Central Bank Forecasting: An International Comparison

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FORECASTS, WHETHER EXPLICIT OR IMPLICIT, ARE AT THE HEART OF POLICY MAKING. IN CONSIDERING FORECASTING FOR MONETARY POLICY, THIS ARTICLE CONTRASTS THE FORECASTING PROCESS AT THREE CENTRAL BANKS—THE RESERVE BANK OF NEW ZEALAND, THE BANK OF ENGLAND, AND THE U.S. FEDERAL RESERVE. THESE BANKS' PROCESSES ARE CHOSEN FOR discussion not only because they are fairly well documented but also because it could be argued that their forecast procedures are representative of those of other central banks.

An obvious initial question that arises when considering central bank forecasting is that of whose forecasts are being discussed. This article concentrates mostly upon the forecasting process of policy advisers rather than that of policymakers, even if there may be considerable overlap. In the United States staff forecasts are presented to policymakers as a basis for policy discussions, but these forecasts need not represent the forecasts of an individual policymaker (see Reifschneider, Stockton, and Wilcox 1997). The influence of these staff forecasts on policy decisions is largely unknown. It is clearly not zero, but a reading of some of the Federal Open Market Committee (FOMC) discussions shows that individual U.S. policymakers' responses to the projections of policy advisers can vary a great deal (see Edison and Marquez 1998).[1] In other cases, such as at the Bank of England, there is an official published forecast that is the outcome of an explicitly defined interaction between the bank staff and the policy committee (George 1997). These forecasts therefore come much closer to representing those of the policymakers. A similar, but less formal, interaction takes place at the Reserve Bank of New Zealand, which publishes forecasts on a regular basis under the name of the governor, although the projections themselves are based on staff models (Drew and Frith 1998).

The next section of the article sets out a number of common elements in the forecasting processes of central banks. The discussion then summarizes the forecasting procedures at the Reserve Bank of New Zealand, the Bank of England, and the Board of Governors of the U.S. Federal Reserve System, with particular attention given to the differences and similarities among the core models used by staff at

these institutions. The conclusion suggests that there is considerable similarity across central banks in the basic mechanics in producing forecasts. However, there are differences in the emphasis given to model-based forecasts relative to judgmental forecasts and those based on expert opinion. Banks with mandated inflation objectives have tended to favor model-based approaches as part of a strategy of ensuring that policy decisions are consistent with their inflation objectives and are as transparent to the public as possible.

Some Forecasting Issues

What Needs to Be Forecast and for How Long? For monetary policy decisions, forecasts of inflation and aggregate output growth are the obvious candidates, but policymakers may also want to examine forecasts of variables such as investment, consumer spending, and wages as well as projections for the global outlook. Even so, this list is rarely exhaustive, simply because the construction of a forecast for, say, inflation may require a forecast of other variables such as productivity. These intermediate forecasts may or may not be presented to the policymakers, but they are often implicitly provided when discussing the environment surrounding a forecast. A second reason why a relatively large number of variables may need to be forecast is that a policy adviser needs to provide an explanation of the forecasts. For example, a forecast of aggregate demand may need to be separated into consumption and investment components since the current economic environment may suggest that these are likely to evolve in different directions. As Dawes (1999) observes, it is easier to be convincing about a forecast's validity if one can provide a plausible economic interpretation, and some degree of disaggregation may aid this process. Policymakers would need to weigh the plausibility of the aggregate forecasts against their own beliefs about the constituent parts. Disaggregation creates problems, however; some components are inherently more difficult to predict compared with either the aggregate or other components. One example is the relative ease in forecasting the output of the manufacturing sector, for which data are relatively accessible, compared with forecasting the quantitatively more important service sector, for which reliable data are sparse. Also, the degree of disaggregation cannot be too extreme as it can easily become hard to present a consistent story about the whole picture.

The length of the forecast horizon will depend in large part on how long it is believed to take for changes in policy instruments to affect the economy. Generally, households and firms seem to respond with sufficient inertia to require forecasts with a one- to three-year horizon.

