymptotic distribution of the restricted model, so it is applicable to models that are overidentified. The error bands are computed based on 12,000 random draws. Thanks to Tao Zha for providing the code for the procedure.
27. Industrial production, however, is noted for its cyclical sensitivity, so the speed of its response to policy ought to be interpreted cautiously. A broader measure of output, such as gross domestic product, which includes services, may not display such a sharp short-run response.
28. The initial equilibrium is normalized to be the unconditional sample means of the funds rate and total reserves.
29. Unemployment's response to its own unanticipated increase turns negative after about eighteen months and then falls significantly, providing corroborating evidence that the Fed's response effectively reverses the initial increase. (This result is not reported in the chart.)
30. This is an old but frequently overlooked point. The earliest mention of it known to the author is in Kareken and Solow's (1963) criticism of Milton Friedman's empirical work.
31. Some readers may be concerned that the introduction of "sweep" accounts by several large banks in 1994 may distort the results from this model. Sweep accounts transfer a customer's other checkable deposit account balances in excess of a certain threshold into a money market deposit account. Because money market deposit accounts are not reservable, sweep accounts benefit banks by reducing their required reserves. In addition, customers may earn more interest on money market accounts. In general, the more costly it becomes for banks to hold non-interest-earning reserves, the greater is their incentive to exploit sweep accounts. The use of sweeps should reduce the derived demand for reserves at any given funds rate.

    For the sample period used in this study, sweeps affect the level of total reserves in only a couple of months in 1994, the last year of the data set. For those months, Model 1 accounts for the decline in reserves due to sweeps as part of the predictable part of the derived demand for reserves, as theory implies the model should. Thus, it does not appear that the introduction of sweep accounts affects the inferences drawn from Model 1. Corroborating evidence that Model 1 adequately explains sweeps' behavior comes from Gordon and Leeper (1994). The authors estimate a version of Model 1 using data from December 1982 to April 1992, a period that predates sweep accounts. The qualitative results from that work parallel those reported in this article.
32. One of the themes of Sims and Zha's (1994) work is the problems that may arise from this assumption. They argue that the strong effects of monetary policy shocks reported by Gordon and Leeper (1994) stem from this assumption.
33. The standard-deviation bands for the impulse response functions are computed based on 10,824 random draws.
34. If the increase in the funds rate in the short run is sufficiently strong, the expectations theory of the term structure may hold even though the model appears to have questionable longer-run implications.
35. To see this, normalize the supply functions in the two models to have ones on TR^s. Model 2 implies a coefficient on commodity prices of .021, and Model 3 implies a coefficient of 3.25.
36. As before, the chart is drawn for a policy shock that raises the funds rate 25 basis points at impact. The standard-deviation bands for the impulse response functions are computed based on 9,664 random draws.
37. As reported in Tables 2 through 4, classical hypothesis tests reject Model 1 at a 2 percent confidence level and Model 2 at a 5 percent level. Model 3 cannot be rejected. Using Sims's (1980a) correction to improve the small sample properties of the test statistic, Models 1 through 3 can never be rejected at higher than a 10 percent confidence level.

    The Akaike criterion for the (just-identified) models that impose extreme assumptions on interest elasticities of the supply of reserves—Models TR and R—is 3234.189, while the Schwarz criterion for these models is 3152.023. Consequently, the Akaike criterion ranks the models in the order: Model 3, Model 1, Model 2, Models TR and R. The Schwarz criterion ranks them in the order: Model 1, Model 2, Model 3, Models TR and R. The Akaike criterion, and the Schwarz criterion even more strongly, penalize the fit of the model for requiring many parameters. Because Models TR and R estimate twenty-eight parameters, Model 1 estimates twenty-three, Model 2 estimates twenty-four, and Model 3 estimates twenty-six, it is possible for these alternative model selection criteria to imply different rankings in terms of goodness of fit than the straight likelihood criteria.
38. Under the normalization that the shocks have mean 0 and variance 1, a "big" surprise in the funds rate requires policy shocks of magnitude at least 1.23 in Model R, 1.69 in Model 1, 4.51 in Model 3, and 29.20 in Model 4.
39. A "typical" shock is taken to be 1 standard deviation, which equals unity in each model.

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FYI

Testing the Informativeness of Regional and Local Retail Sales Data

Gustavo A. Uceda

Among the potentially useful and informative low-level government data are monthly retail sales data series produced by the U.S. Department of Commerce. Although part of this large collection of retail sales estimates released to analysts does not meet Commerce's publication standards because of the small samples from which the estimates are generally derived, the unpublished data may still provide valuable historical and industry detail for several U.S. geographic areas dating back to 1978. Analysts monitoring retail spending in states and metropolitan statistical areas (MSAs) may find them useful supplements to the Commerce Department's published data.

