Evaluating the Effects of Monetary Policy with Economic Models

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V OLUMINOUS STUDY OF MACROECONOMICS HAS CONCLUDED THAT MONETARY POLICY OPERATES WITH A LONG LAG. THE LAG WITH WHICH A POLICY CHANGE EXERTS SIGNIFICANT INFLUENCE ON THE ECONOMY IS VARIABLE, DEPENDING ON BOTH PAST POLICY ACTIONS AND THE CURRENT STATE OF THE ECONOMY. IT CAN BE AS LONG AS TWO OR THREE YEARS, ESPECIALLY THE IMPACT ON INFLATION. SUCH A LONG, VARIABLE LAG REQUIRES TODAY'S POLICY ACTIONS TO BE ANTICIPATORY IF THEY ARE TO ACHIEVE A TIMELY IMPACT (KOHN 1995; GREENSPAN 1999; BLINDER 1997; KING 1998). THE POPULAR PRESS AND POLICYMAKERS DESCRIBE THIS FORWARD-LOOKING POLICY AS PREEMPTIVE. IN THE WORDS OF ONE FEDERAL RESERVE GOVERNOR, MONETARY POLICY "IS MOST SUCCESSFUL WHEN IT IS PREEMPTIVE, RESPONDING TO EARLY WARNING SIGNALS OR FORECASTS OF UNFAVORABLE DEVELOPMENTS ON THE INFLATION AND EMPLOYMENT FRONTS" (FERGUSON 1998, 2).

Policymakers always rely on some kind of explicit model to infer the future impact of their actions on economic variables. Such preemptive policy further requires a model to be capable of providing not simply a single-point forecast but, more importantly, a useful evaluation of how alternative policy options might affect the actual economy. By consulting a menu of such alternative outcomes, called policy projections, policymakers then have better information for deciding on a particular policy action that will most likely lead to economic results commensurate with policy objectives.

The task of developing a model to accurately extrapolate quantitative effects of alternative monetary policy actions on the future economy has proved to be a challenge, however. Economists know very well that "a new complete model can easily require years to develop; millions of dollars and careers may be devoted to the effort" (Geweke 1999, 54). It is simply impossible to have a super model that encompasses every aspect of the actual economy. Therefore, a modeler must consciously choose the kinds of questions a model is designed to address. In this article the class of policy questions considered concerns those that policymakers

regularly ask when the central bank is facing a decision about monetary policy. In the U.S. economy, for example, policymakers routinely ask for forecasts of key macroeconomic variables such as inflation and the unemployment rate if the Federal Reserve adopts different federal funds rate paths over the next three years. Assessing a model's usefulness in providing a menu of such projected outcomes for decision making depends on particular criteria. The modeler should therefore be all the more explicit about the criteria set forth in developing the model.

This article focuses on five distinct criteria frequently stressed in the economic literature as important for assessing whether a model is usable. The model should (1) be transparent and reproducible for independent evaluation and further improvement; (2) be able to incorporate new information to update its forecast without ad hoc periodic judgmental adjustments; (3) adequately capture the complicated, dynamic interactions among the multiple key macroeconomic variables of concern to the policymaker; (4) be based on economic theory and offer reasonable economic interpretations of the central bank's behavior; and (5) be able to provide a menu of policy projections under alternative policy scenarios in an economically coherent way. Many existing models meet only some of these criteria. For a model to be usable for actual policy decisions, however, all five are necessary.

The first three emphasize how well an explicit model is fit to the data. The fourth criterion addresses the issue of separating the central bank's behavior from that of the rest of the economy. This issue is referred to as identification of monetary policy, a topic that has received considerable attention in the recent literature (see Zha 1997 and references therein). All four of these criteria are prerequisite to the fifth one—the evaluation of alternative policy scenarios.

This article uses the dynamic, six-variable model of Leeper and Zha (1999) as a pedagogic example of how to combine a well-fit model (criteria 1–3) with a successful identification (criterion 4) to provide a menu of policy projections under alternative policy scenarios (criterion 5). It begins with a discussion of the difficulties and challenges associated with modeling monetary policy in the actual economy. The five criteria are reviewed in light of comparison among different classes of models to highlight the strengths and limitations of empirical modeling for policy projections. The article explains the distinction between a forecasting model and a policy model and then discusses in detail the two distinct aspects of policy making: baseline forecast and identification of monetary policy. The final discussion illustrates the complex assemblage of these two aspects as an integrated process of evaluating monetary policy effects under alternative scenarios.

Difficulties of Modeling Monetary Policy in Reality

To evaluate the effects of monetary policy under alternative scenarios, one must model the behavior of monetary policy. The more explicit and rigorous the model is, the better the model can be understood and improved, and hence result in more effective policy making over time. For the purpose of regular policy making, the model must be able to capture the complex interactions among the key macroeconomic variables that concern policymakers. Because of their complexity, simple rules or expressions, although useful at times, generally do not characterize these interactions adequately.

