Identifying Monetary Policy: A Primer

TAO ZHA

The author is an economist in the macropolicy section of the Atlanta Fed's research department. *He is grateful to Roberto Chang, Frank King, Eric Leeper, Larry Wall, and especially Jerry Dwyer and Mary Rosenbaum for valuable comments.*

THE POPULAR PRESS AND UNDERGRADUATE ECONOMICS TEXTBOOKS HAVE LONG CONCLUDED THAT AN INCREASE IN THE FEDERAL FUNDS RATE TARGET BY THE FEDERAL OPEN MARKET COMMITTEE (FOMC) TENDS TO SLOW GROWTH OF NATIONAL OUTPUT AND REDUCE INFLATIONARY PRESSURES. ECONOMISTS GENERALLY AGREE ON THIS POINT, BUT THEY DISAGREE CONSIDERABLY ABOUT THE QUANTITATIVE IMPACT OF MONETARY POLICY. FOR EXAMPLE, A GROUP OF ECONOMISTS CALLED MONETARISTS ARGUE THAT "IN THE SHORT RUN, WHICH MAY BE AS LONG AS THREE TO TEN YEARS, MONETARY CHANGES AFFECT PRIMARILY OUTPUT" BUT NOT PRICES (FRIEDMAN 1992, 48) WHILE OTHER ECONOMISTS SUCH AS REAL BUSINESS CYCLE THEORISTS POSTULATE THAT MONETARY CHANGES AFFECT ONLY PRICES BUT HAVE LITTLE OR NO EFFECT ON OUTPUT (COOLEY AND HANSEN 1995).

As it stands, economists' beliefs about the quantitative importance of monetary policy stem largely from theoretical models through which the policy effects of changing monetary policy are inferred. It is no surprise, then, that different conclusions arise from different experiments or theories. The actual economy, however, is not the result of any such controlled experiment. Obviously, a central bank cannot change policy for the sake of examining its effect on the economy. In the real world, inferences about the quantitative effect of monetary policy must rely on observations of actual economic activity in which many variables are changing simultaneously. What can be observed is the equilibrium outcome of interaction among all players in the economy—the central bank, financial market participants, producers, and consumers. On this playing field, sorting out the central bank's behavior from that of the many other participants is the first and critical step in attempting to estimate the actual impact of monetary policy. This sorting-out process is known in technical parlance as identification.

Identification of monetary policy is partly a conceptual (economic) issue and partly an empirical (technical) one. Conceptually, the process requires that one understand the economics of the demand and supply of money, or, in other words, the interaction between the central bank's reaction to economic conditions and the private sector's response to policy actions. Empirically, one needs sophisticated mathematical tools to isolate the central bank's behavior from all other behaviors in the observed data and examine its consequences.

The purpose of this article is to explain these two issues: the conceptual one of why identification of monetary policy is important and the empirical issue of how difficult it is in practice. The article focuses on these two issues exclusively because of how vital careful identification is for an accurate assessment of policy effects. Given this purpose, the article refrains from discussing how to resolve the disparate views about the actual quantitative effect of monetary policy on a given country's economy. The discussion first explores identification of monetary policy as having much in common with issues familiar to us from basic economics principles. The article then discusses the identification issue special to the analysis of monetary policy and illustrates the process with a few examples of identifying monetary policy in different countries.

Demand and Supply

The abstract concept of money is clear: money is something the public accepts in exchange for goods and services. In reality, however, the measure of money is not so well defined: money can be currency in circulation, reserves, the monetary base (the sum of currency in circulation and reserves), M1 (currency plus checkable deposits), or M2 (M1 plus other assets). Whichever monetary aggregate is used, the analysis of monetary policy inevitably encounters the two blades of the monetary scissors: demand for and supply of money. Thus it is appropriate to begin exploring the importance of identifying monetary policy with an analysis of the demand and supply of money.

A simple, familiar example is instructive: the demand-supply relationship in the market of goods and services, in this case the wine market. If one has the data on the price of wine (p) and the quantity bought and sold (q), the bivariate demand-supply relationship can be described by the following two equations:

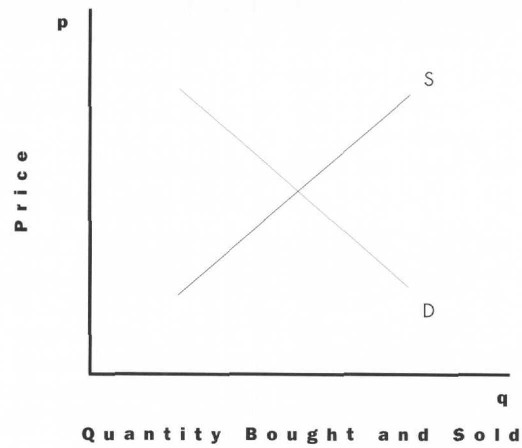
$$q = \alpha_1 p + \alpha_2 X + \epsilon_d \quad \text{(demand)}, \qquad (1)$$

$$q = \beta_1 p + \beta_2 Y + \epsilon_s \quad \text{(supply)}, \qquad (2)$$

where X is a set of variables (such as the government's excise tax and consumers' income) that affect the demand for wine, Y is a set of variables (such as the government's excise tax and weather condition) that affect the supply of wine, the α coefficients describe the behavior of consumers, and β, the behavior of producers.

Before proceeding, explaining a few common notations and notions will lay the groundwork for discussion of these and additional equations. The notations q, p, X, and Y in equations (1) and (2) are variables while α_1, α_2, β_1, and β_2 are coefficients. The sharp distinction between the "coefficient" and "variable" is an important one. A variable has a quantitative value observed in the data so that, for example, the variable q represents the price of wine bought and sold. A coefficient does not come directly from the data; rather, its quantitative value must be obtained by statistical methods. The process of obtaining the value of a coefficient is called estimation, a concept

CHART 1
Demand for and Supply of Wine

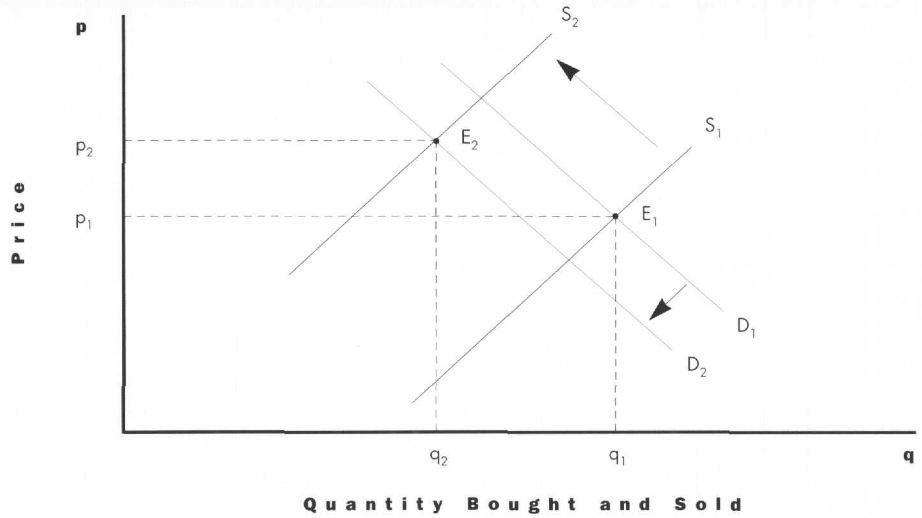


important throughout the article. For instance, coefficients such as α_1 are to be estimated through equations (1) and (2). Finally, the notation ϵ_d represents a random change that cannot be described by normal demand behavior, and this article calls ϵ_d a demand shock. The word *shock* has its familiar meaning of referring to something unpredictable. Similarly, the supply shock ϵ_s in equation (2) indicates an unpredicted change in the supply of wine.

Economic theory implies that price is inversely related to quantity demanded (that is, $\alpha_1 < 0$). It also tells us that when the price is higher, the firm is willing to produce more wine ($\beta_1 > 0$). These relationships can be depicted in a two-dimensional figure like Chart 1, where the downward-sloping curve represents demand behavior and the upward-sloping curve represents supply behavior. Chart 1 is drawn under the assumption that variables other than p and q are held fixed. Therefore, if there are any changes in X or Y, the curves in Chart 1 will shift from the original equilibrium position. For example, when the government raises the tax on wine, both demand and supply will fall, their curves will shift to the left, and the equilibrium will change from E_1 to E_2 (Chart 2). How much the quantity of wine will be reduced (from q_1 to q_2) in the market depends on the behavior of consumers and producers, which is described in equations (1) and (2). In other words, it depends on how far the demand and supply curves in Chart 2 will shift. The policy analyst, to assess the tax's effect on the behavior of consumers and producers, must understand (correctly identify) both the demand function (1) and the supply function (2).