Available in both printed and electronic forms, the regional, state, and metro area data feature detailed accounts of personal consumption expenditures, a measure that accounts for about two-thirds of the nation's gross domestic product (GDP). The data report provides monthly observations on overall and selected categories of retail sales for the nation and several subnational areas. While the amount of detail is impressive, these estimates have several limitations that are worth discussing along with the ways in which the data are useful.

The purpose of this article is to examine whether the range of historical, geographic, and product information in the retail sales data can offset limitations such as small sample size and volatility. The discussion considers the usefulness of combining the unpublished with published data, tests its

The author is an economic analyst in the regional section of the Atlanta Fed's research department. *He thanks Irving J. True of the U.S. Bureau of the Census for reviewing the article and especially Frank King, Tom Cunningham, and Andrew Krikelas for valuable comments on early drafts.*

correlation with regional trends, and explores the relationship between the Sixth Federal Reserve District's retail sales as depicted by this data and measures of district employment.[1]

Published and Unpublished Monthly Retail Trade Data

Each month the Department of Commerce publishes a wide variety of retail trade statistics in *Monthly Retail Trade—Sales and Inventories* (*MRT*). *MRT* series are also available in electronic form from several data-retrieval information vendors and the Commerce Department's Economic Bulletin Board. The published data report the dollar value of retail sales in selected categories recorded during the reference month and the most recent twelve-month period for the nation, four geographic census regions, nine census divisions, nineteen states, twenty-five metro areas, and nineteen submetro areas, including the nation's four largest cities. *MRT* also provides national estimates of end-of-month inventories by category of retail trade establishment. For states and metropolitan areas, the data estimate total retail sales, sales of nondurable goods, department store sales, and general merchandise, apparel, or furniture store (GAF) sales. For the Southeast, published estimates of these groupings are available for only three states (Florida, Louisiana, and Tennessee), three metropolitan statistical areas (Atlanta, Miami-Hialeah, and Tampa-St. Petersburg-Clearwater), and one consolidated metropolitan statistical area (Miami-Fort Lauderdale).[2]

Unpublished estimates differ from the published reports in two ways that add to their importance. First, the unpublished data provide retail sales estimates for nine additional states/areas: four from the South (Delaware, Georgia, Kentucky, and the District of Columbia), three from the West (Arizona, Colorado, and Washington), and one each from the Northeast (Connecticut) and Midwest (Kansas) census regions. Second, the unpublished data include additional information on consumer spending in states and metropolitan areas. For most states and MSAs, data for up to fifteen retail categories (see Table 1 for a list) are available from January 1978 to the present and can be obtained from the Bureau of the Census, for a fee, in printed form or on computer diskettes. In releasing these data to the public, however, the bureau explicitly notes that these unpublished estimates are not nearly as statistically reliable as the more highly aggregated data series reported in *Monthly Retail Trade—Sales and Inventories*.

Understanding the Published Data

In order to be clear about the significance of differences in the published and unpublished data, it is necessary to keep in mind that both preliminary and revised monthly retail sales figures are derived from a survey of approximately 12,500 retail establishments across the nation.[3] Several key concepts and methodologies used in the production of the retail survey and the published report are important for understanding the reliability of retail sales as a regional economic indicator.[4]

It is crucial that analysts distinguish between preliminary and revised benchmark statistics. The statistics published in *Monthly Retail Trade—Sales and Inventories* are compiled from a comprehensive reporting process linked to the Commerce Department's Annual Retail Trade Survey and its five-year *Census of Retail Trade*. Monthly estimates are revised each year according to benchmarks obtained from the Annual Survey of Retail Trade. With each January release, the benchmarking operation revises monthly estimates for several recent years, adjusting twelve monthly estimates for a given year to annual sales figures derived from the *Census of Retail Trade* and Annual Retail Trade Survey.

Analysts interested in greater accuracy and detail should refer to the most recent *Census of Retail Trade*, which is the most complete retail information available for low-level data. The *Census of Retail Trade* features retail sales data compiled from approximately 1.5 million retail establishments throughout the United States, organized by the fifty states, the District of Columbia, MSAs, and counties. It includes detailed Standard Industrial Classification (SIC) retail data for most geographic areas, in addition to retailers' payroll employment data. Unfortunately, this level of detail is available only with a considerable time lag; the most recent *Census of Retail Trade* contains data through 1992.