The Use of Models. Perhaps the main factor in favor of a central bank using models relates to the issue of what is called transparency. Even if a model and its forecasts are only one element in the thinking behind a policy action, examining its structure can be very useful in educating and informing markets about the reasoning behind changes in policy instruments. In order to focus on key issues and to avoid being distracted by excessive detail, most central banks appear to have adopted relatively small-scale econometric models as the main vehicles for their medium-term forecasting exercises.[2]

There also appears to be a growing tendency in central banks to use information from more than one type of model. For example, although a detailed model may give a relatively precise short-term forecast of inflation, a simpler and more stylized model may be of greater use for understanding the longer-term relation between the instruments of policy and targets such as output growth and inflation. In part this characteristic reflects the fact that models are used in the policy process for other purposes, such as estimating the likely effects of alternative policy prescriptions or changes in the way inflation expectations are formed. These types of simulations may be difficult to implement in the primary forecasting model. Even if it is feasible, there is often a desire to provide consistency checks on the simulations using smaller theoretically based models. Moreover, it is doubtful that policymakers place great emphasis upon the point forecasts presented to them, frequently seeing the forecasting process instead more as an aid to bolstering their understanding of the available options.

There are, of course, many private forecasting agencies that produce forecasts, and these forecasts are relatively easily accessible to central banks. All this information might be collated and used; one motivation for doing so would be that one would thereby acquire information from a wide variety of "models," something that policymakers might find attractive. The main disadvantage of relying strictly on pooled information is the lack of a consistent story that can be associated with the resulting forecasts. This lack of a comprehensive picture is an obvious impediment to use of this kind of information by policymakers, but it is also of limited value for policy advisers, as the latter generally need to address policy meetings and so must have formed some view on the economic rationale for a particular forecast outcome.

What then are the types of models central banks use? The Bank of England (1999) details five types

of models that contribute to decisions made by its Monetary Policy Committee, and their categories are useful for commenting briefly on the nature of models used in forecasting in a monetary policy environment.

The "Core" Model. Most policy-setting institutions have a "core" model that summarizes the main relationships within the macroeconomy and is the reference point for forecasting and policy evaluation in the medium term. These models usually contain about 30–50 stochastic equations and determine another 100–200 variables through identities. The modeling philosophy often involves selecting a set of long-run relations such as a constant labor share and debt-to-output ratio, a production function, and a constant long-run real exchange rate. A variety of mechanisms is then invoked to relate the short run and the long run, with departures from the long-run equilibrium values being an important factor in the adjustment process. Of course, this philosophy is now a very standard one in macroeconomic modeling, finding its most precise expression in error correction models.[3] Even though there is a shared vision in these models, there are also significant differences, particularly in regard to the relative roles played by expectations in determining nonfinancial variables, such as the rate of inflation or levels of expenditure.

Core models often do not generate the most accurate forecasts, particularly at a fairly short-term horizon. Nonetheless, when the forecast horizon lengthens and one wishes to look at the sensitivity of outcomes to a policy change, it is hard to find a better alternative. The importance of a core model depends largely on the relative mix of scenario analysis and forecasts in the making of policy decisions. Well-designed core models can have some specific features that may be of assistance in formulating policy. One of these is a steady-state solution that can be consulted to view the long-run consequences of a policy action. Another, once values for variables not determined within the model are incorporated, is the generation of medium-term equilibrium paths, that is, the core model's prediction of where the economy is heading in the medium term.

Small, Forward-Looking Models. These models embody what has sometimes been referred to as the central bank model (see McCallum 1999 and Clarida, Gali, and Gertler 1999). They contain a so-called IS curve that relates growth in gross domestic product (GDP) to factors such as interest rates, expected inflation, and past and expected output growth. They also contain a Phillips curve that connects inflation to past and expected future inflation as well as the deviation of output from "capacity" levels. The small, forward-looking models also usually contain some mechanism for setting policy. If money supply is the instrument, then a money demand function needs to be appended to the system, but in most cases the system is closed with a simple interest rate rule. These models differ from the core models in terms of the degree of aggregation. However, they also often tend to place greater emphasis upon forward-looking behavior in the IS curve and the wage-price sector than do the larger-scale models. It is probably true that these models are used more for simulating policy actions than for forecasting per se, but the distinction is a fine one. The Batini-Haldane model discussed in Bank of England (1999) is a good example of an open-economy version of this framework that augments the fundamental elements above with an uncovered interest-parity condition. The Reserve Bank of New Zealand has developed a similar model

Some institutions favor a forecasting approach that is structured explicitly within a model framework. Others place much greater emphasis upon the judgments of sector experts and the experience of policy advisers.