The argument about the importance of identifying the demand for and supply of wine can be carried over to the money market, although monetary analysis is of course far more complicated (see, for example, Leeper 1992). To begin with, one can think of the quantity of

CHART 2 Effect of the Government's Tax on Wine



money as resembling the quantity of wine and the opportunity cost of holding money (the interest rate) as the price of wine. Let M represent money and R, the nominal interest rate. Thus, analogous to the wine market, where q and p are jointly determined, M and R are determined by both demand and supply in the money market. Assume that all deposits in M do not bear interest.[1] The demand function for money derived in standard textbooks can be expressed as

$$M - P = \alpha_1 y + \alpha_2 R + \epsilon_{MD} \text{ (money demand)}, \quad (3)$$

where y represents national output; P, the general price level; α_1, the coefficient of y; α_2, the coefficient of R; and ϵ_{MD}, the money demand shock.[2] The coefficient α_1 measures the percent change in demand for money in response to a percent change in output y, and the measure is known as the income elasticity of money demand.[3] As consumer income rises, the demand for goods and services will increase, and in turn their demand for money will rise so that they can purchase goods and services. Thus, the coefficient α_1 is expected to be positive. The coefficient α_2, known as the interest elasticity of money demand, measures the percent change in money demand in response to a percent change in the interest rate. Since the public is willing to hold less (real) money $(M - P)$ when the cost (R) of holding money increases, the interest elasticity α_2 is expected to be negative. If one depicts the demand curve in the (M, R) plane (see Chart 3), the curve of demand for money has a negative slope (analogous to the downward-sloping curve in the demand for wine in Chart 1).

When broad monetary aggregates such as M1 or M2 are used, the term *money supply* in general involves not merely the behavior of the central bank but also the behavior of banks and other financial institutions whose liabilities (such as checking deposits) serve as part of the medium of exchange as well as the behavior of depositors who decide how much currency to hold in relation to deposits. A central bank, through its open market operations or discount window lending, can affect monetary aggregates through the banking system. To see how a monetary aggregate such as M2 is affected, suppose that the Federal Reserve decides to increase the monetary base (the sum of the currency in circulation and reserves) by buying Treasury securities worth, say, $\$\chi$ from a seller. Suppose the seller, now becoming a depositor, decides to deposit the full amount of $\$\chi$ in Bank A, creating $\$\chi$ in deposits in the bank. After meeting the reserve requirement (that is, the certain percentage of $\$\chi$ that must be kept in the bank), Bank A lends part of the deposit to households who, now becoming depositors, decide to deposit the loans in, say, Bank B. The process can continue. Eventually, such a chain of deposit expansions through bank loans makes an increase in M2 a multiple of the initial increase in the monetary base. Thus the term *money multiplier*, defined by the ratio of the monetary aggregate (like M2) to the monetary base, is used to indicate the extent to which money is created or multiplied through the participation of both banks and depositors.

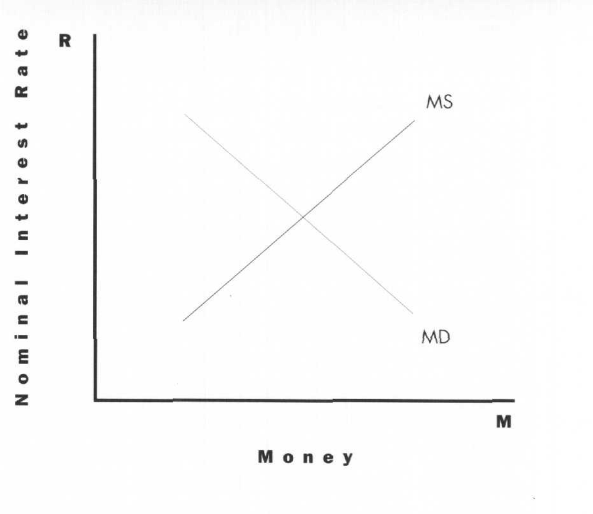
The incentive to increase deposits in the banking system lies in the prospect of making profitable loans. If the prospect is dim or the demand for loans falls off, banks may not create deposits up to the limit the reserve requirements allow. Thus they may, from time to time, have excess reserves in addition to required reserves. Furthermore, because of the uncertainty about deposit flows and transaction clearing within a day and from day to day, banks typically hold some excess reserves although there are incentives to minimize them. Clearly, banks' decisions about how much needs to be held as excess reserves, combined with depositors' decisions about how their portfolio should be allocated, can cause the supply of money to change. The central bank is not the only player whose behavior influences the money supply or the money multiplier. Taking all these behaviors into account, the supply function for money can be derived from the money multiplier (see Box 1 on page 32) and usually has the following form:

$$M = \alpha_3 R + \alpha_4 X_s + \epsilon_{MS} \text{ (money supply)}, \qquad (4)$$

where the coefficient α_3 is the interest elasticity of money supply, the coefficient α_4 is the elasticity in relation to X_s, which is a set of variables (such as reserves and output) that can influence the supply of money, and ϵ_{MS} is the money supply shock, which is uncorrelated with the money demand shock ϵ_{MD}. The α coefficients are to be estimated, and the sign of α_3 is expected to be positive. One interpretation for the positive sign of α_3 follows the logic in Box 1: since each dollar of excess reserves is costly to hold because of forgone interest, the amount of excess reserves tends to decline as the rate of interest rises. Through the money multiplier effect, deposits and monetary aggregates tend to increase. Thus, one would expect an upward-sloping curve for the money supply function as depicted in Chart 3.

From the viewpoint of the policymaker the question is, Why is it important to separate the demand for money from the supply of money? Remember that in the example of the wine market, distinguishing the demand behavior of consumers and the supply behavior of producers is important for assessing the effect of the government's tax on the behavior of consumers and producers (recall Chart 2). Here, the central bank needs to assess policy effects in order to attain its objective. When policy actions shift the money supply curve (for example, from MS_1 to MS_2 in Chart 4), the change in the equilibrium quantity of money and the equilibrium rate of interest (from E_1 to E_2 in Chart 4) depends on two factors: the slope of the money demand curve as well as the slope of the money supply curve. Thus this section has shown that understanding the demand and supply of money is crucial for assessing (identifying) policy effects on, say, the quantity of money (M) and the rate of interest (R).

CHART 3
Money Demand and Money Supply



Central Banks' Behavior

The distinction between the demand for and supply of money, explained in the monetary model (3)-(4), is analogous to the intuitive demand-supply analysis in the wine market. What the model does not show is a problem unique to policy analysis: separating the central bank's behavior from the behavior of the banking system and depositors. It is the purpose of this section to discuss in detail the behavior of the central bank.

For simplicity of analysis, textbooks usually use the money supply curve in Chart 3 to represent the central bank's behavior under either of the following two assumptions. One is that the central bank is in complete control of a broad monetary aggregate like M2, in which case the money supply curve is vertical (Chart 5). The other assumption is that unpredicted changes in reserves are caused solely by unpredicted monetary policy shifts (ϵ_{MS}) and that these changes are the only random sources affecting (that is, shifting) the money supply curve in Chart 3.

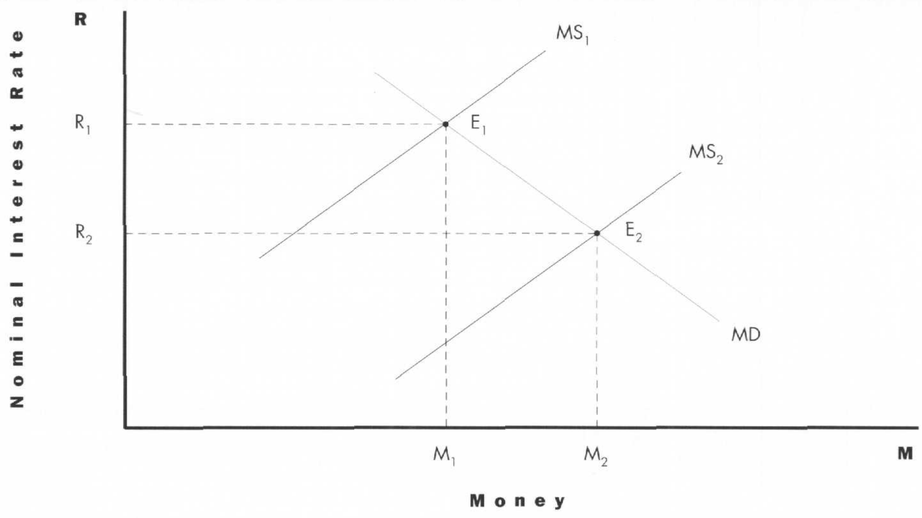
Two caveats are in order. First, these two assumptions are generally not a good description of what actually happens. The central bank can heavily influence broad monetary aggregates such as M2 but cannot control them completely. Moreover, unpredicted changes in reserves can be caused by shifts in banks' demand for reserves or by depositors' portfolio adjustment and thus

1. *This assumption is made for the convenience of analysis. Some deposits such as savings accounts in M2 do pay interest on their balances. Then, the cost of holding these assets is reflected by the difference between the interest rate on these assets and the interest rate on other assets such as government bonds. This feature would complicate the analysis but not alter the basic conclusions.*

2. *All variables discussed in this article except for interest rates are logarithmic. Thus,* M – P *is the log of real balances (the money stock deflated by the general price level).*

3. *Note the adherence to the convention of using the term* income *instead of* output; *both names denote the variable* y. *The concept of elasticity, the percent change in one variable in response to a percent change in another variable, is frequently used in the article.*

CHART 4 Shift of the Money Supply



do not necessarily indicate policy shocks. Second, even if these two assumptions are reasonable, the money supply function discussed does not to this point describe the real world of the central bank's behavior.