Although the monthly retail survey results are regularly rebenchmarked to reflect the sales levels recorded in the more comprehensive annual surveys and the quinquennial censuses of retail trade, the revised retail sales figures in their final form still contain a great deal of information from samples. As survey results, therefore, each of the individual series reported in *Monthly Retail Trade—Sales and Inventories* are subject to sampling and nonsampling errors, including errors generated by inappropriate stratification of the survey sample and flaws in the collection and reporting of the data. In order to provide users with a sense of the size of these

Table 1
Coefficients of Variations in Percent for Median Retail Sales Estimates by Kind of Business
(September 1994-February 1995)

	United States	South Region	East-South Central Division	Florida	Georgia	Louisiana	Tennessee	Atlanta MSA	Miami CMSA	Tampa MSA
Total Retail	**0.7**	**1.3**	**3.5**	**3.9**	5.6	**9.0**	**7.0**	**7.7**	**7.6**	**10.8**
Nondurable	**0.8**	**1.2**	**3.5**	**3.6**	5.7	**8.2**	**5.8**	**7.0**	**8.9**	**10.1**
General Merchandise	**0.2**	**0.7**	**3.0**	**2.4**	3.8	4.1	3.5	5.9	5.3	0.5
Food	**1.0**	**1.9**	6.5	8.2	10.6	15.5	12.9	15.9	14.0	21.1
Grocery	**1.0**	**2.0**	6.7	8.5	11.0	16.5	13.3	17.2	14.6	21.9
Gas Service Stations	**2.0**	**3.6**	9.6	8.2	7.5	15.6	16.1	15.7	15.4	32.6
Apparel	**1.9**	**3.7**	9.6	7.3	7.7	12.8	13.7	9.6	10.8	7.4
Eating/Drinking	**4.2**	**5.5**	13.1	12.0	20.6	26.6	16.6	20.4	38.9	20.2
Drug Stores	**1.2**	**9.2**	13.0	17.4	44.9	55.9	20.8	32.0	37.0	43.8
Other Nondurable	**4.4**	**5.0**	18.8	7.4	12.2	25.0	33.5	6.2	9.2	10.7
Durable	**1.2**	**2.5**	**6.5**	**6.4**	11.0	**15.3**	**10.7**	**14.6**	**10.6**	**18.9**
Building Materials	**2.3**	**5.6**	9.8	18.1	22.0	24.2	21.2	40.0	34.8	34.5
Automobile Dealers	**1.6**	**3.6**	9.9	9.6	17.7	19.2	19.0	25.7	12.8	31.0
Furniture	**1.6**	**4.8**	12.6	10.4	23.7	19.5	21.9	23.5	15.5	15.6
Other Nondurable	**4.5**	**6.1**	15.5	10.1	16.6	23.1	22.1	20.8	17.3	23.2
GAF	**0.6**	**1.3**	**3.5**	**3.0**	7.1	**6.2**	**7.4**	**6.9**	**5.7**	**4.7**

Geographic areas are census regions. Based on monthly sales estimates not adjusted for seasonal variations, holiday, or trading-day differences. Published estimates in bold type. GAF represents stores that specialize in department-store types of merchandise (general merchandise, apparel, and furniture).

Source: *Monthly Retail Trade—Sales and Inventories* and unpublished tables. U.S. Department of Commerce, Services Division. Bureau of the Census. March 1995.

errors, Appendix B of the *MRT* includes an estimate of the coefficient of variation (CV) for each of the series reported, a statistic that provides a measure of the size of a one-standard-deviation sampling error for each series. The CV is defined as the standard deviation of the sample, times 100, divided by the mean of the estimated sample.

Table 1 reports the coefficients of variation for fifteen categories of retail sales in ten census-defined geographic regions. The CV for total retail sales in the nation is listed as 0.7, which is quite small compared with some of the other standard errors shown. For example, the CV for total retail sales for the Atlanta MSA is 7.7 percent while for eating and drinking establishments in Atlanta the standard error increases to more than 20 percent. This disparity in accuracy is at least partially a statistical property of the sample size.

The information in this table reveals two definite patterns: (1) the CVs for each retail category are smallest at the national level and grow larger as the geographic areas become more specific, and (2) the CVs for particular sales categories differ according to geographic area, with some regions producing consistently larger standard errors than others. Because the CVs for many of the unpublished series are quite large, it is easy to understand why the Census Bureau advises caution in using these data for analytical purposes.

One reason for caution is that the Census Bureau's sample has been chosen to represent retail stores in the entire nation rather than the stores located in each of the geographic areas. In addition, low-level data for local areas and retail groups may have a limitation arising from potential overlap in reporting merchandise groupings, which can occur because retailers sell an ever-changing merchandise mix. Merchandise groupings are listed according to the products accounting for the largest percentage of total sales for each establishment. For example, stores deriving their largest percentage of revenues from the sale of food products are grouped as food retail stores despite the fact that they may also gain revenues from sale of a wide range of nonfood items like housewares, gasoline, and pharmacy products. Analysts should keep in mind that this reporting method may not accurately represent retail sales trends of particular lines of merchandise sold in such establishments.

Clearly, data users must exercise caution when drawing conclusions from unpublished monthly low-level data. Nonetheless, these data may be a valuable source of information about retail activity as long as the analyst takes the data limitations into account. Those who favor using the unpublished reports point out that the estimates are linked to a consistent methodology designed by the Census Bureau in producing the annual and five-year estimates.