1. It should be noted that Federal Reserve disclosure policies permit public examination of official forecast documents only with a five-year delay. Hence, some of the discussion in the article may not accurately describe current practice by the staff of the Board of Governors. The Bank of England, the Reserve Bank of New Zealand, and other central banks release current forecast documents on a quarterly basis.
2. The role of judgment in forecasting is one important aspect of the forecasting process that will not be discussed systematically in what follows basically because it is hard to get specific information on how it is used. One thing that is clear, however, is that monetary policy institutions rarely, if ever, rely solely on mechanical model-based forecasts. If the science of forecasting is the model, then the art of forecasting is the judgment that is applied by the individuals involved.
3. Error correction equations relate current growth rates to past deviations from equilibrium and lagged growth rates. However, some models describe the out-of-equilibrium behavior of nonfinancial variables either in terms of so-called polynomial adjustment cost (Brayton and others 1997) or target-seeking behavior (Coletti and others 1996). The resulting equations differ from standard error correction equations by also including discounted expected future equilibrium values. This forward-looking aspect is a key feature of the core models of all the central banks discussed in this article.

(Hargreaves 1999). Because of the relatively small size of this type of model, it is relatively easy to experiment with alternative assumptions and altered parameter settings. Hence, they can provide a useful cross-check on the policy simulations from the core model. However, the high degree of aggregation and the tendency to have a simplified dynamic structure means that they may not be very useful for either short-term forecasting or for explaining sources of business cycle variation.

Vector Autoregressions. Vector autoregression (VAR) models are used primarily to explore specific questions such as the role of monetary aggregates in predicting inflation and output growth.[4] As such, VAR models are rarely used as the core model. One difficulty in using them for policy analysis is that they treat policy as partly unexpected (exogenous) events and partly as determined by the history of the variables appearing in a VAR. It is true that an exogenous policy shock may be identified through a VAR with some loose economic reasoning, but such shocks are rarely easy to relate to actual policy events (see Rudebusch 1998). Moreover, in practice VARs ascribe most of the variation in policy instruments to systematic behavior. A user of VAR forecasts therefore has to accept that the policy instrument will vary continuously over the forecast horizon, something that is not easy to explain to policymakers who are considering whether to make a change in a policy instrument that they feel will be sustained over the forecast horizon.[5] Such reservations mean that VARs tend to be used simply as forecasting devices and not for policy analysis. In the former role the emphasis can be placed upon their statistical characteristics, and this characteristic perhaps accounts for why the most popular versions have been Bayesian VARs. The latter involve approximate prior restrictions upon the coefficients that might be regarded as plausible given the nature of many economic times series (see, for example, Robertson and Tallman 1999). Even in that role they have the disadvantage that it is hard to isolate the story that underlies any predictions made with them (see Meyer's 1999 comment in this vein). Fundamentally, the case for a VAR in prediction relies on the fact that prediction can be based on recognition of regularities in data without requiring explanation of these regularities.

Most central banks appear to have adopted relatively small-scale econometric models as the main vehicles for their medium-term forecasting exercises.

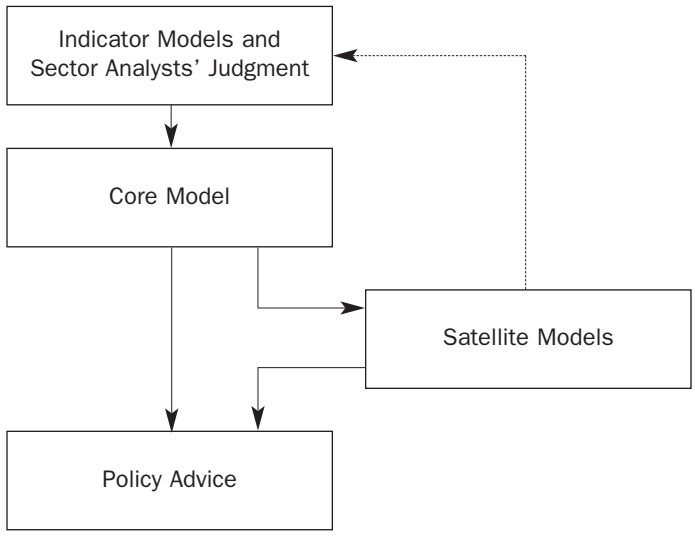
Single-Equation Regression Models. Examples of single-equation regression models are Phillips curve models and relations summarizing the connection between the exchange rate and the terms of trade (or commodity prices) in open economies. The main advantages of such models are their simplicity and that they can be readily used to calculate forecasts conditional on a range of alternative paths for the explanatory variables. In some cases the conditional forecasts might be used as cross-checks on the forecasts from the core model, and sometimes the purpose is to give policymakers some feel for longer-term relationships in the economy.

Dynamic Optimizing Models. Often it is necessary to form a view about the likely economic consequences of a particular structural change or an atypical shock. One general problem with using regression-based models for this task is that their coefficients are functions of underlying preferences and technology as well as government policy, and it is usually difficult to predict the effect that a change in these parameters would have for the estimated coefficients. Largely because of their stronger structural basis, dynamic optimizing models tend to be the mainstay of the academic literature. They rarely produce forecasts directly but can be an ingredient in a forecast and are sometimes important in producing an understanding of forecasts. Models in this class range from dynamic stochastic general equilibrium models and asset pricing models to more deterministic versions such as McKibbin and Wilcoxen's (1995) G3 model.