What is the real world behavior of the central bank, after all? More important, to what extent can a policy analyst write down a function (functions) or equation that gives a good approximation of that behavior? The macroeconomic policy aspect of many central banks' behavior reflects both their responsibility for controlling inflation and their attention to policy's effect on overall economic activity. In the day-to-day implementation of U.S. monetary policy, for example, the Federal Reserve sets a target for the federal funds rate according to its objective. Its attempts to meet the target require tracking the amount of reserves and subsequently of deposit flows and monetary aggregates. In choosing its target, the Federal Reserve regularly examines economic forecasts prepared by its staff. The staff frequently explore the historical relationships between key macroeconomic variables (such as inflation and output) and policy instruments (such as reserves and the federal funds rate) and provide alternative economic outlooks under different assumptions about policy instruments such as different levels of the federal funds rate. Policymakers then decide what actions to take in order to attain their objectives.

The process of such policymaking is common across different industrial countries. For example, for the Bank of France, senior management "assesses the reserve position of the banking system and evaluates whether current market interest rates, especially the interbank rate, are consistent with the current stance of monetary policy and foreign rates. Instructions are then given to the money market trading room at the Bank of France to intervene in the interbank market on the basis of the evaluations of money market and general macroeconomic conditions" (Batten and others 1990, 78). The Bank of Canada "uses economic projections to translate the Bank's objectives into suggested paths for the instruments of policy, and uses various economic and financial indicators, notably monetary aggregates, to monitor progress and help the Bank to act in a timely fashion when necessary" (Duguay and Poloz 1994, 197).

In short, a central bank tries to achieve its objective subject to the constraints imposed by the private sector's activity. As a result, the central bank comes out with a strategy or plan by reviewing the state of the economy.[4] This article refers to this strategy as the policy reaction function(s) and henceforth uses it to mean monetary policy or the central bank's behavior throughout. The reaction function is therefore composed of two components: the systematic reaction of policy to economic conditions and unexpected shifts in policy (policy shocks).

The discussion first turns to the systematic component of monetary policy because it is the essence of the specification (that is, description) of a reaction function. For illustration, suppose the Federal Reserve's objective is to stabilize inflation at some low level with the federal funds rate as a policy instrument. Since the Federal Reserve has no direct control over the general price level, it uses the federal funds rate to influence intermediate targets such as the three-month Treasury bill rate and M2. Unfortunately, there is no simple linkage of the federal funds rate with M2 and of M2 with the general price level, at least in the short run. The price level today is affected not only by current and past movements in other variables such as the federal funds rate, M2, and output but also by previous changes in the price level itself. The changes in all the variables reflect the interaction between policy actions and economic activity in the current and previous periods. To attain price stability, the Federal Reserve will adjust its federal funds target in response to changes in all crucial economic variables such as M2, the price level, and output. The reaction function can therefore be summarized as

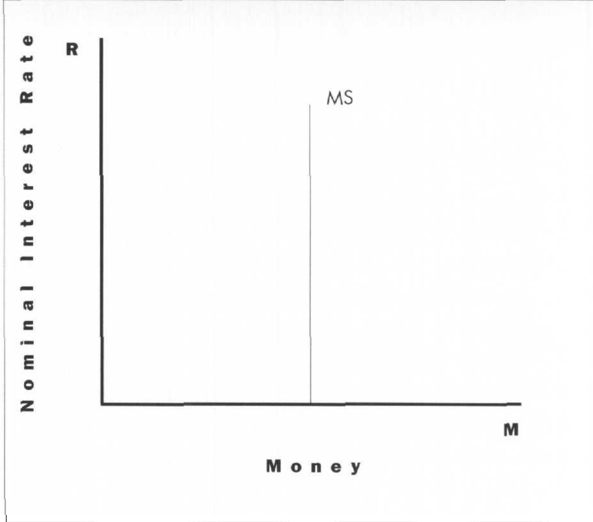
$$FR = \beta_1 M + \beta_2 R + \beta_3 X + \epsilon_{MS} \text{ (policy reaction)}, \quad (5)$$

where FR stands for the federal funds rate; M, for M2; R, the three-month Treasury bill rate; and X, a set of other crucial variables that are used by the Federal Reserve to predict fluctuations in the general price level.[5] To give an example of which variables are contained in X, suppose monthly data are used to estimate the β coefficients in the Federal Reserve's reaction function (5). The set X should include all the crucial variables the Federal Reserve uses in making its policy decisions. The variables that may be excluded in X are the price level and output in the present month, on the grounds that the data on these variables are available only after the end of the month. Similarly, one should include in the reaction function not only variables (such as the federal funds rate, commodity prices, M2, exchange rates, output, and the price level) in the previous months but also variables such as commodity prices, M2, and exchange rates in the present month. Current data on commodity prices and financial variables provide the Federal Reserve with information about the market's expectation of future inflation while the data from the previous months help predict future economic activity.

Given the systematic component $\beta_1 M + \beta_2 R + \beta_3 X$ in the policy reaction function (5), the sign of the coefficient β_1 is particularly interesting because it indicates how the federal funds rate responds to a change in the monetary aggregate. Suppose there is an increase in the monetary aggregate. If the central bank believes that such an increase will lead to a rise in future inflation, it will tend to increase the federal funds rate in order to offset the rising monetary aggregate. The sign of β_1 is therefore expected to be positive.

The second component of equation (5) is the random shock ϵ_{MS}, which reflects an unpredicted shift in monetary policy. The notion of randomness here is the same as when newspapers use the term *shock* to refer to an oil shock, which appears random because it is unpredictable. Likewise, policy shocks occur when the central bank's instrument changes unpredictably. To explain further, consider the Federal Reserve's policy. Suppose the Federal Reserve's objective is to keep inflation low in the long run and its policy instrument is the federal funds rate. In the short run (say, three to ten years), however, the dynamic relationships between output, unemployment, inflation, and the federal funds rate are complicated, and the trade-off between inflation and output may be substantial and is uncertain. A policy decision reached by sifting through such uncertain relationships can be as unpredictable as any other economic condition.[6] Such an unpredicted movement in the federal funds rate is called a policy shock—ϵ_{MS} in equation (5)—while the predicted movement (systematic reaction) is characterized by $\beta_1 M + \beta_2 R + \beta_3 X$.

CHART 5
Perfectly Inelastic Money Supply (α_3=0)



Note the close connection between the functional forms (4) and (5): the reaction function (5) can be rearranged to have the same functional form as the money supply function (4), and X_s in (4) can then be thought of as including both X and the federal funds rate (FR) in (5). Is the sign of α_3 in the newly derived function (4) positive as in the original money supply function? Recall the argument for the positive sign of β_1 in equation (5): the Federal Reserve tends to increase the federal funds rate in order to offset the rising monetary aggregate (leaning against the wind, so to speak). When the federal funds rate (FR) is expected to rise, the three-month Treasury bill rate (R) will tend to rise because there is a strong positive relationship between R and expected FR.[7] Thus one should expect the positive sign of

4. Formally, one can think of the strategy coming from the first-order conditions in the central bank's maximization problem in a theoretical model.

5. The term ϵ_{MS} will be discussed later.

6. See Leeper, Sims, and Zha (1996) for further discussions.

7. Such a relationship is known as the expectation theory of the term structure in the economic literature. For details of the theory, the reader can consult any standard textbook of monetary economics or finance—for example, Mishkin (1992).

Traditional Approach to the Supply of Money

In standard textbooks, "money supply" typically refers to the joint behavior of the central bank, commercial banks, and depositors. The derivation of the money supply function or equation in this box draws directly from McCallum (1989, 55-73). Suppose that M1 is the definition of money and the central bank resembles the Federal Reserve. By definition,

$$M = C + D, \tag{A1}$$

where C stands for the currency in circulation (held by the nonbank private sector) and D the checkable deposits. The monetary base MB that is heavily influenced by the central bank is

$$MB = C + TR. \tag{A2}$$

Note that TR stands for the total reserves, which can be further broken into two components:

$$TR = RR + ER, \tag{A3}$$

where RR is the required reserves and ER is the excess reserves.[1] The key relationships between the deposits and the other variables are

$$C/D = cr, \tag{A4}$$

$$TR/D = rr, \tag{A5}$$

$$RR/D = k, \tag{A6}$$

$$ER/D = e(R), e'(R) < 0, \tag{A7}$$

where the ratios cr, rr, and k are assumed to be constant (or are not influenced by other variables if changing over time). The assumption that $e(R)$ decreases with R is based on the belief that the banks will hold less excess reserves when the interest rate R rises. A rise in R indicates the opportunity cost of holding the excess reserves.