In the continuing, day-to-day implementation of U.S. monetary policy, for example, the Federal Reserve constantly evaluates and reevaluates current economic conditions and updates the forecasts of key macroeconomic variables such as inflation and output under alternative policy scenarios. After weighing the alternative outcomes, the Federal Open Market Committee votes on how to direct a main policy instrument, which currently is the federal funds rate. The decision on whether to raise or lower the target for the funds rate or to keep it at the current level depends in large part on the assessment of the dynamic effects of changes in the federal funds rate on various macroeconomic variables such as inflation and the unemployment rate in the next few years.

Such policy making is common across developed countries. At the Bank of France, for example, 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 taken to the money market trading room at the Bank of France to intervene in the interbank market on the basis of the evaluations of monetary 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).

> **Because of limited knowledge about how the actual, complex economy operates, policymakers depend on models for understanding the workings of the economy.**

To what extent a particular monetary policy action will achieve its intended effects on output growth and inflation depends crucially on how the economy develops over time. Many unforeseen developments are outside the central bank's control: an unexpected decline in commodity prices, a surprising improvement in the labor market, an unanticipated strength in output growth, or a sudden fall in the exchange rate, for example. These private shocks, coupled with the central bank's particular policy actions, affect economic performance and often drive the economy along paths different from those forecast. When favorable or unfavorable shocks arrive, policymakers need to "be flexible in revising forecasts and the policy stance in response to new information contradicting their previous predictions" (Kohn 1995, 235) and adopt different policy actions accordingly (Blinder 1997).

Consumers and producers in the private sector also evaluate the dynamic impact of monetary policy regularly in making their own investment decisions. They understand that particular policy actions depend on the changing state of the economy. Thus their investment plans take into account the uncertain factors in actual monetary policy actions. The outcome of such a complex interplay between monetary policy and the private sector is reflected in the data observed in the actual economy. The data themselves, however, do not distinguish the behavior of the private sector from that of the central bank and depend on models to infer what the policy behavior is. Because different models lead to different conclusions, learning the central bank's behavior from the data requires careful effort in approximating the actual economy in a workable framework.

The notion of "workable" is important because there does not and cannot exist a model that perfectly represents the actual economy. The central bank's real-life behavior, as described above, is far more complicated than can be completely captured by any kind of model, empirical or theoretical. All well-specified models at best approximate the actual economy, offering different perspectives on the key interactions among a set of variables and having their relative strengths in some dimensions and weaknesses in others. Thus, the reasonableness of a particular model depends on how usable the model is for certain questions and under certain criteria.

Three Classes of Models

The policy questions addressed in this article concern evaluating the dynamic effects of monetary policy as the central bank faces decisions about raising or lowering the interest rate. This section analyzes three popular classes of models used for this kind of policy analysis.

One class of models searches for a *single policy variable* (such as a monetary aggregate or an interest rate) as an indicator of monetary policy. According to this approach, the policy variable, be it a money stock or an interest rate, is controlled by the central bank but unaffected by other variables. Policy actions must evolve autonomously, independent of the changing state of the economy. This scenario allows tracing the effects of alternative policy choices represented by the movements in the policy variable conveniently and unambiguously through the variable's correlations with other macroeconomic variables.

While such a model offers simplicity, its conditions are scarcely met in actual economies. It would therefore be difficult to have economically coherent interpretations for imposing these conditions in a policy model (Tobin 1970). For example, the federal funds rate target is not set autonomously; rather, it is regularly adjusted to reflect the Federal Reserve's concern about its own objectives of, for instance, price stability and full employment. When fluctuations in economic activity or the repercussions of past policy choices threaten this objective under the current level of the federal funds rate, a new target rate will be chosen. Clearly, there is feedback between the state of the economy and the policy variable. The practical reality of state-dependent policy choices makes it most likely that the conditions underlying the indicator approach violate criteria 4 and 5.

Another class of models seeks a *simple rule* for describing the central bank's behavior. Simple rules provide a convenient or even compelling way for policy analysts to explain complex economic activity to policymakers, but they are unlikely to adequately capture the intricate dynamics taking place in the actual economy. Consequently, the assumptions embedded in these rules are often questionable. The assumption of a NAIRU (nonaccelerating inflation rate of unemployment) relationship is an example. This rule states that whenever the unemployment rate is below some threshold level, inflation will soon rise. If such a threshold level could be unambiguously determined and if such a relationship were stable, the rule would provide an appealing story to policymakers about the future path of inflation. The threshold level of unemployment, however, cannot, in fact, be measured. It is often estimated with large errors (Staiger, Stock, and Watson 1997). The estimation is fragile because this rule ignores the effects of other important factors (such as monetary policy itself) on the path of inflation and employment (Chang 1997; Espinosa and Russell 1997). Consequently, this rule provides neither a forecast of macroeconomic variables other than inflation nor a forecast of inflation under a different policy option, so it does not meet criteria 3 and 5.