The Reserve Bank of New Zealand

Monetary policy at the Reserve Bank of New Zealand is conducted in the context of an explicit inflation target (currently 0–3 percent in a consumer price index that excludes interest payments) and is implemented via the Bank's influence on overnight interbank cash rates. There are eight interest rate reviews each year. The governor of the Bank makes policy decisions after advice from an internal monetary policy committee. The forecasts published in the quarterly *Monetary Policy Statement* are actually issued under the governor's name. These institutional arrangements are similar to those of the Bank of Canada. Indeed, the forecasting and policy system implemented at the Reserve Bank of New Zealand was inspired by the Bank of Canada's so-called quarterly projection system and was built under contract by some of the Canadian system's developers.

CHART 1
Basic Structure of the Reserve Bank of New Zealand's Forecasting and Policy System



Source: Breece and Cassino (1998, figure 1)

Forecasts for a wide range of variables in the New Zealand economy, not just output and inflation, are published each quarter. In particular a forecast is given for the ninety-day bill rate. By doing so, the central bank is effectively also providing a statement about the anticipated future course of policy. It seems that the Reserve Bank of New Zealand is unique among central banks in providing such a statement on a regular basis.

As described in Drew and Frith (1998) and Drew and Hunt (1998b), the forecasting round begins with previous baseline and updated forecasts of exogenous variables taken from a number of outside sources. Indicator models are then used to produce forecasts over the monitoring quarters, and these become the starting points for producing forecasts from the core model for the longer horizons. Modifications are then made through intercept adjustments or "add" factors in each of the equations of the model until a central scenario emerges, which then forms the basis of the published forecasts.

The Core and Related Models. In terms of dividing the forecasting process into four elements, the forecasting and policy system explicitly deals with three of them: (1) indicator models to handle short-run predictions (up to two quarters); (2) a core model used to produce medium-term (one- to two-year) forecasts and to perform policy analysis; and (3) satellite models that disaggregate the forecasts from the core model. The basic structure of the forecasting and policy system can be summarized in the schematic in Chart 1.[6]

The indicator models used within the bank are not publicly documented but are designed to capture the short-term time series characteristics of detailed macroeconomic data and to utilize the sector analyst's judgment. For example, data for tons of cement produced are found to have a close relationship to data for commercial construction (Drew and Frith 1998, 318).

The core model contains the key features that were present in the Bank of Canada Canadian Policy Analysis Model (Black and Rose 1997); that is, it contains a well-defined steady state, explicit stock-flow accounting and budget constraints, endogenous monetary policy with an inflation target as the nominal anchor, and the separation of dynamic adjustments in nonfinancial sectors into "expectational"

4. VAR models used for forecasting in a policy environment are described in Zha (1998). Basically, a VAR model attempts to describe the mathematical expectation of future values for a set of variables as a linear function of current and recent past values of these variables. The adequacy of the description is usually measured in terms of forecast accuracy.
5. Of course, nothing precludes one from doing forecasts by constructing shocks that keep the monetary policy instrument on some given path (Leeper and Zha 1999). However, in order to be consistent with the notion of rational expectations, the required shock sequence would have to be not too persistent and not too large.
6. It seems reasonable to suppose that a similar schematic summarizes the forecasting system at the Bank of Canada.

and "intrinsic" components. Monetary policy is accounted for with a policy reaction function based on forward-looking inflation control targets with a six- to seven-quarter horizon. Numerical values of parameters in the model are set to produce "reasonable" responses rather than being estimated directly from time series data. Because the short-term forecasts are not generated directly from the core model, the model's short-term fit to historical data is not used as a criterion for adequacy.

Most of the nonfinancial sector of the forecasting and policy system core model is specified using a framework that describes out-of-equilibrium behavior in terms of adjustment costs. For example, growth in consumption by forward-looking consumers converges to its equilibrium value subject to an adjustment structure as well as to the influence of certain special disequilibrium effects. The specification of the price adjustment mechanism in the forecasting and policy system model departs from this approach, however, and instead resembles more the type of Phillips curve equation common to the small forward-looking models described earlier. In particular, price inflation for domestically produced and consumed output is driven primarily by current and past deviations between the demand for goods and services and the productive capacity of the economy (the so-called output gap).[7] Inflation expectations also play an important role, with expectations assumed to have both a backward-looking and a forward-looking, model-consistent component and with most weight on recent inflation and near-term expected inflation. Changes in the costs of production inputs also influence inflation even if there is no output gap. These costs include wage growth and changes in indirect taxes. The direct effects from exchange rates and changes in the foreign dollar price of imported consumption goods are added to domestic prices to derive consumer price inflation.