Using (A4), one can rewrite equation (A1) as

$$M = (cr + 1)D. \tag{A8}$$

Combining (A2), (A3), (A4), (A5), (A6), and (A7) leads to

$$MB = [cr + k + e(R)]D. \tag{A9}$$

The money multiplier, defined by the ratio of money to the monetary base, can be derived from equations (A8) and (A9):

$$\frac{M}{MB} = \frac{cr + 1}{cr + K + e(R)}. \tag{A10}$$

Using the expression $\mu(R; k, cr)$ to summarize the right-hand term of equation (A10) yields the simple money supply function:

$$M = \mu(R; k, cr)MB. \tag{A11}$$

It is obvious from (A7) and (A10) that the money supply function (A11) implies the upward-sloping curve of money supply. Thus, the function (A11) can be written in the form of equation (4), where the condition $\alpha_3 > 0$ reflects the upward-sloping curve of the money supply.

1. *Some central banks, like Canada's, no longer have the legal reserve requirement. But such banks still hold reserves in response to the withdrawal of deposits. In the case of Canada,* RR *can be thought of as the desired reserves—the amount the banks desire to hold (see Barro and Lucas 1994).*

α_i and the upward-sloping curve of the newly derived function (4) when depicted in the two-dimensional (*M*, *R*) chart. Now, however, the new function (4) has a different interpretation: it describes the policy behavior, not a joint behavior of the central bank, commercial banks, and depositors. Despite the nuances in interpreting the same functional form (4), the practice of calling the reaction function "money supply" is very common because it is always intuitive to think of demand and supply. Accordingly, this article shall continue to interchange the terms.

In summary, this section discusses the behavior of the central bank, emphasizes the significance of understanding the policy's systematic response to economic conditions, and shows how such behavior can be modeled or approximated by the policy reaction function (5). Moreover, it reinterprets the traditional money supply function discussed in the previous section as the policy reaction function but does so without changing the characteristics of the money supply function (for example, the upward-sloping curve of the supply function). Given this reinterpretation, one is able to analyze the effect of monetary policy in the intuitive framework of demand and supply, as will be shown in later sections.

Other Points about Identifying Monetary Policy

The antecedent sections establish the importance of identifying monetary policy (separating money demand from money supply) and describe how the money supply function (4) can be used to approximate a central bank's behavior. Even so, the point about the importance of identifying monetary policy is still often misunderstood. Two popular contentions merit further discussion.

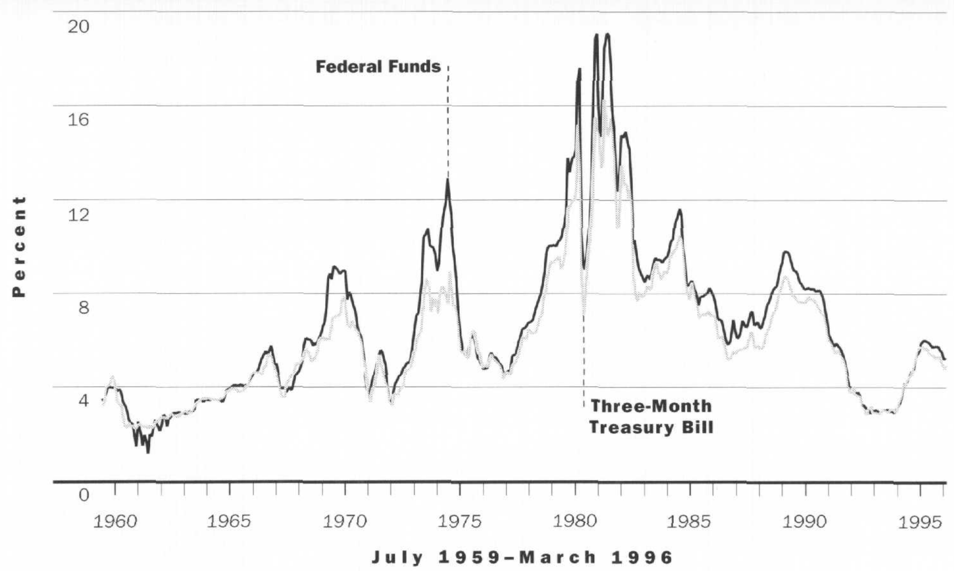
One position is that central banks know exactly what their monetary policy or behavior is and from their viewpoint there is no need to separate the money demand and money supply. For example, if a central bank's objective is a commitment to price stability, monetary policy is to make the general price level stable, and thus the private sector's behavior (such as the demand for money) is not the policymaker's concern. While this notion seems prima facie sensible, it is simply incorrect. It confuses the central bank's objective with its policy, which, as the discussion in the last section argues, is a strategy designed to achieve the objective. The real issue is not whether the central bank knows its objective; the real issue is whether it knows how to form a strategy (monetary policy) to attain its objective. The formation is difficult and requires a thorough understanding of the interaction between the central bank's behavior (money supply) and the private sector's activity.

Consider, for example, Canadian monetary policy. Analysis of Canadian monetary policy is instructive not only because most countries resemble Canada in the sense that they are small and open relative to the U.S. economy but also because it is of interest to U.S. policymakers as the U.S. economy has become increasingly integrated with the rest of the world, especially with other major industrialized countries. Suppose the price of world commodities suddenly drops while other conditions or variables do not change. Since Canada is an exporter of raw materials and commodities, Canadian residents' income will decline. Falling Canadian income means a decrease in the demand for Canadian money, which by itself would lower the exchange value of Canadian currency. If a falling Canadian currency has a direct positive impact on Canadian prices in the short run (see Dornbusch and Krugman 1976), the Bank of Canada will try to stabilize the exchange rate in hopes of stabilizing the price level. In the process of formulating such a monetary policy, the Bank of Canada must have a fairly accurate idea of the demand for Canadian money. It also must have a strong sense of its own behavior (money supply) in order to predict the equilibrium quantity of money and the equilibrium rate of interest (the intersection of demand and supply in Chart 3), as changes in both the money stock and the interest rate will affect the exchange rate and the price level. This example is important because monetary policy in most countries, unlike in the United States, resembles Canadian monetary policy in the sense that the domestic economy is heavily influenced by foreign economies and the exchange rate plays a considerable role in policy formation.

To assess the effect of monetary policy requires understanding the interaction between the central bank's behavior and the private sector's activity.

In the case of the United States, some would say that monetary policy is easy to formulate: it calls for simple adherence to the federal funds rate target the Federal Reserve itself chooses. Again, this argument is a sophism. The federal funds rate target is not set arbitrarily; it reflects the Federal Reserve's concern about its own objective of, say, price stability. When fluctuations in economic activity or the repercussions of past policy choices threaten such an objective under the current rate of federal funds, a new target for the federal funds rate will be chosen. Indeed, as shown in Chart 6, the federal funds rate has changed over time, sometimes frequently. How the target is set reflects how the Federal Reserve reacts to the changing state of the economy, which is described by the reaction function (5) or (4). The Federal Reserve's

CHART 6
Time Series Pattern of Federal Funds Rate and Three-Month Treasury Bill Rate



reaction function can be complicated because there is no simple relationship between the federal funds rate and the general price level, at least within three to ten years.

The other popular contention that questions the role of separating money demand and money supply argues that although a central bank's decision is based on its staff's forecasts of a wide range of macroeconomic variables, such forecasts do not identify distinctive behaviors of the central bank and the private sector. For example, in most models that forecast real gross domestic product (GDP), monetary aggregates, interest rates, and prices, the central bank's reaction function is not explicitly specified or sorted out. But it does not follow that the policymaker has no idea of money demand and money supply. In fact, during the process of decision making, the central bank's behavior and the private sector's behavior are closely examined by looking into the past movements of various key macroeconomic variables (such as M2 and the general price level). When conducting monetary policy, the policymaker always wants to know how much changes in M2 are influenced by present monetary policy (the money supply side) and how much those are merely caused by portfolio shifts in the private sector (the money demand side). If, say, the money demand curve shifts to the right from MD_1 to MD_2 and if the central bank desires to have the money stock at M^* (Chart 7) in order to keep inflation in check, an economic model that explicitly separates the central bank's behavior and the private sector's behavior can undoubtedly aid the policymaker in deciding how the money supply curve needs to be shifted accordingly (from MS_1 to MS_2 in Chart 7). Moreover, such a model allows one to forecast different paths of macroeconomic variables conditional on different policy actions in the future. For example, the Federal Reserve may be interested in deciding whether the federal funds rate in the next two years should be 5 percent or 6 percent or 4 percent. If the economic model distinguishes policy behavior and the private sector's behavior, it can be used to examine how policy actions in the future would lead to different forecasts of the price level, M2, the unemployment rate, and other variables.

