Commentary

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Over the past decade or so, researchers at academic institutions and central banks have been active in specifying and estimating dynamic stochastic general equilibrium (DSGE) models that can be used to analyze monetary policy.[1] Although the first-generation models were relatively small and stylized, more recent models typically embed a much more elaborate dynamic structure aimed at capturing key aspects of the aggregate data.[2] Indeed, several central banks now use DSGE models in the forecasting process and in formulating and communicating policy strategies.[3] In following that approach, however, it is crucial to investigate the sensitivity of the optimal policy prescriptions of a given model—that is, comparing the policy implications of alternative specifications of the behavioral mechanisms or exogenous shocks—and to identify policy strategies that provide robust performance under model uncertainty.

The authors' paper (Svensson and Williams, 2008) makes an important contribution in analyzing Bayesian optimal monetary policy in an environment in which the central bank faces a set of competing models and uses incoming information to update its probability assessments regarding which model is the best representation of the *actual* economy. Moreover, because private sector expectations play a key role in determining economic outcomes, the optimal policy not only characterizes the central bank's current actions but also involves a complete set of commitments regarding which future actions will be taken under every possible contingency. Given this approach, the analysis is made tractable—and very elegant—by the use of Markov jump-linear-quadratic methods.

In this environment, the Bayesian optimal policy is influenced by an "experimentation" motive, because the central bank recognizes that its current policy actions can influence the flow of incoming information and thereby affect the degree of model uncertainty in subsequent periods. In effect, experimentation is a form of public investment that incurs a short-run cost (in terms of greater macro volatility) in exchange for the medium-run benefit of a more precise estimate of the structure of the economy that will thereby facilitate better stabilization policies. Thus, the paper also makes a valuable contribution by comparing the Bayesian optimal policy with an "adaptive optimal control" strategy (in which the central bank updates its probability assessments of the competing models but does not engage in experimentation) and with the case of

[1] Pioneering early studies include King and Wolman (1996, 1999), Goodfriend and King (1997), Rotemberg and Woodford (1997, 1999), Clarida, Galí, and Gertler (1999), and McCallum and Nelson (1999).

[2] See Christiano, Eichenbaum, and Evans (2005), Smets and Wouters (2003), Levin et al. (2006), and Schmitt-Grohé and Uribe (2006).

[3] Examples include the Bank of Canada, the Bank of England, the European Central Bank, and the Sveriges Riksbank. Recent DSGE model development at the Federal Reserve Board is described in Erceg, Guerrieri, and Gust (2006) and Edge, Kiley, and Laforte (2007).

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"no learning" (in which the central bank never changes its probability assessments).

Interestingly, this analysis reaches conclusions regarding the role of experimentation that are broadly similar to those obtained in earlier studies such as Wieland (2000, 2006). In particular, the experimentation motive has relatively modest effects on the characteristics of the Bayesian optimal policy, and welfare comparisons indicate fairly minimal costs of using adaptive optimal control. Indeed, as John Taylor described in a recent interview (Leeson, 2007), he arrived at essentially the same conclusions several decades ago when he applied Bayesian optimal control to a small structural macro model: "My Ph.D. thesis...problem was to find a good policy rule in a model where one does not know the parameters and therefore had to estimate them and control the dynamic system simultaneously. My main conclusion...was that in many models, simply following a rule without special experimentation features was a good approximation [to the optimal policy]."

In the remainder of this commentary, I discuss a few conceptual issues regarding the formulation of model uncertainty, the characterization of optimal policy under commitment, and the specification of how the private sector's information set differs from that of the central bank.

CHARACTERIZING MODEL UNCERTAINTY

In analyzing the monetary policy implications of model uncertainty, it seems reasonable to assume that there will never be any single "true" model, because *every* macro model is merely a stylized approximation of reality. Moreover, ongoing progress in economic theory and empirical analysis not only shifts policymakers' probability assessments about which existing model is the best approximation, but it also inevitably generates a winnowing process whereby new modeling mechanisms are developed while obsolete models are completely discarded. Over the past few decades, for example, many central banks have undergone a sequence of transitions from traditional Phillips curve models (which implied a positive long-run relationship between output and inflation) to structural macro models embedding rational expectations—most recently to DSGE models with formal microeconomic foundations. Furthermore, it seems reasonable to anticipate that this process of model development and refinement will continue at a similar pace in the years ahead.

From this perspective, a stationary Markov process does not seem to be the ideal approach to represent the sort of model uncertainty that is relevant for monetary policymaking. In the present analysis, each competing model corresponds to a specific node or "state" of the Markov process; hence, model uncertainty is represented by the policymaker's assessments of the probability that each of these nodes is the correct model of the economy, and the learning process is represented by how these probability assessments are updated in response to incoming information. Thus, if the economy switches from one node to another, this implies that the "true" model of the economy has suddenly shifted. Such shifts may well occur, but it seems doubtful that the process is stationary: that is, the true economy does *not* shift back and forth among the members of the set of competing models.