Another example of simple rules is the Taylor rule. In its often-used version the Taylor rule states that the federal funds rate changes in response to only two variables: the gap between current actual gross domestic product (GDP) and potential GDP and the four-quarter inflation rate. The attractiveness of this rule is its ability to present a simple story involving only these two variables. Such simplicity, however, has serious weaknesses of its own. Because potential GDP is an abstract concept rather than something that can be measured, the movement in the fed funds rate crucially depends on how potential GDP is estimated. Like determining the threshold of the unemployment rate in the NAIRU rule, the estimation of potential GDP can be very imprecise and controversial. Furthermore, in estimating the Taylor rule it is often assumed that movements in output and inflation are independent of those in the federal funds rate. This assumption itself disables the rule from assessing the dynamic effects on output and inflation of changes in the federal funds rate (criteria 3 and 5).

In some research programs, the Taylor rule is used as one of many relationships in a larger model. In such a model, changes in the Taylor rule are examined and the effects on macroeconomic variables of these changes are analyzed. In essence, the changes arbitrarily alter the way and the degree in which the fed funds rate responds to the GDP gap and inflation. These exercises are often undertaken under the assumption that a change in the Taylor rule does not affect the observed relationships among a set of macroeconomic variables in the actual economy. But this assumption is economically incoherent because, as Lucas (1976) has long argued, the observed relationships among macroeconomic variables will change with different policy rules. Because of the Lucas critique, as this argument is dubbed in the economic literature, these kinds of exercises examining monetary policy effects do not meet criterion 4.

A third class of models comprises *large-scale econo-metric models* designed to capture in detail the structure of the real economy as completely and accurately as possible. Such a model often deals with a large number of industries and sectors of the economy and may involve hundreds of equations and variables. The main objective of most large-scale models is not simply to provide forecasts of multiple key macroeconomic variables. Rather, it is to provide detailed stories about the economy and to assess the impacts of different kinds of shocks at a disaggregate level unavailable in smaller models. Policymakers would like to be informed about the details of the state of the real economy. They may want to know, for instance, what happens to the durable goods sector, what the outlook is for the labor market in the service sector, or what the impact is on the U.S. economy of the Asian financial crisis.

Large-scale models, however, also come with costs. They are often difficult to reproduce and evaluate independently (criterion 1). Because modifying so large a model can be quite costly, judgmental adjustments are called in periodically to address new, unanticipated information (criterion 2). Furthermore, given a short span of historical data observed in the actual economy, it is impossible to have precise estimation of hundreds and thousands of equations and variables in a single framework. Thus, the large-scale model is often broken into separate parts by imposing strong assumptions. Many of these assumptions have been criticized by Sims (1980) as "incredible" because they are imposed not from the viewpoint of having a reasonable approximation of the economy as a whole but from the separate, partial consideration of keeping various parts of the model manageable (criterion 3). These drawbacks are likely to compromise the modeler's original aim of representing the detailed structure of the economy as completely and accurately as possible.

> **For models to be usable for evaluating monetary policy effects, modelers must recognize that fluctuations or shocks in the actual economy are often driven by developments beyond the central bank's control.**

Dynamic Multivariate Modeling

In this and subsequent sections, the discussion turns to another class of models—dynamic multivariate models—and explains their advantages in light of the five criteria set forth in the introduction.[1] The term *dynamic* connotes the idea that economic variables influence one another through variable lags over time. For example, a change in the interest rate today

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1. Dynamic multivariate models are frequently referred to as vector autoregressive (VAR) models in the economic literature. A sample of the work includes Bernanke (1986), Blanchard and Watson (1986), Sims (1986), Bernanke and Blinder (1992), Gali (1992), Gordon and Leeper (1994), Strongin (1995), Pagan and Robertson (1995), Cochrane (1996), Leeper, Sims, and Zha (1996), Cushman and Zha (1997), Bernanke, Gertler, and Watson (1997), Christiano, Eichenbaum, and Evans (forthcoming), Bernanke and Mihov (1998), and Robertson and Tallman (1999a, 1999b).

will affect inflation over the next few years. The term *multivariate* implies a single framework in which multiple economic variables are considered. Thus, a dynamic multivariate model is a single framework that uses multiple equations to incorporate the dynamic relationships among multiple economic variables.

Dynamic multivariate modeling offers an approach to policy analysis that is different from those discussed in the previous section. It is designed to address a small set of recurring questions that constitutes the core of policymakers' concerns. Policymakers need to know, on a regular basis, how the future paths of key macroeconomic variables such as output, inflation, and the unemployment rate will change if the policy instrument—in this case the federal funds rate—follows different paths in the future. The main advantage of dynamic multivariate modeling is to focus on this set of questions by evaluating, as accurately as possible, the quantitative effects of policy actions on key macroeconomic variables under different policy scenarios. To this end, a system of multiple equations in a dynamic multivariate model avoids postulating a simple but unrealistic rule of monetary policy. Such a system approach explicitly recognizes the intertwined, complex relationships between a policy variable like the interest rate and other key macroeconomic variables such as inflation and the unemployment rate (Leeper, Sims, and Zha 1996). At the same time, the dynamic multivariate model typically selects only a small set of key macroeconomic variables to avoid unreasonable assumptions in the model's estimation. In other words, dynamic multivariate modeling is designed to capture the joint, complicated behavior of the central bank and the private sector in one single framework without imposing too many strong assumptions and without sacrificing its connection to modern economic theories (Leeper and Sims 1994; Sims 1996; Diebold 1998; Cooley and Quadrini 1998a, 1998b). In the discussion below, the Leeper-Zha model for the U.S. economy illustrates how a dynamic multivariate model is designed to meet the first four of the five criteria listed in the introduction section.