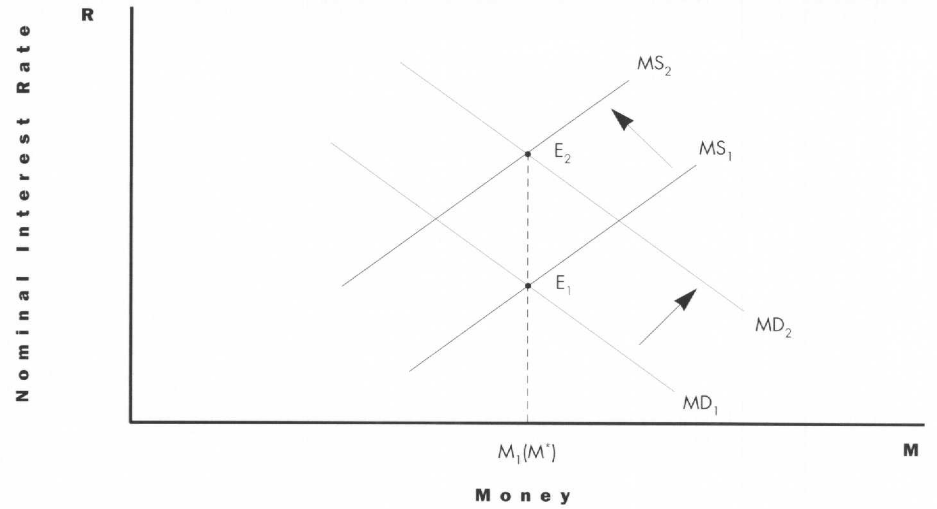
The discussion in this section replies to some prevalent naive thinking about the issue of identifying monetary policy. It reinforces the point that the actual formation of monetary policy in any country is a complicated process. To assess the effect of monetary policy requires understanding the interaction between the central bank's behavior and the private sector's activity.

More on Demand and Supply

So far, the discussion has been concerned with why identification of monetary policy is important in policy analysis. It has not yet answered the question of how we identify monetary policy in practice. How difficult is it to estimate the money demand function (3) and the money supply function (4) or to obtain from the observed data the values of α coefficients in both equation (3) and (4) so that the actual curves of money demand and supply can be plotted? This section turns to this "how" question, which is the essence of identification integral to all empirical study in economics. It begins with the familiar wine market example and then discusses how to estimate the demand and supply of money.

As shown in the dots in Chart 8, the data on the quantity and price of wine are the equilibrium outcome from movements in both demand and supply. These

CHART 7 Monetary Policy Reaction



movements, caused by either the ϵ shocks or other factors such as the government's tax and the consumers' preference for wine over beer, or by both, make the estimation of the demand and supply curves a challenge. A popular approach uses the data to estimate the relationship of quantity to price with the equation

$$q = \gamma_1 p + \epsilon. \tag{6}$$

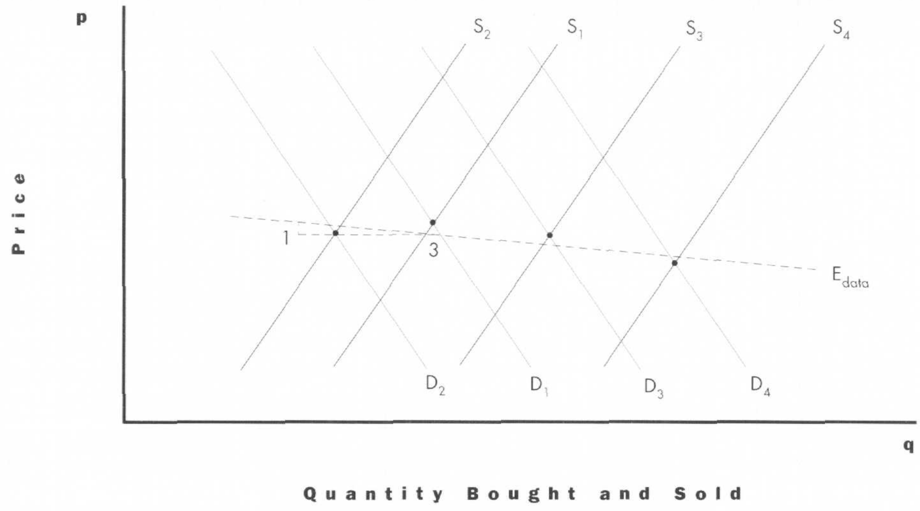
The obvious problem with this approach is that one cannot be sure whether equation (6), after being estimated, is a demand function, a supply function, or a combination of the two. Suppose γ_1 is estimated to be –3 as indicated by the curve E_{data} in Chart 8, implying that the quantity of wine increases by 3 percent when the price falls by 1 percent. This estimated relationship between q and p does not mean that the actual demand for wine (indicated by the curve D in Chart 8) is as elastic as –3. The reason γ_1 and α_1 are not equal is that γ_1 represents the coefficient in the relationship (6) that is directly observed in the data while α_1 represents the coefficient in the wine demand function (1) that is not directly observable.[8] Suppose that the policy analyst mistakenly took the estimated function represented by E_{data} in Chart 8 as the demand function. The analyst would anticipate that the quantity demanded will rise substantially when the price of wine drops. But since the actual demand curve represented by D in the chart is much steeper than the curve E_{data}, the actual demand is less elastic than the one estimated and the quantity actually demanded will not rise so substantially. Then, any conclusions based on this estimate of consumer behavior can be misleading.

The wine market example illustrates that even when demand and supply have simple, uncomplicated relationships, identifying (that is, estimating) each of them is difficult. The same identification problem exists if one tries to estimate both money demand and money supply from the observed data because the data themselves are not sufficient to distinguish supply from demand. Suppose one wants to identify the money supply function. The question is, How can one distinguish the specific behavior of the central bank from the observed data, or how can one figure out the money supply curve in Chart 3? Clearly, one cannot follow the practice of estimating equation (6) in the wine market example and use the data on M and R to estimate such a relationship. Some factor or factors are needed that will shift the money demand curve but not the supply curve. Then, if one traces out the observed data as illustrated by the dots in Chart 9, the time series pattern will precisely reveal the money supply curve that describes the central bank's behavior. Thus, the basic idea of achieving identification is to isolate factors that are in one of the relationships, such as the money demand function (3), but not shared with the others, such as the money supply function (4). An assumption about which factor influences which equation is called an identifying assumption.

Are there such factors? As discussed above, since the central bank is unable to observe the data on output (y) and the general price level (P) within the present month, the set of variables X_s in (4) does not contain y and P. Thus, changes in current output and the current price level serve as the shifters that move the money

8. *For similar reasons,* γ_1 *and* β_1 *are not equal.*

CHART 8 Equilibrium Quantity and Price of Wine



demand curve but not the money supply curve (Chart 9) and help estimate the money supply curve from the data.

The money demand function can also be estimated (identified) in similar spirit. Recall that the information set X_s in the money supply function (4) contains the exchange rate or the commodity price index or both, which are excluded in the money demand function (3). Movements in the exchange rate or commodity price index will shift the money supply curve but not the money demand curve (Chart 10). The money demand curve can then be traced out when there are enough changes in the exchange rate or commodity price index.

Charts 9 and 10 demonstrate the basic idea of achieving identification, but the actual estimation of both the money demand function (3) and the money supply function (4) is far more complicated. When both output (shifting the money demand curve) and the exchange rate (shifting the money supply curve) change at once, the money demand and money supply curves will shift simultaneously (Chart 11).[9] Therefore, one cannot estimate the demand function (3) or the supply function (4) in isolation, as Charts 9 and 10 seem to suggest. Indeed, both functions must be estimated jointly, not in isolation. See Box 2 (page 38) for a discussion of the technical difficulties involved. Nonetheless, the basic idea of achieving identification is clear: conceptually, to do so one needs factors that shift the demand curve independent of the supply curve or vice versa; technically, the demand and supply functions must be estimated simultaneously.

Different Empirical Approaches

Economic research has historically used a variety of empirical approaches to uncover (identify) policy effects from the observed data. To circumvent both the conceptual and technical difficulties in identifying monetary policy, many approaches invoke implausible identifying assumptions. This section considers a few examples or approaches taken from economics journals and argues that assumptions that are convenient for statistical purposes but are not sensible in economics terms are likely to generate misleading results.

Example 1. One traditional approach, which has been exploited at least since Friedman and Schwartz (1963), is to use a single variable (such as a monetary aggregate, an interest rate, or an exchange rate) as an indicator of monetary policy. For example, unpredicted changes in a monetary aggregate—be it reserves or an M variable—are often attributed mainly to monetary policy shocks. The common practice is to estimate the relationship of the monetary aggregate to the other variables and then interpret the residuals calculated from such an estimation as policy shocks (for example, Barro 1977 for the United States and Wogin 1980 for Canada).

The assumption underlying this practice is that this relationship represents the central bank's behavior. Unfortunately, this single-equation approach, analogous to the estimation exercise along the line E_{data} in Chart 8, fails to take account of the fact that the data on monetary aggregates are what is observed at equilibrium (the point intersected by the demand and supply curves). Indeed, monetary aggregates such as reserves or M2 are influenced by not only the central bank's behavior but also the demand behavior of other sectors in the economy. Suppose that the equilibrium outcome is such that the monetary aggregate and the interest rate are positively correlated as indicated by the single estimation curve E_{data} in Chart 11. Apparently, it is a mistake to interpret the curve E_{data} as the actual money supply curve MS.