Retail Sales Data as an Indicator of Regional Economic Activity

Analysts use the national retail sales report as a key economic indicator. Retail jobs make up about one-fifth of the nation's nonfarm employment. The data also play an important role in deriving personal consumption expenditures. In addition, like nonfarm employment, the retail sales data series is a component of the coincident index of economic activity, an important national indicator designed to confirm the timing of business cycle changes. In short, at the national level retail sales are "probably the most closely followed indicator used for judging the strength of the consumer sector. In popular analysis, it also tends to be used as a broad yardstick for the health of the economy" (R. Mark Rogers 1994, 62).

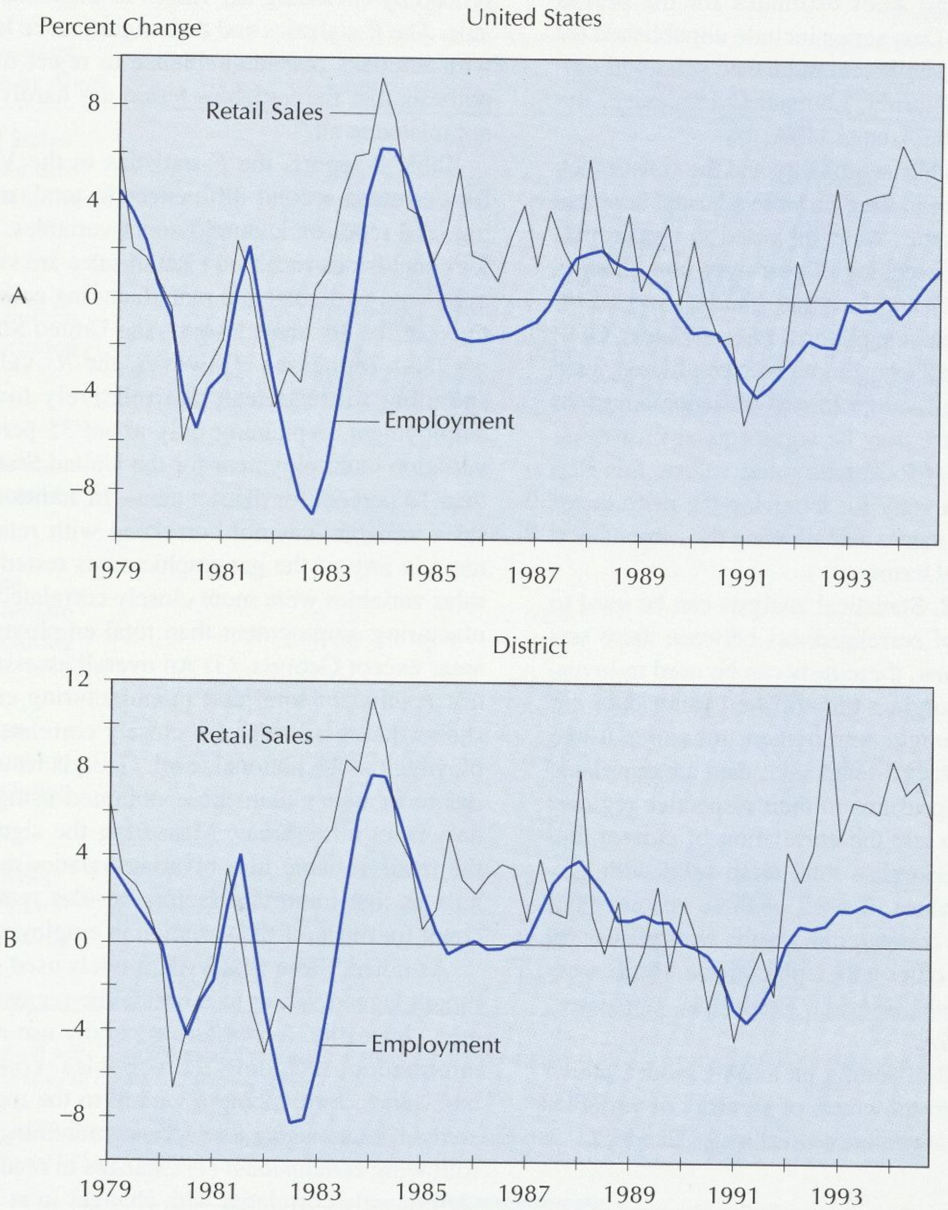
But is the retail sales report an equally useful barometer for regional analysts? Do published and unpublished regional retail sales data also contain information useful in forecasting regional economic performance? Chart 1, which compares the data over time, suggests a clear association between real retail sales values and manufacturing employment for the United States and the district during the 1990-94 period. While this chart is useful for illustrating the linkage between consumer spending and manufacturing employment, it tells little about how changes in one variable are associated with changes in the other.