Baseline Forecast. When a dynamic multivariate model is constructed, a minimum set of restrictions needs to be imposed. These restrictions include the choice of variables, the length of time over which variables are allowed to interact with one another, and some mathematical assumptions that make the model tractable (criterion 1). As a starting point, the model avoids further restrictions such as particular economic views on the exact interactions between monetary policy and the private sector. Because these economic views are not present, such a model is called in technical parlance a reduced-form model. The reduced-form model is designed to allow the data, not the modeler, to determine the complicated dynamic interactions among the economic variables. Thus, the model is designed to fit to the data (criterion 3).

A baseline forecast, sometimes referred to as a reduced-form forecast, is produced from a reduced-form model. Once the model is specified, the baseline forecast is updated upon the arrival of new information without ad hoc adjustments (criterion 2). Often, the forecasting performance is measured by the difference between the baseline forecast and the actual outcome over time. The performance thus measured has sometimes been compared with other forecasts, and evidence has shown that it has been comparable. (Litterman 1986; McNees 1986; Meyer 1998; Zha 1998; Robertson and Tallman 1999a).

The reduced-form Leeper-Zha model is a dynamic, six-variable monthly model consisting of a system of six equations. Besides an index of commodity prices, the variables include the key macroeconomic variables policymakers are most concerned about: the federal funds rate, the M2 stock, the consumer price index (CPI), real (inflation-adjusted) GDP, and the unemployment rate. The six equations, as a system, allow policy variables such as the federal funds rate to interact with other macroeconomic variables such as output and the CPI, both within a month and through variable lags (criterion 3). Because of the complicated dynamics inherent among actual macroeconomic variables, this dynamic and multiple-equation feature of the model is critical for allowing the variables to interact with one another contemporaneously and over time without ad hoc periodic adjustments (criterion 2).

The movements in these macroeconomic variables tend to be very persistent over time. Thus, when modeled in one framework, the past values of the variables often have strong predictive power in forecasting future values. As a result of this feature of persistence, the Leeper-Zha model has consistently produced baseline forecasts of these key macroeconomic variables over the past twenty years that are comparable to other forecasts. The fact that the model is small-scale and explicit makes it transparent enough to be reproduced, evaluated, and improved over time (criterion 1).

Although it is tempting to add more variables to such a small-scale model, the addition would have costs. Either it is increasingly infeasible to obtain precise estimation with the model as it grows larger or one must impose ad hoc strong assumptions or make judgmental adjustments to keep the size of the model manageable. These costs are not trivial as they often lead to conflicting economic stories and even misleading policy analysis.

While it is true that the Federal Reserve has information about hundreds and even thousands of variables beyond the six key macroeconomic variables in the Leeper-Zha model, the issue is not whether the Federal Reserve has the data for a large number of variables.

Instead, the real issue is related to criterion 3. That is, the issue is whether other variables (for example, the number of orders for automobiles, workers' wage compensations, or the consumer confidence index) would significantly help in modeling the interactions among the variables the Federal Reserve is ultimately interested in. No consistent evidence indicates that adding other variables would help the model better fit those core macroeconomic variables.

Identification of Monetary Policy. The foregoing subsection discusses the reduced-form Leeper-Zha model in light of criteria 1–3. The reduced-form model is often used purely as a forecasting tool in the forecasting literature, so the performance of baseline forecasts in comparison with others has been a central focus. There is a tendency, however, to overemphasize forecasting performance as a sole criterion in judging whether the model can be used in evaluating monetary policy actions. Doing so can be seriously misleading.

To understand this argument it is important to note the distinction between a forecasting (reduced-form) model and a policy (structural) model, which has profound implications about the importance of an identification of monetary policy (criterion 4). The reason that a forecasting model is regarded as a reduced form rather than a structural form is that, as argued before, it imposes no economic structure to distinguish the central bank's behavior from the rest of the economy. Thus, the scenario represented by a baseline forecast is often not the one that interests policymakers. The baseline forecast serves as a basis only in the technical sense that the modeler is able to conveniently use it to produce a menu of alternative scenarios in which policymakers may be interested. At a minimum these alternative scenarios require imposing restrictions on the interactions between economic variables that allow extracting the central bank's behavior from the data. These restrictions are called identifying restrictions, and this process of sorting out the central bank's behavior from that of the rest of the economy is, as explained earlier, called identification of monetary policy. A model that is able to identify monetary policy is called a structural model or policy model. Clearly, the structural or policy model imposes more restrictions than the reduced-form model.