The point that the policy behavior inferred through the time series patterns of a single variable can be mis-

CHART 9 Tracing Out the Money Supply Function

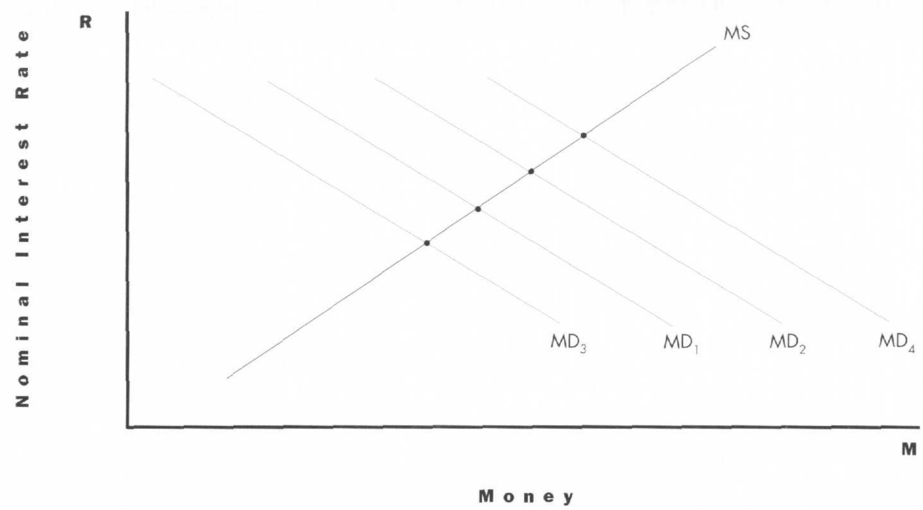
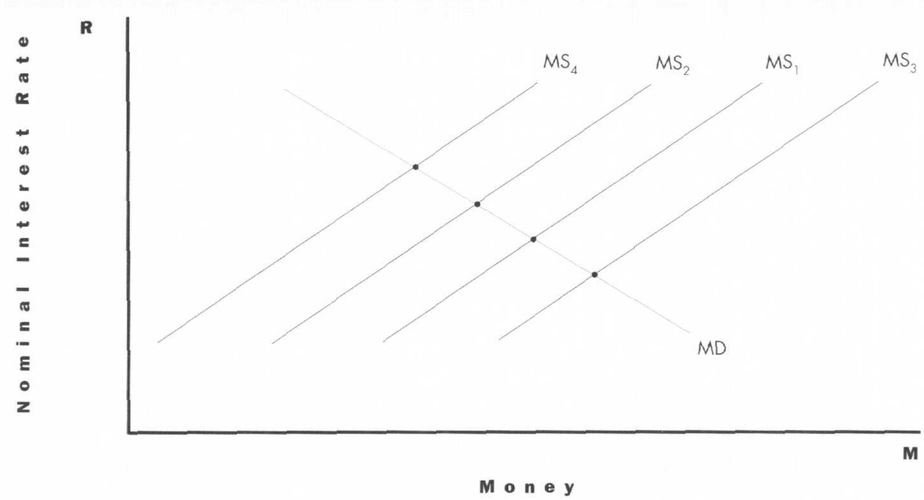


CHART 10 Tracing Out the Money Demand Function



leading was made long ago by Tobin (1970). Tobin presented a dynamic general equilibrium model to show that the same time series evidence used by Milton Friedman and other monetarists could lead to a completely different interpretation of monetary policy effects. Despite Tobin's warning, however, researchers oftentimes continue to use the single-equation approach to modeling monetary policy, at least in part because identifying monetary policy is conceptually difficult and mathematical tools are only now being developed to address the identification issue seriously.[10]

Example 2. In recognition of both the inadequacy of single-equation approaches and the nature of a central bank's reaction to the state of the economy, recent research on identification of monetary policy has developed ways of handling the complex relationships of multiple economic variables (see Box 2). One approach is to include both policy instruments (such as an interest rate) and other macroeconomic variables (such as the general price level) in the same framework (as in Sims 1992, Grilli and Roubini 1995, Eichenbaum and Evans 1995, and Dungey and Pagan 1997). This approach is certainly a

9. The situation is analogous to that depicted in Chart 3.

10. Romer and Romer (1989, 1990), following the spirit of Friedman and Schwartz, invent a single dummy variable indicating the changes in U.S. monetary policy. But as Leeper (1997) forcibly argues, the Romers' dummy variable does not identify the Federal Reserve's behavior.

Empirical Methods

This box, focusing on the case of a small open economy, is largely drawn from Zha (1996). Assume the structural model is of a linear, dynamic form called vector autoregression (VAR):

$$A(L)y(t) = \epsilon(t), \qquad \text{(B1)}$$

where $A(L)$ is an $m \times m$ matrix polynomial in lag operator L, $y(t)$ is an $m \times 1$ vector of observations of m variables, and $\epsilon(t)$ is an $m \times 1$ vector of i.i.d. structural shocks so that

$$E\epsilon(t) = 0, E\epsilon(t)\epsilon(t)' = I. \qquad \text{(B2)}$$

The reduced form of (B1) can be obtained by multiplying A_0^{-1} through (B1).

A natural way of estimating the model is to explore the shape of a likelihood function (which describes how likely the model parameters are to lie within a certain range of values) and to obtain the values of parameters that are most likely to occur (the values so obtained are called maximum likelihood [ML] estimates). If the likelihood function is complicated, finding ML estimates may become problematic. For the reduced form of (B1), however, the ML estimates turn out to be simply the ordinary least squares (OLS) estimates in each equation. The OLS estimation is straightforward and can be easily computed using any statistical software package.

To see how the system (B1) can be used to model a small open economy, break (B1) into two blocks—the first block concerns the home (small) economy, and the second block concerns the foreign (the rest of the world) economy. To be specific, let

$$A(L)=\begin{pmatrix} A_{11}(L) & A_{12}(L) \\ A_{21}(L) & A_{22}(L) \end{pmatrix},$$

$$y(t)=\begin{pmatrix} y_1(t) \\ y_2(t) \end{pmatrix},$$

$$\epsilon(t)=\begin{pmatrix} \epsilon_1(t) \\ \epsilon_2(t) \end{pmatrix}.$$

The matrix A_s is the coefficient matrix of L^s in $A(L)$, where L^s is the lag operator L raised to s power. In most works of the identified VAR literature, the restrictions are imposed only on A_0—the contemporaneous coefficient matrix. The ML estimates of A_0 depend only on the estimated covariance matrix ($\hat{\Sigma}$) of reduced-form residuals; this can be easily seen by writing out the concentrated likelihood function of A_0 (see Sims and Zha 1995 for details):

$$\left|A_0\right|^T \exp\left[-\frac{T}{2} trace\left(\hat{\Sigma}A_0'A_0\right)\right]. \qquad \text{(B3)}$$

Because of (B3), obtaining the estimates of and inference about model parameters is in principle straightforward (Sims and Zha 1995), and when A_0 follows a successive representation, the estimation is straightforward even in practice (Sims 1980).

If the small open economy framework is taken seriously, one will impose the restriction that $A_{21}(L) = 0$, meaning that the small country takes changes in foreign economic conditions as given or exogenous. This small-economy restriction makes the easily implemented procedure developed by Sims and Zha (1995) invalid, mainly because the concentrated likelihood (B3) no longer holds. In principle, various iterative procedures can be used. For example, one begins with the unrestricted $\hat{\Sigma}$ to solve the ML estimate of A_0 with the restriction $A_{0_{21}} = 0$ imposed. The estimates of other structural parameters (A_s, $s \geq 1$) can then be recovered, and a new reduced form covariance matrix is accordingly formed.[1] Use this new matrix to replace the previous $\hat{\Sigma}$ and repeat the procedure until $\hat{\Sigma}$ converges.

Since the size of a small open economy model is typically large relative to closed economy models, this iterative procedure not only is cumbersome but can be computationally prohibitive as well, especially when one computes the inference of the ML estimates. Consequently, previous researchers have not accounted for the small open economy features in their models. The method developed in Zha (1996), which allows for more general cases than the small open economy example here, provides a practically feasible way of obtaining the ML estimates as well as their inference.

1. The details of how the estimates are recovered are discussed in Zha (1996). The idea of this iterative procedure is also mentioned in Dias, Machado, and Pinheiro (1996).