More detailed and sophisticated tests of the regional retail sales data's usefulness involve using what are called Granger-causality tests. Simply put, a data series X (say, retail sales) is said to Granger-cause a series Y (say, employment) if Y can be better forecast by using past values of X in addition to past values of Y than it can be by using past values of Y alone. (See the box on page 46 for a more detailed discussion of Granger-causality and Thomas A. Doan 1992, chap. 6, 10.)

These tests are easily performed using a vector autoregression (VAR), which is a set of equations using simple linear regression techniques. (Details of the models are discussed below.)

The analysis uses two sets of VARs. The first set tests bivariate relationships between three different employment series—total nonfarm, manufacturing, and retail—and total retail sales. The second set of

Chart 1
Retail Sales and Manufacturing Employment
(Quarterly year-to-year percent change, 1979.1–1994.4)



Source: Federal Reserve Bank of Atlanta and U.S. Department of Commerce. *Monthly Retail Trade—Sales and Inventories* data converted to real terms using GDP price deflators for personal consumption expenditures.

Granger-causality tests uses multivariate VARs with two major retail sales variables along with three key employment series that likely would be included in a regional forecasting model.

The data series described are published and unpublished monthly retail sales estimates for the period from 1978 to 1994. Data series include unpublished total retail sales for Georgia and published sales and employment data for Florida, Louisiana, Tennessee, the United States, and the Atlanta MSA.

To address issues like seasonality and the consistency of nominal retail values, the data were adjusted in several ways. First, the series were subjected to transformations of monthly differencing of year-over-year changes to cancel seasonality and long-run trends.[5] Second, in the absence of comparable regional price deflators, GDP deflators for personal consumption expenditures were used to convert retail values to real (inflation-adjusted) terms. Although there may be arguments against using national deflators for local area retail values, this step was considered necessary for removing the price factor from nominal retail values and allowing the computation of retail series in real terms.

Testing by VAR. Statistical analysis can be used to assess the degree of correlatedness between these sets of series. In particular, these tests can be used to investigate whether Georgia's unpublished retail data are correlated with Georgia employment measures in the same way that published retail sales data are correlated with employment measures in their respective regions. The approach is to test the correlation of current and lagged values of Georgia's total retail sales with current and lagged values of each of three employment measures and then compare the results with similar relationships in five other geographic areas. These areas are the United States, Florida, Louisiana, Tennessee, and the Atlanta MSA.

The test consists of setting up a VAR model, which basically relates current values of an array of variables to past values of that vector (see Table 2). That is,

$$\begin{bmatrix} Y_t \\ X_t \end{bmatrix} = \begin{bmatrix} C_y \\ C_x \end{bmatrix} + \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix} \begin{bmatrix} Y_{t-s} \\ X_{t-s} \end{bmatrix} + \begin{bmatrix} u_{yt} \\ u_{xt} \end{bmatrix},$$

where Y_t is employment at time t, X_t is retail sales at time t, C is constant, $u_{\cdot t}$ is the residual term, and the null hypothesis is expressed as $H_0 : \beta_{12} = 0$ for all $s = 1, \ldots, 6$.

The model estimates the regression coefficients using lag values of a bivariate relationship with an exclusion restriction that enables identification of statistically significant coefficients. In this case, employment variables (Y) are related to one- to six-month lag values of retail sales (X) and also by lagged values of the dependent employment variable. A hypothesis test that past X is not correlated with the current Y is then probed by excluding lag values of the retail sales variable. The F-statistics and their significance levels noted with asterisks provide evidence to reject the null hypothesis that the variables tested are hardly related or not related at all.

Table 2 reports the F-statistics in the VAR model for corrected second differences in total, manufacturing, and retail trade employment variables. Three major conclusions result: (1) Retail sales are significantly correlated with total and manufacturing employment in three of the six areas tested—the United States, Georgia, and Tennessee. However, the R^2 values corresponding to these tests are relatively low for total employment, explaining only about 35 percent of the variation in employment for the United States and less than 18 percent for district areas. In addition, the retail sales variable was not correlated with retail employment in any of the geographic areas tested. (2) Retail sales variables were more closely correlated with manufacturing employment than total employment for all areas except Georgia. (3) An overall assessment of the test results for total and manufacturing employment shows that retail sales are closely correlated with employment at the national level. Georgia results are similar to or better than those obtained using published data from other areas. Measuring the significance of the retail variable in a bivariate relationship, this test tells us that important factors besides retail sales account for much of the variation in employment.

As noted, these first VAR models used one- to six-month lagged values to estimate the regression parameters. In reality, forecasters generally use all available information, including the variables' contemporaneous values. Introducing a variant to the regression described above, using zero- to six-month lags, led to the following conclusions: (1) Changes in retail sales were significantly correlated with changes in at least two of the employment variables in five of the six geographic areas tested, with Georgia results showing consistency with those of the United States and other areas. (2) The R^2 values were noticeably stronger in manufacturing for most areas but particularly for the United States. The results also indicated that one-fourth of the variation in the nation's retail employment can be predicted by changes in retail sales.