Because the observed data are the outcome of the dynamic, complex interplay between monetary policy and the private sector, they themselves do not distinguish the behavior of the Federal Reserve from that of the rest of the economy. Therefore, in addition to the minimum set of restrictions imbedded in the reduced-form model, one must further impose a particular economic view on the model in order to identify monetary policy. Any set of identifying

restrictions used to reflect such a view can be controversial because economists disagree on particular views about how the actual economy works. Such dissension largely stems from the complicated nature of the economy, of which economists have limited understanding and which no single model can encompass. The fact that identifying restrictions can be controversial, however, by no means implies that one should abandon developing a formal (that is, model-based) economic framework. Rather, it means that when particular identifying restrictions are imposed, the economic meanings behind these restrictions must be explained carefully and explicitly in the context of a model.

The phrase "in the context" is the quintessence of credible identification because without an explicit model to serve as a framework it would be impossible to distinguish the Federal Reserve's own behavior from that of the rest of the economy. And if the Federal Reserve's behavior is not explicitly specified, there is no way to evaluate the quantitative effects of different policy actions in a formal, transparent way (criterion 1). In other words, an explicit model provides a context in which the effects of monetary policy can be quantified and evaluated (Shapiro 1994).

> **It is simply impossible to have a super model that encompasses every aspect of the economy. Therefore, a modeler must consciously choose the kinds of questions a model is designed to address.**

Although a particular set of identifying restrictions may not be accepted universally, it should be guided by economic theory and have reasonable economic interpretations (criterion 4). A previous article in this publication by Zha (1997) discusses this issue in detail. Here, the meaning of criterion 4 is illustrated in the context of the Leeper-Zha model.

Identification in the Leeper-Zha model is accomplished by specifying interactions among macroeconomic variables in terms of several sectors. One of the sectors is the money market. In that market, both the demand for and supply of money determine the level of the interest rate. When the demand for money increases, the interest rate is driven up. If the Federal Reserve desires to keep the interest rate from rising, it must supply more reserves, thereby causing an increase in broad money stock (here, M2). Thus, one equation in the model, called the money demand equation (MD), describes the behavior of money demand, and one equation, called the monetary policy

equation (MP), describes how the Federal Reserve supplies money to keep the interest rate at a certain level:

$$M = \alpha_1 R + \alpha_2 P + \alpha_3 y + \alpha_4 X_{MD} + \epsilon_{MD} \quad \text{(MD)}$$

$$R = \beta_1 M + \beta_2 P_{cm} + \beta_3 X_{MP} + \epsilon_{MP} \quad \text{(MP)}. \tag{1}$$

In system (1), M stands for M2; R, for the federal funds rate; P, the CPI; P_{cm}, the index of commodity prices; y, real GDP; X_{MD}, a set of lagged variables in the MD equation; and X_{MP}, a set of lagged variables in the MP equation.[2] Lagged variables are important in helping predict the dynamic fluctuations of the macroeconomic variables in the future. The values of the α parameters in the MD equation and the β parameters in the MP equation, unlike those of the variables, do not come from the data and thus must be estimated. The notation ϵ_{MD} denotes the money demand shock, and ϵ_{MP} the monetary policy shock. The term *shock* is used because it describes behavior that cannot be predicted by the model, a point that will be further discussed in the next section.

The two equations have reasonable economic interpretations by standard economic theory: In the MD equation in system (1), the demand for money depends on income (which is approximated by real GDP), the interest rate, and the price level. The MP equation implies that the Federal Reserve can change the interest rate by influencing the money stock and by quickly responding to changes in the index of commodity prices (which serve as a signal of future inflation). Because of the delay in the release of the data on output and the price level, however, the Federal Reserve cannot respond to changes in these variables instantly (here, within a month). But the Federal Reserve can respond to changes in the lagged variables (X_{MP}), which serve to predict the current and future fluctuations of output and CPI. Because M and R enter both equations in system (1), the money stock (M) and the interest rate (R) are determined by both the MD and MP equations simultaneously.

The successful identification of monetary policy involves estimating all parameters jointly from the data. This joint estimation and inferential conclusions drawn from this estimation present a technical challenge.[3] Nonetheless, the joint feature of the model as shown in system (1) is needed to realistically account for the simultaneous and dynamic interactions among policy variables and other macroeconomic variables. This realistic account is an important aspect of reasonableness in economic interpretations (criterion 4). In the money market, for instance, it is known that the money stock and the interest rate influence each other simultaneously through both demand and supply of money. The results would be misleading if one assumes away this simultaneous interaction without having confirmation by empirical estimates of the parameters α_1 and β_1 in system (1). If, for example, β_1 is assumed to be zero but the empirical estimate of β_1 turns out to be significantly different from zero, the monetary policy equation would be misspecified by the zero β_1 assumption.

A Menu of Policy Projections under Alternative Scenarios

The preceding sections discuss the reduced-form Leeper-Zha model according to criteria 1–3 and the structural Leeper-Zha model according to criterion 4. This section offers an intuitive explanation of how such a structural model can be used to produce a menu of policy projections under alternative policy options. The discussion addresses criterion 5, that is, the model's ability to provide alternative forecasts under different policy scenarios. It is this ability that marks structural dynamic multivariate models as promising and rich tools in evaluating the effects of monetary policy in an economically coherent way (without violating the Lucas critique).