CHART 11 Simultaneous Changes in Money Demand and Money Supply

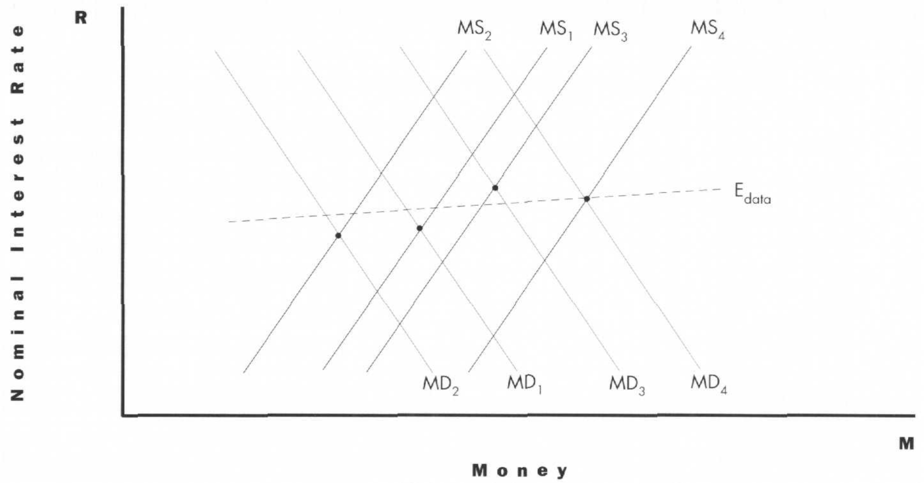
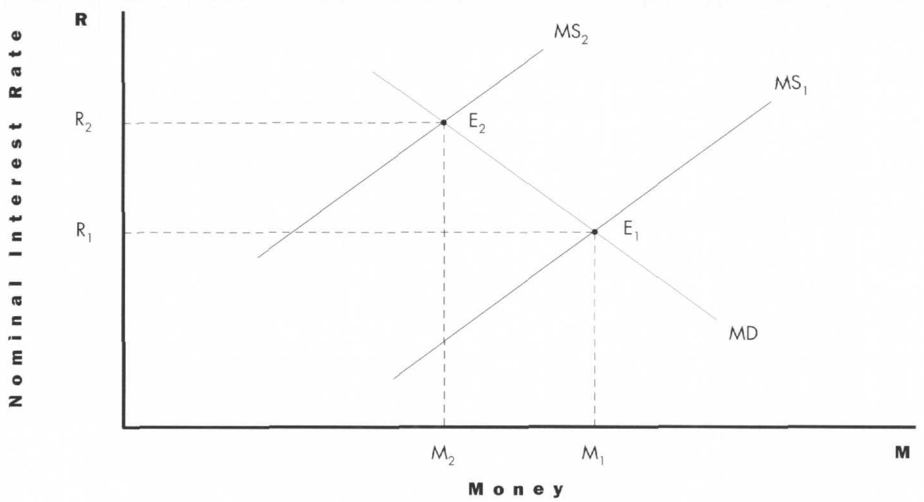


CHART 12 Effect of Contractionary Shock (E_{MS})



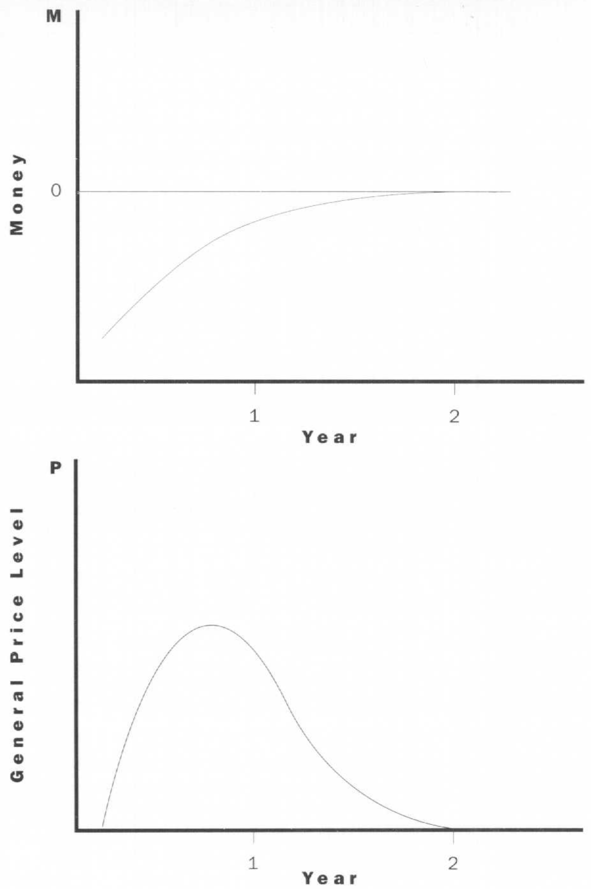
considerable improvement over that outlined in Example 1. Nonetheless, all these works suffer from a common problem: they make identifying assumptions that seem implausible in the description of a central bank's behavior.

As explained above, identifying assumptions are those that help distinguish different behaviors (for example, demand and supply) in the actual economy. They are necessary because, analogous to the example of demand and supply, one needs some factors that shift only the supply curve in order to identify the demand function (Chart 10) and other factors that shift only the demand curve in order to identify the supply function (Chart 9). While the aforementioned works use assumptions that are convenient for statistical computations, the important difference in the approach called for in the previous sections is that it argues for economically sensible assumptions.

Specifically, the common assumption used in the works cited is that different behaviors follow successive relationships. Although the successive assumption makes it convenient to estimate the model (see Box 2), it seldom represents the structure of the actual economy. For example, in Eichenbaum and Evans (1995) the money stock M influences the interest rate R contemporaneously but not vice versa, an assumption that essentially takes α_3 in the money supply equation (4) to be zero, implying that the money supply is perfectly inelastic (Chart 5).[11] In their study of the U.S. economy, for example, Eichenbaum and Evans use nonborrowed reserves as M and the federal

11. The money demand function is not explicitly specified in their papers.

CHART 13
Perverse Dynamic Responses of Price after Monetary Contraction: The Price Puzzle



funds rate as R. Thus, an inelastic money supply ($\alpha_3 = 0$) means that the Federal Reserve does not respond, within the month, to fluctuations in the federal funds rate. In fact, the Federal Reserve frequently influences the federal funds rate in pursuit of its objective, so the assumption that money supply is perfectly inelastic seems at odds with the Federal Reserve's targeting of the federal funds rate. It is therefore not surprising that this extreme assumption would lead to results that are inconsistent with views widely held by both policymakers and economists (Gordon and Leeper 1994 and Leeper 1995).

Before reviewing an example of these inconsistent results, it is important to explain the concept of contractionary monetary policy shock that is often used in economics journals. Recall that this article uses the phrase *policy shocks*—ϵ_{MS} in the money supply equation (4)—to describe unpredicted shifts in monetary policy. Thus, the shock ϵ_{MS} in equation (4) is said to be contractionary if it shifts the money supply curve to the left (from MS_1 to MS_2 in Chart 12), moving the equilibrium outcome from point E_1 to point E_2. The word *contractionary* is adopted because, subsequent to this shock, the money stock M contracts from M_1 to M_2 while the interest rate R rises from R_1 to R_2.

Now, to present an example, consider one of the firmly established views in policy analysis: the price level falls after an unpredicted contraction in monetary policy. When one uses Eichenbaum and Evans's successive assumption to model several industrial countries such as the United States, Japan, and Germany, the model generates the inconsistent result (often termed the price puzzle) that the price level would rise, not fall, in response to a contractionary monetary policy shock (Chart 13).[12] If the model is intended to be useful for policy decisions, such a puzzle is indeed troublesome because it implies that monetary policy must expand the money stock (or lower the federal funds rate) in order to lower inflation. Would one recommend such a policy? Does anyone really believe that inflation will fall if the central bank increases the supply of money (or lowers interest rates)?

When a model produces inconsistent results such as the price puzzle, one needs to examine carefully the underlying (identifying) assumptions to see if they make good economic sense. If a central bank reacts quickly to changes in the interest rate, it makes no economic sense to assume that the interest elasticity α_3 in the money supply equation (4) is zero. If one insists on a successive representation by letting α_3 be zero, equation (4) is then no longer the policy reaction function (or the money supply function).

Example 3. The above example suggests that a reasonable identification of the central bank's behavior inevitably leads to a breakdown of the successive representation commonly used in economics journals. A recent work of Cushman and Zha (1997) argues for a better representation of policy's systematic behavior and makes progress in the specification and estimation of behavioral relationships. In that study, both the money demand equation and the money supply equation are in the same form as equations (3) and (4) in this article. Using Canada as a study case, the paper devotes special attention to Canada's relationship with the U.S. economy and the systematic component ($\alpha_3 R + \alpha_4 X_s$) in the policy reaction function (4). In particular, the set X_s contains a wide variety of macroeconomic variables to which the Bank of Canada would react. Some information, such as output and the general price level in both Canada and the United States, is not readily available to the Bank of Canada in a timely fashion (because data such as industrial output and the consumer price index for a given month are not released until after the end of the month). These pieces of information are therefore excluded from X_s in the money supply function (4). The Bank of Canada, however, can react quickly to changes in other key macroeconomic conditions—the exchange rate, the U.S. interest rate, and commodity prices—for which data are available daily. These economic conditions convey information about the current state of both the Canadian economy and the U.S. economy, about possible actions in U.S. monetary policy, and about future inflation.

The estimated money demand and money supply curves by Cushman and Zha (1997) are depicted in Chart 14. The money supply is almost inelastic to the domestic interest rate but, as shown in Chart 15, very elastic to the exchange rate. This condition implies that the Bank of Canada, unlike the Federal Reserve, responds mainly to changes in the exchange rate rather than to the domestic interest rate. Evidently, systematic behavior of central banks may differ across countries (such as the United States and Canada). For the U.S. economy, it is a mistake to assume the interest elasticity α_3 in the money supply function (4) to be zero because the Federal Reserve targets the federal funds rate. In other words, assuming $\alpha_3 = 0$ may be expedient statistically, but it yields results that are not sensible. For the Canadian economy, it is a mistake to assume the exchange elasticity in the money supply function to be zero because, as shown in Chart 15, the Bank of Canada responds to changes in the exchange rate. Indeed, if the exchange rate elasticity were assumed to be zero, the price puzzle, which does not exist in Cushman and Zha's original model, would be present.