Monetary policy at the Reserve Bank of New Zealand is conducted in the context of an explicit inflation target and is implemented via the Bank's influence on overnight interbank cash rates.

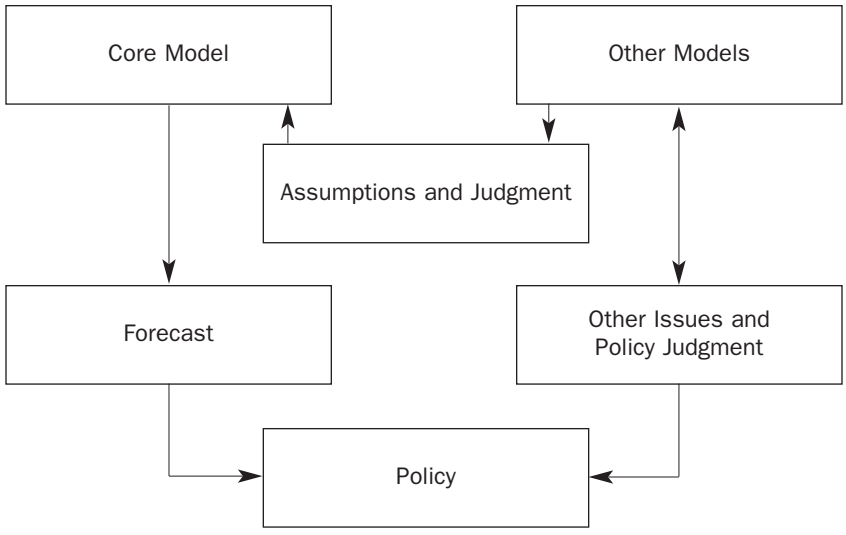
The forecasting and policy system core model is simulated to produce paths for the main macroeconomic variables, including policy variables, that are consistent with the Bank's inflation targets. Three satellite models are then used to translate this projection into implications for more disaggregated variables. The method used for disaggregation is to first prescribe an equilibrium share on the basis of some idea about where particular components are headed. The dynamics around the equilibrium path for variables in the satellite models are then derived from estimated "autoregressive" functions. The adjustment rate is not constant but is modified according to variables such as relative prices and disequilibrium in stocks and flows. In practice the equilibrium paths are derived using a detrending procedure that converges to a fixed steady-state share (Breece and Cassino 1998). The main advantages of this process are that it allows the dynamics of the core model to be kept relatively simple and the satellite models are quite transparent and amenable to modification by sector specialists. In addition to its role in providing a framework for the preparation of economic forecasts, the forecasting and policy system core model has been used as a policy analysis tool. The basic technique of analysis is stochastic simulation (see Drew and Hunt 1998a and Ha 2000).

Auxiliary Models. A smaller forward-looking, demand-side model has been developed by Hargreaves (1999) and denoted as the SDS-FPS model. Designed to produce simulations even more cheaply than the larger forecasting and policy system core model, it is nonetheless calibrated to replicate the dynamic properties of the core model for key aggregates. The heart of the SDS-FPS model is an IS curve, a Phillips curve, an exchange rate equation, and a monetary policy reaction function. It also contains additional equations to determine the relative prices of consumption goods, inflation and exchange rate expectations, interest rates, and the prices of exports and imports. A VAR model was constructed in Drew and Hunt (1998a) that is mainly used to produce shocks that could be fed into the forecasting and policy system and SDS-FPS models for stochastic simulation purposes.

The Bank of England

In the United Kingdom monetary policy is set by the *Monetary Policy Committee*, which is composed of three Bank of England representatives and six non-Bank members. This committee meets monthly. It has a stated inflation target of 2.5 percent in a retail price index (with a reporting range of plus or minus 1 percent). Forecasts of inflation and output have been presented quarterly in the Bank's *Inflation Report* since February 1993. These forecasts are meant to summarize the views of the Monetary Policy Committee members and, as such, are intended to explain any policy actions. The current forecasting process at the Bank of England and

CHART 2
The Bank of England's Forecasting Process



Source: Vickers (1999)

the resulting inflation and output "fan charts" represent an explicit attempt to map the policymaker's uncertainty about alternative economic assumptions onto a distribution of future outcomes via a combination of models and judgment. Chart 2, taken from Vickers (1999), provides a schematic summary of the forecasting process and how it relates to policy decisions.