To demonstrate how the structural Leeper-Zha model—the policy model—can be used to provide alternative forecasts under different policy options, the discussion begins with technical notions of the terms *endogenous* and *exogenous*. The part that can be predicted by the model—for example, the terms with the α and β parameters in system (1)—is endogenous to the model; the part that cannot be predicted by the model is exogenous to the model—for example, ϵ_{MP} and ϵ_{MD}—and thus is often approximated by a stochastic (random) process. Because of this random feature, ϵ_{MP} is called a monetary policy shock and ϵ_{MD} a money demand shock. Clearly, the shock ϵ_{MP} makes sense only in the context of a specific model. What can be predicted by one model may not be consistent with what another predicts. What is a random shock to a particular model may not be random or exogenous to other models or from the perspective of particular policymakers.[4]

In the context of the Leeper-Zha model, a menu of policy options and their corresponding effects can be produced by combining the baseline forecast and exogenous shocks. The baseline forecast is a projection under the assumption that there is no shock in the economy (that is, $\epsilon_{MP} = \epsilon_{MD} = 0$). This scenario seldom occurs because there will always be shocks in the future. A projection that deviates from the baseline reflects a scenario in which the effect of monetary policy is different from what the baseline implies. Such a projection therefore combines the baseline with a hypothetical path of exogenous shocks.

Charts 1 and 2 depict the MP and MD equations in system (1) on the R and M plane. These two charts provide examples of two simple scenarios in which alternative policy projections are simulated with the policy model. In both charts the horizontal axis represents the money stock, M, and the vertical one represents the interest rate, R. In Chart 1, the two thick red lines represent the baseline situation in which $\hat{P}_{cm}$, $\hat{P}$, $\hat{y}$, $\hat{R}$, and $\hat{M}$ represent the baseline forecast and X_{MP} and X_{MD} are the data that have been observed. The thick red MP line, as indicated in system (1), depends on $\hat{P}_{cm}$, X_{MP}, and $_{MP}$ (whose value here is zero). Similarly, the thick red MD line depends on $\hat{P}$, $\hat{y}$, X_{MD}, and $_{MD}$ (whose value is also zero). These two red lines intersect at $\hat{R}$ and $\hat{M}$ as an equilibrium outcome. The forecast variables $\hat{P}_{cm}$, $\hat{P}$, $\hat{y}$, and $\hat{M}$ represent the effect of monetary policy consistent with the funds rate, $\hat{R}$. If, for example, policymakers want to explore the effect on the macroeconomic variables of lowering the funds rate to the level of R^*, one can use the model to compute how much an exogenous shift in monetary policy is required to achieve this target. If the computed value of such a shift is $_{MP}^*$ one can calculate a new forecast, denoted as, P_{cm}^*, y^*, R^*, and M^*. Consequently, the two red lines move to the positions of the two thin black lines. Thus, the new forecasts, P_{cm}^* (commodity prices index), P^* (the general price level), y^* (GDP), and M^* (M2), different from the baseline, represent the effect of this new policy choice of keeping the federal funds rate at R^*.

Chart 2 presents a more complicated situation. Suppose that the Federal Reserve has information about a liquidity problem in the banking system. Furthermore, suppose that this information is not captured by the predictable (endogenous) part of the model but can be approximated by the random (exogenous) part in the money demand equation. If the value of this exogenous MD shock is $\tilde{}_{MD}$, the model's forecast will deviate from the baseline. This deviated forecast is denoted by $\tilde{P}_{cm}$, $\tilde{P}$, $\tilde{y}$, $\tilde{R}$, and $\tilde{M}$. The two thick red lines in Chart 2 represent the MP and MD equations in this situation. Policymakers may also be concerned about the inflation rate implied by the price level, $\tilde{P}$, and want to bring the inflation rate down. If $\overline{P}$ represents the price level consistent with the inflation level desired by the policymakers, the model can then be used to calculate the corresponding monetary policy shock, the value of which is denoted by $\overline{}_{MP}$ The new forecast of other macroeconomic variables can
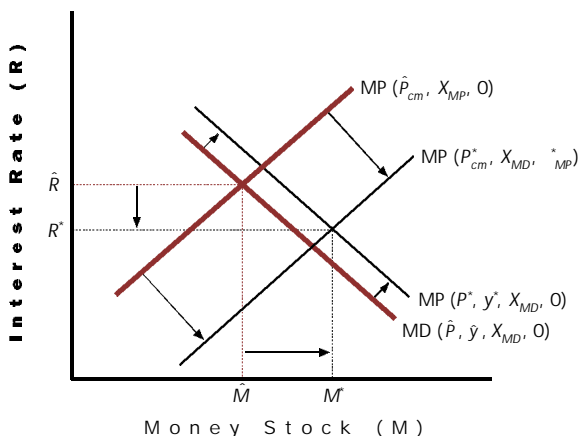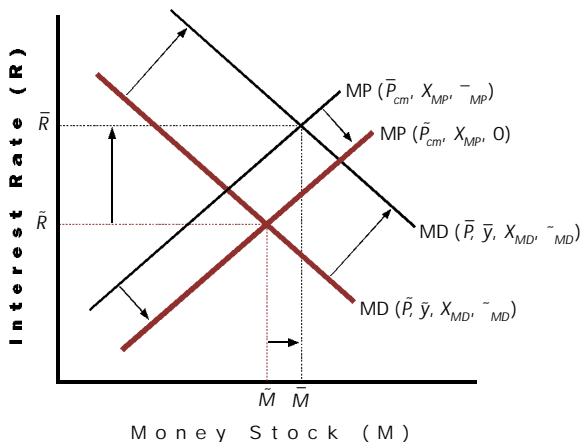