On the basis of these bivariate tests it seems fair to say that the use of regional retail sales data, including

Table 2
VAR Tests on Employment Measures Predicted by Total Sales Data

Employment Variables by Areas	Retail Sales, Lagged One to Six Months		Retail Sales, Lagged Zero to Six Months	
	F-tests	R^2	*F*-tests	R^2
United States				
Total Nonfarm	3.36***	0.35	7.08***	0.44
Manufacturing	4.18***	0.50	4.77***	0.52
Retail	0.84	0.09	5.64***	0.23
Georgia				
Total Nonfarm	3.03***	0.18	4.07***	0.21
Manufacturing	2.09**	0.15	3.27***	0.19
Retail	0.90	0.03	1.78*	0.06
Florida				
Total Nonfarm	0.59	0.18	3.06***	0.26
Manufacturing	1.52	0.39	2.12**	0.41
Retail	0.41	0.13	0.88	0.15
Louisiana				
Total Nonfarm	0.55	0.09	2.52***	0.15
Manufacturing	0.99	0.23	1.30	0.24
Retail	0.52	–0.04	0.49	–0.05
Tennessee				
Total Nonfarm	2.93***	0.13	5.09***	0.20
Manufacturing	2.26**	0.33	4.35***	0.38
Retail	0.50	–0.02	1.48	0.01
Atlanta MSA				
Total Nonfarm	1.51	0.07	3.14	0.13
Manufacturing	0.26	–0.02	2.27	0.05
Retail	1.72	0.03	2.13	0.05

An *F*-statistic noted with *** indicates a significance at the 1 percent confidence level. Likewise, ratios marked with ** and * stand for a significant confidence level of 5 and 10 percent, respectively.

Source: Calculated by Federal Reserve Bank of Atlanta using data from the U.S. Department of Commerce and the U.S. Department of Labor, Bureau of Labor Statistics.

unpublished data, can sometimes add information important for forecasting changes in levels of regional employment. An additional step in exploring these data relationships would be to test for Granger-causality in more complex VARs. This research expands the coverage of retail and employment variables by computing multivariate VARs with three employment and two retail sales variables. These variables are nonmanufacturing, durable manufacturing, and nondurable manufacturing employment and durable and nondurable retail sales. The employment variables add up to total nonfarm employment; the retail sales variables, to total retail sales.

Together, these five variables provide a partially disaggregated view of employment and total retail sales in each of the regions examined. Table 3 presents the results of the seven sets of five-variable Granger-causality tests performed on these data. In each case, the figures in the cells of the table report the F-statistic with the corresponding confidence level associated with testing the null hypothesis: The column variable does not Granger-cause the row variable. If this hypothesis is rejected one accepts the alternative hypothesis: that the column variable does indeed Granger-cause the row variable.

The larger the F-statistic the lower the likelihood that the researcher will make a mistake by incorrectly rejecting the null hypothesis of no linear relationship. The confidence levels noted with asterisks state the probabilities of errors that support such rejection. Observing asterisks in the two right-hand columns for each region is a quick way to determine whether the retail sales variables contain information that might be useful to regional employment forecasters.[6]

The tests indicate that retail sales data do contain information useful in predicting employment series in several regional areas, with the correlations existing at the state and metropolitan area levels. For example, test results for Florida, Georgia, Louisiana, the Atlanta MSA, and the district all indicate that one or both of the retail sales variables contain information that might be useful for predicting at least one of the regional employment series. However, these tests also indicate that retail sales data would be of little value in improving employment forecasts for Tennessee.

The most interesting findings reported in Table 3 are the ones contained in the off-diagonal cells of each five-variable model, particularly those in the last two columns. These results indicate that in every geographic region, at least one of the retail sales variables appears to contain information useful for predicting one or more of the other four variables. For example, in the nation the results suggest that each of the two retail sales variables contain information useful for predicting the other sales variable. According to these tests, though, national retail sales data do not contain any information useful for predicting the three employment series examined.

One final set of results reported in Table 3 deserves mention. Tests for each of the seven regions indicate that at least one of the employment variables contains information that would improve forecasts of the retail sales variables. At the national level, only nondurable manufacturing employment is correlated. However, results for all the regions indicate that employment variables Granger-cause more than one of the retail sales variables, particularly in Georgia, where nonmanufacturing employment Granger-causes both durable and nondurable retail sales while nondurable goods manufacturing employment Granger-causes sales of nondurable goods. Test results also indicate that for both Louisiana and the Atlanta MSA, nondurable goods manufacturing employment Granger-causes sales of both durable and nondurable goods. Generally, understanding temporal causality between these variables can have practical applications for users of regional data.