As described in Britton, Fischer, and Whitley (1998) and in Vickers (1999), a series of meetings takes place between the Monetary Policy Committee and the Bank of England's forecasting staff, beginning about one month before the *Inflation Report* is published. At the first meeting, current issues, key assumptions, and an initial assessment of the relative likelihood of various future paths for the economic variables are discussed. Following these discussions the forecasting staff prepares central (most likely) forecast paths together with forecast distributions constructed to reflect as accurately as possible the Monetary Policy Committee's assessment of relative risks (skewness) and the overall uncertainty (variability). These forecast distributions might be revised following subsequent meetings between the committee and Bank staff. If the Monetary Policy Committee judges that the distribution is inconsistent with its assessment of the issues, then the staff will be asked to make changes. For example, the type of assumptions, their probability, or perhaps the core model itself might be changed. Notably, two sets of forecasts are published in the *Inflation Report*. The first is based on the assumption of unchanged U.K. short-term interest rates during the forecast period while the second allows interest rates to follow the Monetary Policy Committee's assessment of market expectations.

The Core Model. The Bank of England maintains a suite of models and has made descriptions of the various models publicly available (Bank of England 1999). However, exactly what relative weights are ultimately given to these models in the committee's published forecast is unknown. Speeches of Monetary Policy Committee members have not shed a great deal of light upon this question. The core model, termed MM (Bank of England 1999), involves about 20 behavioral relations and 130 variables in total. In some respects the MM model can be categorized as having been constructed from a "bottom-up" (equation-by-equation) perspective rather than the "top-down" philosophy that is a feature of the Reserve Bank of New Zealand core model. Also, unlike the New Zealand model, the parameters of the MM are estimated econometrically from time series data.

The underlying structure of the MM involves the specification of (1) a long-run equilibrium in real variables that is independent of the price level and exhibits no long-run inflation trade-off; (2) a

7. The inflation dynamics also depend on an asymmetric output gap term from which the positive effect of excess demand on inflation is stronger than the negative effect of the equivalent degree of excess supply.

nominal variable equilibrium determined via an inflation target and a feedback rule for short-term nominal interest rates; and (3) a sluggish adjustment to shocks due to both real and nominal rigidities. The explicitly forward-looking expectation aspects of the MM are limited to the foreign exchange market, and the dynamics of nonfinancial sectors are generally determined by conventional error correction mechanisms. Thus, for example, a forward-looking Phillips curve cannot be derived analytically from the wage-price system within MM. In equilibrium, retail prices are set as a markup over marginal costs, with marginal costs a weighted average of unit labor costs and import prices. Retail price inflation adjusts slowly, and it responds to past deviations from equilibrium as well as to changes in wages, import prices, and the level of capacity utilization. As part of preparations for the forecast in which alternative risks are assessed, the MM is used extensively to estimate the effects of various exogenous shocks such as a shift in the inflation target or a temporary change in short-term interest rates.

The current forecasting process at the Bank of England attempts to map the policymaker's uncertainty about alternative economic assumptions onto a distribution of future outcomes via a combination of models and judgment.

Auxiliary Models. The Bank also maintains some small, forward-looking models, of which the leading example is that based on Batini and Haldane (1999). This model is a less-detailed but more theoretically consistent version of MM, and its estimated parameters are chosen to satisfy numerous theoretically motivated constraints. The smaller size makes it more tractable, and the results are often easier to interpret in economic terms. Also, because there are fewer equations and parameters it is easier to experiment with alternative behavioral assumptions, such as the degree of forward-looking behavior in agents' decision making. Against these advantages is that the higher level of aggregation means that the smaller model is not necessarily as accurate or reliable a forecasting tool as the larger-scale version, particularly at short horizons.

Bank of England staff have also used various single-equation Phillips curve models to investigate the relationship between inflation and summary measures of disequilibrium in the real economy and to simulate the implications for inflation of alternative unemployment rate paths. Along with VAR models, these are used as a cross-check on the inflation forecasts produced by the core model.

The U.S. Federal Reserve

Monetary policy in the United States is set by the Federal Open Market Committee (FOMC) and consists of twelve voting members: seven members of the Board of Governors of the Federal Reserve System and the presidents of five of the twelve Reserve Banks ("regional Feds").[8] The staff of the Board of Governors prepares forecasts of U.S. and international economic activity prior to each of the eight FOMC meetings held each year. Independently, the staff of each of the regional Feds may also produce forecasts as part of briefing their Bank's president prior to an FOMC meeting. The various Board and regional Fed forecasts are not made publicly available until several years after an FOMC meeting. However, a summary of the outlook of the policymakers is contained in the forecasts of GDP, inflation, and unemployment documented in the Humphrey-Hawkins testimony on monetary policy submitted to Congress twice each year. The focus here is on the forecasting system implemented at the Board of Governors.