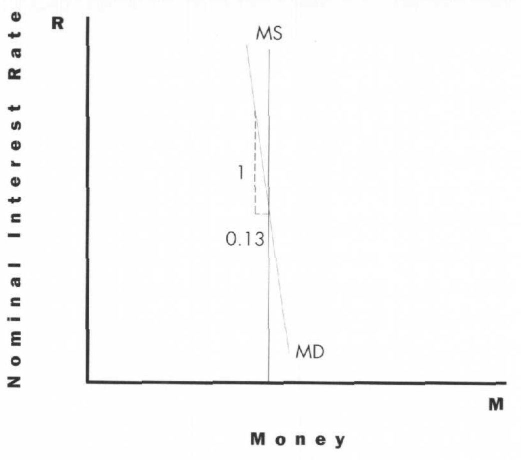
The above example of identifying Canadian monetary policy shows the importance of using sensible identifying assumptions even though such assumptions may raise empirical difficulties. Identifying the U.S. monetary policy involves a similar task of separating the Federal Reserve's behavior from the private sector's behavior. Leeper, Sims, and Zha (1996) discuss how difficult it is to achieve reasonable identification of U.S. monetary policy. Understanding each country's relationship with the rest of the world and each central bank's systematic behavior is a necessary step when one makes identifying assumptions.

This section reviews several identification approaches used in policy analysis. Some, such as the single-equation approach, fail to separate policy's systematic response to the state of the economy from the response of the economy to policy (supply from demand). Those that attempt such separation have often imposed extreme assumptions that would lead to inconsistent or puzzling results. All the examples discussed echo the same message: avoiding extreme or unreasonable identifying assumptions when modeling monetary policy in a given country is crucial for eliminating puzzling results, achieving correct identification, and producing sensible monetary policy analysis.

Conclusion

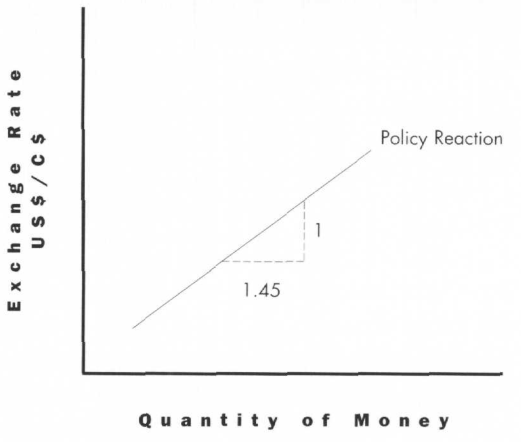
The monetary policy reaction in any actual economy is complicated, and "the policy framework is a pragmatic one. There are no simple rules" (Duguay and Poloz 1994, 197). The discussion here establishes the importance of identifying monetary policy, explains the difficulties involved in identification, cautions about the potential danger of making extreme assumptions about the behavioral relationships, and sheds some light on the progress there has been toward adequately identifying monetary policy (as in Cushman and Zha 1997). In particular, the article uses the simple examples of demand and supply to illustrate how quickly the difficulty in identification of monetary policy can become overwhelming if one wishes to separate the central bank's behavior from

CHART 14
Estimated Money Demand and Money Supply Functions



Source: Adapted from Cushman and Zha (1997).

CHART 15
Relationship between Money Supply and Exchange Rate



12. *The author thanks Roberto Chang for suggesting such an exercise.*

others' behavior in the economy. The difficulty contributes to the disparity and uncertainty in economists' views on the effects of monetary policy.

The essential point is that because of the complexity inherent in monetary policy reaction unique to different countries, an economic model usable for policy analysis in a given country requires both cogitable reasoning conceptually and serious effort empirically. Notwithstanding significant progress in both theory and econometrics, the gap between economic theory and empirical observations is still wide because theoretical models have not yet produced the same time series pattern of macroeconomic variables as those that characterize the actual economy. The challenge in future research is to narrow the gap and move toward a good economic model usable for a discussion of actual policy effects in different countries.

REFERENCES

Barro, Robert J. 1977. "Unanticipated Money Growth and Unemployment in the United States." *American Economic Review* 67 (March): 101-15.

Barro, Robert J., and Robert F. Lucas. 1994. *Macroeconomics*. Burr Ridge, Ill.: Richard D. Irwin, Inc.

Batten, Dallas S., Michael P. Blackwell, In-Su Kim, Simon E. Nocera, and Yuzuru Ozeki. 1990. "The Conduct of Monetary Policy in the Major Industrial Countries: Instruments and Operating Procedures." International Monetary Fund Occasional Paper 70, July.

Cooley, Thomas F., and Gary D. Hansen. 1995. "Money and the Business Cycle." In *Frontiers of Business Cycle Research*, edited by Thomas F. Cooley, 175-216. Princeton, N.J.: Princeton University Press.

Cushman, David O., and Tao Zha. 1997. "Identifying Monetary Policy in a Small Open Economy under Flexible Exchange Rates." *Journal of Monetary Economics* 39 (June, forthcoming).

Dias, Francisco C., Jose A.F. Machado, and Maximiano R. Pinheiro. 1996. "Structural VAR Estimation with Exogeneity Restrictions." *Oxford Bulletin of Economics and Statistics* 58 (May): 417-22.

Dornbusch, Rudiger, and Paul Krugman. 1976. "Flexible Exchange Rates in the Short Run." *Brookings Papers on Economic Activity*, no. 3:537-75.

Duguay, Pierre, and Stephen Poloz. 1994. "The Role of Economic Projections in Canadian Monetary Policy Formulation." *Canadian Public Policy* 20, no. 2:189-99.

Dungey, Mardi, and Adrian Pagan. 1997. "Towards a Structural VAR Model of the Australian Economy." Australian National University, unpublished manuscript.

Eichenbaum, Martin, and Charles Evans. 1995. "Some Empirical Evidence on the Effects of Shocks to Monetary Policy on Exchange Rates." *Quarterly Journal of Economics* 110 (November): 975-1009.

Friedman, Milton. 1992. *Money Mischief: Episodes in Monetary History*. New York: Harcourt Brace Jovanovich.

Friedman, Milton, and Anne J. Schwartz. 1963. *A Monetary History of the United States, 1867-1960*. Princeton, N.J.: Princeton University Press.

Gordon, David B., and Eric M. Leeper. 1994. "The Dynamic Impacts of Monetary Policy: An Exercise in Tentative Identification." *Journal of Political Economy* 102 (December): 1228-47.

Grilli, Vittorio, and Nouriel Roubini. 1995. "Liquidity and Exchange Rates: Puzzling Evidence from the G-7 countries." Yale University, unpublished manuscript.

Leeper, Eric M. 1992. "Facing Up to Our Ignorance about Measuring Monetary Policy Effects." Federal Reserve Bank of Atlanta *Economic Review* 77 (May/June): 1-16.

———. 1995. "Reducing Our Ignorance about Monetary Policy Effects." Federal Reserve Bank of Atlanta *Economic Review* 88 (July/August): 1-38.

———. 1997. "Narrative and VAR Approaches to Monetary Policy: Common Identification Problems." *Journal of Monetary Economics* 40 (forthcoming).

Leeper, Eric M., Christopher A. Sims, and Tao Zha. 1996. "What Does Monetary Policy Do?" *Brookings Papers on Economic Activity*, no 2:1-78.

McCallum, Bennett T. 1989. *Monetary Economics: Theory and Policy*. New York: Macmillan.

Mishkin, Frederic S. 1992. *The Economics of Money, Banking, and Financial Markets*. 3d ed. New York: Harper Collins.

Romer, Christina D., and David H. Romer. 1989. "Does Monetary Policy Matter? A New Test in the Spirit of Friedman and Schwartz." In *NBER Macroeconomics Annual 1989*, edited by Olivier J. Blanchard and Stanley Fischer, 121-70. Cambridge, Mass.: MIT Press.

———. 1990. "New Evidence on the Monetary Transmission Mechanism." *Brookings Papers on Economic Activity*, no. 1:149-98.

Sims, Christopher A. 1980. "Macroeconomics and Reality." *Econometrica* 48 (January): 1-48.

———. 1992. "Interpreting the Macroeconomic Time Series Facts: The Effects of Monetary Policy." *European Economic Review* 36 (June): 975-1000.

SIMS, CHRISTOPHER A., AND TAO ZHA. 1995. "Error Bands for Impulse Responses." Federal Reserve Bank of Atlanta Working Paper 95-6, September.

TOBIN, JAMES. 1970. "Money and Income: *Post Hoc Ergo Propter Hoc?*" *Quarterly Journal of Economics* 84 (May): 301-17.

WOGIN, GILLIAN. 1980. "Unemployment and Monetary Policy under Rational Expectations: Some Canadian Evidence." *Journal of Monetary Economics* 6 (January): 59-68.

ZHA, TAO. 1996. "Identification, Vector Autoregression, and Block Recursion." Federal Reserve Bank of Atlanta Working Paper 96-8, August.