The Meaning of Granger-Causality

In 1969, C.W. Granger introduced the concept of causality while examining the underlying assumptions of an econometric model estimated from time series data. The Granger test uses the F-statistic to examine whether one variable statistically explains the other. In simple terms, a series X is said to Granger cause Y if the variable Y can be forecast better by using past values of X in addition to past values of Y than it can be by using past values of Y alone. The Granger test consists of running regressions of Y on itself lagged and on a set of lagged X values. If the lagged values of X do not contribute a statistically significant explanation, then X does not "Granger-cause" Y (see Adrian C. Darnell 1994, 41-43). Similarly, to examine if Y causes X the procedure is reversed and the results examined by their F-test values, which in turn determine if the regression coefficients are sufficient to reject the null hypothesis of no linear relationship. The causality concept can be unidirectional (X causes Y, but Y does not cause X) or bidirectional (Y and X cause each other).

The Granger-causality test is closely related to the concepts of exogeneity and endogeneity (when a variable is determined either outside or inside, respectively, a jointly determined model), which hold that a classical exogenous variable can only be a cause and not an effect whereas an endogenous variable can be both cause and effect. In the Granger-causality notion, the premise suggested is that the past can cause the future, the future cannot cause the past, and such temporal ordering is not sufficient evidence to assert causality. The main concerns are with temporal ordering and the predictive ability of variables rather than causality.

The power of the Granger-causality test is greatest when used for the purpose for which it was designed: to determine whether one variable might be able to aid in the forecasting of another. The existence of a temporal ordering among variables, although insufficient to prove causality, generally has some value as a predictive tool in forecasting.

Table 3
Granger-Causality Tests for Selected Geographic Areas

	Variables (*X*)				
	Employment Variables			Retail Sales Variables	
Variables (*Y*)	Nonmanufacturing	Durable Manufacturing	Nondurable Manufacturing	Durable Goods	Nondurable Goods
Florida					
Nonmanufacturing Employment	**4.2129*** **	1.0968	1.3630	2.3919***	3.0288***
Durable Manufacturing Employment	0.7370	**6.4639*** **	2.2129***	2.8499***	1.3866
Nondurable Manufacturing Employment	0.4597	1.6488*	**2.9811*** **	1.7878**	0.6604
Durable Goods Sales	1.5263*	2.1685***	0.2540	**6.4681*** **	1.3202
Nondurable Goods Sales	0.5952	0.8818	0.9949	5.2649***	**7.5913*** **
Georgia					
Nonmanufacturing Employment	**1.8238** **	0.7692	1.0707	1.4392	1.4688*
Durable Manufacturing Employment	2.1168**	**2.4488*** **	1.8245**	0.7801	1.0235
Nondurable Manufacturing Employment	3.6661***	1.3662	**1.7954** **	1.4876*	1.5931*
Durable Goods Sales	3.3574***	0.5857	0.6632	**4.0057*** **	1.8010**
Nondurable Goods Sales	2.2070***	1.0368	1.4876*	0.8978	**5.0384*** **
Louisiana					
Nonmanufacturing Employment	**2.8914*** **	0.7628	2.4851***	1.8432**	1.2295
Durable Manufacturing Employment	1.5366*	**4.8008*** **	0.9178	2.0697**	0.9348
Nondurable Manufacturing Employment	1.5193*	1.9140**	**3.5852*** **	2.4018***	0.9913
Durable Goods Sales	1.2887	1.0353	1.9225**	**5.5501*** **	1.2589
Nondurable Goods Sales	1.0055	0.8977	1.6010*	3.2594***	**4.8426*** **
Tennessee					
Nonmanufacturing Employment	**3.4658*** **	0.8638	1.7489**	0.7732	0.6623
Durable Manufacturing Employment	1.8433**	**6.7232*** **	1.5061*	0.7635	0.8136
Nondurable Manufacturing Employment	0.9263	1.1359	**3.7166*** **	0.4860	1.1412
Durable Goods Sales	2.1613***	1.1203	1.1931	**4.0618*** **	2.6553***
Nondurable Goods Sales	1.1410	0.8215	1.3897*	1.0781	**4.6289*** **
Atlanta MSA					
Nonmanufacturing Employment	**3.6082*** **	0.9275	1.9631**	1.6523*	1.4239
Durable Manufacturing Employment	1.4139	**2.7239*** **	1.6915*	1.0909	1.4208
Nondurable Manufacturing Employment	0.8807	0.9277	**1.9502** **	1.5992*	0.7312
Durable Goods Sales	1.5477*	1.4471	3.0218***	**2.2772*** **	1.3093
Nondurable Goods Sales	0.8437	1.0197	2.6071***	1.5100*	**4.8530*** **
District					
Nonmanufacturing Employment	**3.5588*** **	1.6696*	1.0874	0.8327	1.3438
Durable Manufacturing Employment	0.9179	**8.1049*** **	3.3242***	1.6208*	0.7326
Nondurable Manufacturing Employment	1.1177	1.1490	**2.8674*** **	1.1350	1.1040
Durable Goods Sales	1.7288**	1.0720	0.9791	**5.1070*** **	2.4426***
Nondurable Goods Sales	1.4942*	0.9683	1.1630	3.2554***	**9.4079*** **
United States					
Nonmanufacturing Employment	**3.1997*** **	1.1397	1.4320	0.4816	1.0514
Durable Manufacturing Employment	1.8448**	**6.2042*** **	4.6311***	0.6942	0.7930
Nondurable Manufacturing Employment	0.5231	1.2451	**1.7845** **	0.8504	0.3173
Durable Goods Sales	1.3769	0.6829	0.5890	**2.8196*** **	1.5444*
Nondurable Goods Sales	1.2943	1.1446	1.5985*	2.1102***	**12.8229*** **