Information available to the FOMC policymakers comes from a number of sources. First, each Federal Reserve Bank gathers anecdotal information on current economic conditions in its district through reports from directors of the bank and its branches and interviews with key business contacts, economists, market experts, and other sources. The so-called *Beige Book* summarizes this information. In addition the Board receives information directly from various advisory councils that can provide an assessment of recent economic developments. Second, staff at the Board of Governors produce several documents for FOMC meetings. One is titled "Current Economic and Financial Conditions" and is commonly referred to as the *Greenbook* because of its green cover. The *Greenbook* lays out the staff's assessment of recent developments in the domestic macroeconomy together with an analysis of financial and international developments. The *Greenbook* also presents quarterly point forecasts for key aggregates in the domestic economy such as the broad components of GDP, unemployment, and prices and wages. The forecast horizon in the *Greenbook* is as much as two years ahead although it is sometimes as short as six quarters. Another document, the *Bluebook*, contains model simulations to examine alternative strategies for monetary policy over a longer period, often up to five years. These simulations are presented formally at least twice each year.

Published accounts of the forecasting system suggest that, despite its role in the overall policy-making process, a core macroeconometric model is not the tool used for producing the *Greenbook* forecasts (Reifschneider, Stockton, and Wilcox 1997). In fact, the forecasts are primarily judgmental in nature, relying heavily on the expertise of sector specialists and senior advisers. The process of generating a *Greenbook* forecast begins with a forecast coordinator who provides the conditioning assumptions and initial forecasts for several key aggregates such as inflation and output.[9] Staff experts on various sectors of the economy then quantify how their sector-specific forecasts are affected by the aggregate baseline forecast as well as data that has become available since the last FOMC meeting. Each sector specialist would potentially use a range of econometric models relevant to their sector for guidance in preparing their forecasts. The sector forecasts are then blended by the coordinator into revised aggregate forecasts, which are returned to the sector specialists who may again adjust their sector forecasts in view of the new aggregate baseline. After some iteration, the "consensus" forecast is reported in the *Greenbook*.

High-frequency time series data (monthly, weekly) are used to tune the short-range forecasts by providing better estimates of initial conditions. For example, a newly available monthly labor market report or retail sales report might affect the assessment of current-quarter GDP growth. Several statistical models are used to filter the high-frequency data. Anecdotal evidence also plays a potentially important role in identifying trends that may not yet have shown up in official statistics.

The Core Model. The Board maintains a core domestic model, known as the FRB/US model. This model contains around forty behavioral equations (see Brayton and Tinsley 1996 and Brayton and others 1997 for overviews). There is no money supply and demand relationship with short-term interest rates determined by policy rules that can be toggled on or off. The FRB/US model is the successor to the larger so-called MPS model that was used up until the early 1990s and is distinguished from its predecessor mainly by its explicit separation of the macrodynamics of the nonfinancial sector into adjustment costs and expectations-formation components. In particular, most nonfinancial sector variables are assumed to move gradually to eliminate past disequilibria (deviations of actual from desired levels) and also respond to the path that the equilibrium is expected to follow in the future. This forward-looking "target-seeking" feature is also common to the nonfinancial sectors of the models used at the Bank of Canada and the Reserve Bank of New Zealand, except for the wage/price block as described below. The financial sector of FRB/US is based on various instantaneous arbitrage equilibria. For example, long-term interest rates are determined via the expected path of short rates plus a time-varying term premium while the real value of the stock market is determined via the discounted expected future flow of dividend payments. Like the Bank of England's core model, the parameters of the FRB/US model are estimated econometrically from time series data.

While the Federal Reserve Board of Governors primarily uses an expert-based system for producing baseline forecasts, they rely on a detailed core macroeconometric model for policy analysis.