For example, a recent study of an empirical DSGE model of the U.S. economy found that two alternative specifications of the structure of nominal wage contracts—namely, Calvo-style contracts with random duration versus Taylor-style contracts with fixed duration—have markedly different implications for optimal monetary policy and welfare (Levin, Onatski, J. Williams, and N. Williams, 2006). The analytical framework of this paper can easily be used to characterize the Bayesian optimal policy for this specification uncertainty: One node would correspond to the Calvo-style contract structure, and the other node would correspond to the Taylor-style contract structure. But it does not seem plausible to specify this uncertainty as a stationary Markov process—after all, that would imply that the economy occasionally shifts back and forth between Calvo-style contracts and Taylor-style contracts!

Of course, a stationary Markov regime–switching specification may well be useful for representing occasional shifts in the *state* of the economy, such as stochastic transitions between low growth and high growth. But in the case of model uncertainty, it seems reasonable to specify a diagonal structure for the Markov transition matrix: that is, the true economy never shifts between competing models. In that case, the policymaker has prior beliefs that assign some positive weight to each of these models; these priors are then updated in response to incoming information. Alternatively, one might consider a triangular Markov transition matrix with very small off-diagonal elements, representing the notion that the true structure of the economy might experience very rare shifts but would never revert to its original structure.

CHARACTERIZING OPTIMAL POLICY UNDER COMMITMENT

The "timeless perspective" is an appealing approach to characterizing optimal policy under commitment in a stationary environment (Woodford, 2003). This approach is equivalent to assuming that the government agency established a complete set of state-contingent policy commitments at some point in the distant past (that is, time $t = -\infty$), and that the economy has converged to its stationary steady state under that regime by now ($t = 0$). Moreover, in the general case in which this steady state is not Pareto optimal, the quadratic approximation of household welfare depends on the steady-state values of the Lagrange multipliers of the original policymaking problem (Benigno and Woodford, 2005).

In contrast, for the reasons described here previously, an environment of model uncertainty may be viewed as implying that the economy has not yet reached any stationary steady state, and hence that policy should *not* be characterized from a timeless perspective. Indeed, in this context it might be more natural to characterize optimal policy from the Ramsey perspective, that is, assuming that the policymaker is prepared to establish a complete set of state-contingent commitments starting in the present period (that is, as of time $t = 0$), where these commitments would reflect the anticipation that incoming information in future periods will gradually enable the policymaker to learn which model correctly represents the economy. Of course, that specification would raise further computational issues: Under the Ramsey policy (as opposed to the timeless perspective), the Lagrange multipliers corresponding to the implementation constraints cannot be substituted out of the problem but remain as essential state variables of the linear-quadratic approximation.

CHARACTERIZING THE PRIVATE SECTOR'S INFORMATION

Finally, it is worthwhile to consider the assumptions used in this analysis regarding the information available to private agents:

1. In the benchmark case of *Bayesian optimal control*, the analysis of this paper proceeds under the assumption that neither private agents nor the policymaker know which model is true. Unfortunately, this assumption is somewhat problematic in the context of DSGE models with explicit microeconomic foundations, because those models are formulated under the assumption that each household is aware of its own preferences and that each firm is aware of its own production technology and the characteristics of consumer demand.

   For example, in New Keynesian DSGE models with monopolistic competition and staggered price contracts, it is assumed that each firm sets the price of its product with full knowledge of its own production function and the elasticity of demand for its product. Nevertheless, econometricians may be unable to make precise distinctions regarding the extent to which aggregate price-setting behavior is influenced by factors such as firm-specific inputs and quasi-kinked demand; hence, there may be a strong motive for designing a monetary policy strategy that is robust to this source of model uncertainty (Levin, Lopez-Salido, and Yun, 2007).

Similarly, DSGE models typically involve a consumption Euler equation that is derived from a particular specification of household preferences for consumption and leisure—and of course, each individual household is assumed to have full knowledge of its *own* preferences in making decisions about spending, labor supply, etc. Nevertheless, the available data may be insufficient to enable econometricians to resolve uncertainty regarding several competing specifications of household preferences. Therefore, the central bank may wish to follow a policy strategy that is robust to this source of model uncertainty (Levin et al., 2008).

2. In the case of *adaptive optimal control*, the analysis proceeds under the more restrictive assumption that neither private agents nor the policymaker observe the current vector of shocks—an assumption that precludes consideration of most (if not all) existing DSGE models. In many such models, for example, shocks to total factor productivity play a key role as a source of aggregate volatility in output and employment. But it is by no means clear how an individual firm could determine its own production if the firm did not have contemporaneous knowledge of its own productivity.
3. The case of "no learning" assumes that neither private agents nor the policymaker can recall any of the data that were observed in previous periods. In many DSGE models, however, these data do enter explicitly into agents' decision rules. For example, in specifications with habit persistence in consumption, the household's current spending decision partly reflects its spending in previous periods. Similarly, when investment in physical capital is subject to adjustment costs, each individual firm's decision regarding its current level of investment depends explicitly on its prior investment decisions.

Evidently, in analyzing optimal policy under model uncertainty in the context of DSGE models with explicit micro foundations, further progress is needed to distinguish between the information available to the central bank and the information that is available to individual households and firms.

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