Ratios are *F*-statistics of the test of the null hypothesis that the column variable *X* does not Granger-cause the raw variable *Y*. Ratios reported with * denote the acceptance of an alternative hypothesis that the column variable *X* does in fact Granger-cause the raw variable *Y*. An *F*-statistic noted with *** indicates a significance at the 1 percent confidence level. Likewise, ratios marked with ** and * stand for a significant confidence level of 5 and 10 percent, respectively.

Source: Calculated by Federal Reserve Bank of Atlanta using data from the U.S. Department of Commerce and the U.S. Department of Labor, Bureau of Labor Statistics.

Conclusion

This article suggests that important information is provided by published and unpublished retail sales data. Although the release schedules of the monthly regional retail sales report are several weeks behind the more current employment releases, the data's usefulness in analyzing and forecasting regional economies should not be totally discounted. Despite the limitations of unpublished retail data discussed in this article the relevant amount of information available from regional retail spending data should encourage researchers to test further the usefulness of this data. Recent studies on the refinement of employment forecasts are in fact promoting the use of published and unpublished retail sales data along with an array of economic statistics available to regional researchers.[7]

Given the importance of estimating consumer strength in local communities, published and unpublished data can fill a number of information gaps. For example, the comprehensiveness of retail information being reported today allows users to access important data such as retail markets' potential, retailers' payroll income, and other growth indicators related to locally important consumer markets. Such types of information can be helpful to retailers, developers, and others in making business decisions.

Notes

1. The Federal Reserve's Sixth District encompasses six states in whole or part: Alabama, Florida, Georgia, Louisiana, Mississippi, and Tennessee. In this article, for the purpose of making consistent comparisons with available data, the term *district* also includes the portions of Louisiana, Mississippi, and Tennessee not in the district and the state of Kentucky. The derived district conforms to the availability of retail sales data for the Census' East South Central Division (Alabama, Mississippi, Tennessee, and Kentucky) plus individually reported data for the states of Florida, Georgia, and Louisiana.
2. The Office of Management and Budget defines MSAs as urban centers with populations of at least 50,000. The terms "primary" and "consolidated" metropolitan areas are defined by the Office of Management and Budget on the basis of such factors as commuting patterns, population density, and growth. Metro areas with a million or more people and identified by other specific factors may be subdivided into primary metropolitan statistical areas (PMSAs). When an area is divided into PMSAs, the entire area becomes a consolidated metropolitan statistical area (CMSA). The CMSA is divided into PMSAs generally because of the close social and economic links of the PMSAs with each other and with the CMSA nucleus.
3. For a broad overview of the methodology and data issues related to the Survey of Retail Trade see Rogers (1994).
4. See Mason (1992) and Appendixes A and B of the *MRT* report for detailed discussions of technical concepts like sample selection and methodology for data collection, revisions, and other issues such as the linkage between monthly and annual retail estimates, seasonal adjustment, and benchmarks of the data.
5. The raw data analyzed in these tests were subjected to two transformations. First, in order to eliminate seasonality in the data, all series were differenced annually to produce year-over-year changes. Second, these transformed data were subjected to an augmented Dickey-Fuller test. This test indicated that the majority of the series contained a long-run trend, further suggesting that monthly differencing of the data was appropriate.
6. Readers should note that in the test results presented in Table 3, the on-diagonal elements of the five-variable regional models in bold type are in a majority of cases significant at the 1 percent confidence level. However, it is important to recognize that the results reported in these cells do not represent true Granger-causality tests but rather tests of the hypothesis that past values of the row variable contain information useful for forecasting the row variable itself.
7. Krikelas (1994), for example, argued that the Bureau of Labor Statistics (BLS) might be able to improve upon its preliminary estimates of total nonfarm payroll employment at both the state and national level by using additional information available at the time of the release of those estimates.

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