In the FRB/US model the price-wage system contains an equilibrium condition in which firms set the profit-maximizing price of their output as a markup over marginal costs, with marginal costs a weighted average of unit labor and energy costs. The equilibrium price level of domestic production is also assumed to vary inversely with the degree of slack in the economy as measured by the gap between the actual unemployment rate and the rate of unemployment that is believed to be consistent with nonaccelerating inflation. The dynamic process for inflation depends on the distance between the actual and targeted price level, the intrinsic rate at which inflation adjusts over time, and expectations. The specification gives a little more weight to past price inflation than to unit costs expected to prevail in the future. An increase in the current or expected future unemployment gap has a negative impact on inflation rates because it foreshadows increasing labor market tightness. Finally, consumption prices depend on direct effects due to changes in relative nonoil import prices and energy prices. Thus, apart from the special disequilibrium factors, the price (and

8. The President of the Federal Reserve Bank of New York is a permanent member of the FOMC; the other presidential members rotate on a prespecified annual basis.
9. The key conditioning assumptions, such as the path for the federal funds rate and fiscal policy as well as stock and energy prices, are discussed in the text of the *Greenbook* although generally not in detail.

wage) block of the FRB/US model is modeled in the same manner as the rest of the nonfinancial system.

The FRB/US model is used as input to the *Greenbook* forecasting system, primarily as a check on the plausibility of the forecasts, and for identifying the sources of any discrepancy. Also, if a major change in underlying assumptions occurs between meetings, then the FRB/US model may be used to provide a new benchmark baseline. In practice the core model is add-factored in order to replicate the final *Greenbook* forecasts over the forecast horizon. This adjusted version of the core model is then used for various exercises, such as generating intervals around the *Greenbook* forecasts based on stochastic simulations and occasionally for producing forecasts at horizons beyond two years. The core model also appears to play an important role in simulation experiments such as predicting the effects of alternative policy paths or alternative assumptions about exogenous variables. The simulation results are typically presented in the *Bluebook*.

There is a greater reliance on models in producing forecasts at central banks that have explicit inflation objectives, such as the Bank of England and the Reserve Bank of New Zealand.

Conclusion

This article summarizes some of the basic issues that arise when forecasting is being conducted in the context of a monetary policy decision and describes some of the responses that three central banks have made to these issues. Broadly speaking, the basic mechanism of the forecasting process might be summarized as comprising four elements:

- a series of models or methods that are used to produce short-run (current quarter and one–two quarters ahead) forecasts;
- a relatively small core model that produces forecasts of major aggregates of interest over a one- to three-year horizon;
- a method for disaggregating the aggregated forecasts from the core model to incorporate the insights of sector specialists;
- a collection of auxiliary models that are designed to provide information about policy actions (such as policy simulations) or yield information relating to forecasts that are hard to analyze with the core model (such as the effects of unusual events).

These elements are part of most of the forecasting systems studied in this article although the emphasis given to each differs across institutions. Moreover, the way each component is implemented varies a great deal—for example, the degree to which the core model is closely linked to data versus how much theoretical structure is imposed. Additional theoretical structure might reduce the model's forecast accuracy but will generally aid its economic interpretability.

Some institutions appear to favor an approach that is structured explicitly within a model framework. Of the central banks studied, the Reserve Bank of New Zealand appears to be representative of this approach. Others, such as the Board of Governors, place much greater emphasis upon the judgments of sector experts and the experience of policy advisers in generating forecasts and evaluating policy choices. In some ways the distinction is really between those favoring relatively formal methods of forecasting and those who find the use of expert systems appealing. Of course, the distinction is not a sharp one. For example, while the Board of Governors primarily uses an expert-based system for producing baseline forecasts, they rely on a detailed core macroeconometric model for policy analysis as well as a cross-check on the economic plausibility of the baseline forecasts. At the Bank of England a core model is used to produce forecasts, but the policymakers assign subjective weights to various alternative assumptions in producing a forecast distribution. Ultimately, even if no institution relies entirely on econometric models to produce forecasts, they do use economic models of some variety to provide the rationale for the forecast numbers. It is also perhaps not surprising that there is a greater reliance on models at central banks that have explicit inflation objectives, such as the Bank of England and the Reserve Bank of New Zealand. In those cases it is particularly important that the policymakers ensure that policy decisions are consistent with the inflation objectives and are as transparent to the public as possible.

Although this article has focused on only three central banks it appears that, in general, banks that have moved toward inflation-targeting objectives have also tended to put greater emphasis on producing timely and publicly available model-based forecasts. In doing so these banks have made the monetary policy-making process increasingly transparent. However, even then there can be differences in the nature of the published information. For example, as the discussion shows, the Bank of England publishes point forecasts that are conditional on no change to the policy instrument over

the forecast horizon. But because this course might not be considered the most likely one for future policy, an associated forecast distribution is used to convey the relative risks to the conditional projection. In contrast, the point forecasts published by the Reserve Bank of New Zealand appear to directly condition on a policy instrument path that is consistent with its inflation objectives. In this case an objective-consistent instrument path is conveyed directly to the public rather than being implicit in the shape of the forecast distribution.

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