CHART 1
Policy Change to Target the Funds Rate

MP ($\hat{P}_{cm}$, X_{MP}, O)
MP (P_{cm}^*, X_{MD}, $_{MP}^*$)
MP (P^*, y^*, X_{MD}, O)
MD ($\hat{P}$, $\hat{y}$, X_{MD}, O)

Interest Rate (R)

$\hat{R}$
R^*

$\hat{M}$ M^*

Money Stock (M)

CHART 2
Policy Change to Target the Price Level

MP ($\overline{P}_{cm}$, X_{MP}, $\overline{}_{MP}$)
MP ($\tilde{P}_{cm}$, X_{MP}, O)
MD ($\overline{P}$, $\overline{y}$, X_{MD}, $\overline{}_{MD}$)
MD ($\tilde{P}$, $\tilde{y}$, X_{MD}, $\tilde{}_{MD}$)

Interest Rate (R)

$\overline{R}$
$\tilde{R}$

$\tilde{M}$ $\overline{M}$

Money Stock (M)

also be simulated through the model, with the value of this new forecast denoted by $\overline{P}_{cm}$, $\overline{P}$, $\overline{y}$, $\overline{R}$, and $\overline{M}$. Graphically, the two red lines in Chart 2 move to the two thin black lines, the intersection of which gives $\overline{R}$ and $\overline{M}$. Chart 2 shows that the model can be used to advise policymakers about not only the level of the interest rate, ($\overline{R}$), they need to target to achieve the price level, $\overline{P}$, but also the forecast of other macroeconomic variables.

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2. *All variables except for the interest rate and the unemployment rate are logarithmic.*
3. *See Waggoner and Zha (1999) for details.*
4. *This simple point is not only common across all disciplines in economics but also valid in other social sciences. As novelist Tony Hillerman has amusingly but poignantly observed, "From where we stand, the rain seems random. If we could stand somewhere else, we would see the order in it" (quoted in Robert 1994).*

The charts are used for illustration only. The use of the identified dynamic multivariate model for actual policy projections is far more complicated because it involves not only the dynamic paths of macroeconomic variables under a particular policy option but also the uncertainty around these paths into the future. Nonetheless, Charts 1 and 2 illustrate a point that is central to the approach proposed in Leeper and Zha (1999). The point is that exogenous shocks, such as the MD and MP shocks, are relevant only in connection to the baseline forecast. In other words, the dynamic patterns of exogenous shocks and the baseline forecast constitute an integrated process for quantifying different forecasts of key macroeconomic variables if the federal funds rate follows alternative paths. Such a menu of various policy projections is at the heart of the use of dynamic multivariate modeling for advising policymakers.

Model Improvement

The discussion in this section focuses on what has been learned from the dynamic multivariate model and in what directions the current dynamic multivariate modeling can be improved. The dynamic multivariate model offers a tool for decomposing the model into endogenous and exogenous elements. This decomposition is vitally important for simulating policy projections in an economically coherent way (criterion 5), meaning that the values of parameters (such as α's and β's) do not vary with exogenous shifts in monetary policy. This invariance is the essence of the Lucas critique, which cautions the use of an empirical model if the values of parameters in such a model change with policy shifts. Although discussion of the Lucas critique is beyond the scope of this article, it is important to note that the critique is a subtle concept, and the previous use of dynamic multivariate models has been problematic in this regard.[5]

It is also important to point out that the separation of what is endogenous and what is exogenous is a convenient byproduct of the model, which offers a particular way to help modelers examine and understand the economy. Any model, whether it is the dynamic multivariate model discussed above or another kind, is only an imperfect abstraction of the complex real economy. Different economists or modelers may have different specifications of the Federal Reserve's behavior and the behavior of the private sector, and what is exogenous to one modeler may not be to others. The comparison of exogenous components across different models, as some recent literature has attempted (for example, Rudebusch 1998), misses this fundamental point. The key insight gained so far leads to a need to combine, not separate, endogenous and exogenous movements. It is this combination that provides a way for modelers to produce projections of policy effects under alternative

scenarios. Perhaps there are other economically coherent ways of making similar projections. Ultimately it is the accuracy of such projections that matters to policymakers in their policy decisions. While the model must make both economic and mathematical sense, the goal of model improvement should aim at raising the accuracy of policy projections.

Broadly speaking, the current dynamic multivariate approach can be improved in two directions. First, the dynamic multivariate model could be more closely connected to modern economic theories as called for by Ingram and Whiteman (1994), Leeper and Sims (1994), Sims (1996), and Diebold (1998). The dynamic multivariate model would then be able to offer more detailed economic interpretations or stories for policymakers. Currently, however, the conceptual and technical difficulties associated with such a connection in a multiple-equation framework are overwhelming.[6] Finding a particular way of connecting theory to the dynamic multivariate model that improves, not impairs, the forecasting accuracy will be a long and incremental process.

In the other direction, the empirical features in a class of current dynamic multivariate models could be further refined. The current dynamic multivariate approach often maintains the assumption that the structure of the economy is linear and that the Federal Reserve's behavior remains more or less stable across time. In technical terms these features are called linearity and time-invariance. Researchers have realized the need to relax these features by allowing some kind of nonlinearity and time-variation in the dynamic multivariate model (Sims 1993), but the challenge is to determine what kind of nonlinearity and time-variation would improve current dynamic multivariate models. Most current time-variation and nonlinearity literature has focused exclusively on univariate cases rather than the multivariate framework that is crucial for policy analysis. Furthermore, these works maintain the strong assumption that the real economy evolves in sudden, exogenous, and disruptive ways. Empirical evidence has not supported such an assumption (Sims 1993; Zha 1998). In fact, the evidence in the economic literature has shown little advantage, if not much disadvantage, of nonlinear and time-varying multivariate models (Sims 1993; Uhlig 1997).

The issue here is not whether the economy evolves in a nonlinear and time-varying way because clearly it does. The real issue is how to depict these characteristics in ways that would best characterize the economy and whether researchers have the tools to handle nonlinear, time-varying multivariate models. If introduced inappropriately, nonlinearity and time-variation in a model could deliver a worse forecast than linear multivariate models.

A recent study by Harding and Pagan (1998) offers an illuminating example. Harding and Pagan use different kinds of nonlinear and time-varying models in the existing literature to characterize the business cycles of the real economy. What they find is that the simple linear model (the unit-root model in technical terms) dominates all other seemingly sophisticated models in describing the pattern of business cycles in both the United States and other developed countries. The point, already made, is not that nonlinear and time-varying models are inferior but that introducing a kind of nonlinearity and time variation that can better approximate the real economy is not nearly so straightforward as it may seem.

Clearly, developing model improvements to ensure more accurate results is challenging. Since the economy changes gradually in degrees that are unknown to researchers, determining how to connect the dynamic multivariate model to economic theory or to introduce some kind of nonlinearity and time variation in the dynamic multivariate model requires all the more deliberate and careful effort. Meanwhile, researchers and policy analysts have learned that the linear and time-invariant dynamic multivariate framework provides a reasonable approximation to the economy in comparison with other existing types of models. The assumption of linearity and time invariance allows researchers to overcome some technical hurdles otherwise associated with dynamic multivariate models and to gain a deeper understanding of both the strengths and limitations of these kinds of models (Sims and Zha 1998; Waggoner and Zha 1998, 1999). Such understanding is a necessary step in exploring the feasibility and capacity for improving the dynamic multivariate model or perhaps even replacing it with a viable alternative.

Conclusion

Because of limited knowledge about how the actual, complex economy operates, policymakers depend on models for understanding the workings of the economy. For models to be usable for evaluating monetary policy effects, modelers must recognize that fluctuations or shocks in the actual economy are often driven by developments beyond the central bank's control. There are no simple rules, and neither is there a single model that represents the exact interactions between monetary policy and the rest of the economy (Duguay and Poloz 1994). How good a model is depends on particular criteria. Therefore, modelers must specify a set of criteria in constructing a particular model.

This article assesses the usability of a dynamic multivariate model for policy evaluation on the basis of five specific criteria. In summary, (1) the model's small scale enables the modeler to understand the specific dimensions along which the model can be improved; (2) the single framework enables the model to update the forecast without ad hoc periodic judgmental adjustments; (3) the dynamic, multiple-equation nature of the model enables it to provide a reliable forecast of multiple key macroeconomic variables; (4) the identifying restrictions imposed on the model enable the modeler to infer the central bank's behavior from the data; and (5) a menu of policy projections under alternative scenarios produced from the model provides useful guidance for preemptive monetary policy.

There are no simple rules, and neither is there a single model that represents the exact interactions between monetary policy and the rest of the economy.

With these five criteria in mind, this article uses the example of the Leeper-Zha model to address a set of recurring practical questions regularly asked by policymakers. These questions concern projecting multiple key macroeconomic variables under alternative policy scenarios at the time when the policy decision has to be made. The discussion focuses on the two conceptual issues that are central to answering these questions: the baseline forecast in reduced-form models and identification in structural-form models. The article explains the distinction between forecasting (reduced-form) and policy (structural) models. The use of a baseline forecast serves only as a convenient technical tool for computing a menu of policy projections under alternative scenarios. The important message is that an assemblage, not a separation, of baseline forecast and identified policy shifts provides economically coherent ways of evaluating the effects of monetary policy.

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5. See Leeper and Zha (1999) for detailed discussion.
6. See, for example, Leeper and Sims (1994) and Waggoner and Zha (1998, 1999).

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