CHAPTER SEVEN

The Treatment of Expectations in Large Multicountry Econometric Models

John B. Taylor

Despite more than ten years of research and debate, it is still difficult to cite a definitive judgment by the economics profession on the question of how to treat expectations in empirical macroeconomics. By the late 1970s the rational expectations approach was hailed by many as a macroeconomic revolution. The rational expectations critique—as originally formulated by Lucas (1976)—pointed out that conventional methods of empirical policy evaluation could be improved by replacing the conventional assumption of backward-looking (adaptive) expectations with the assumption of forward-looking, rational expectations. Although clearly not welcomed by those using conventional techniques, many researchers began to develop and experiment with the new rational expectations methods. The econometrics of rational expectations became a field of research in its own right.

Nevertheless, rational expectations models have not replaced large-scale, conventional econometric models, either in the profession at large or among the staffs of policymakers. Moreover, in recent methodological discussions of policy made with the assistance of econometric models, the rational expectations approach has come under attack. Sims (1982) has argued, for example, that the rational expectations critique is a mere "cautionary footnote" and, more recently (1985), citing Sargent (1984) and Cooley, LeRoy, and Raymon (1984) as evidence, that there is increasing recognition that the critique is "logically flawed." According to the published summary of the discussion at the conference where Sims's paper was given, "many discussants agreed with Sims's criticism of the Lucas critique" (General Discussion," Sims 1982, 162).

Recent methodological discussions of rational expectations in policy evaluation, however, have rarely addressed empirical rational expectations models—either the structure of particular models or their uses. The arguments against the approach have been stated in abstract examples, and for this reason it has been difficult to come to any firm, practical conclusions. To be sure, until recently only small empirical rational expectations models have been available, and these models have been viewed as simple prototypes for methodological and theoretical experimentation—see, for example, Blanchard (1980), Sargent (1976), or Taylor (1979a, 1979b, 1979c). These small models are not on the scale of the large conventional models that the rational expectations school had criticized in the first place, and that large-scale rational expectations models were not developed more quickly is frequently used as a point of debate by critics of rational expectations. The optimistic lower bound, given by Lucas (1977), of "five, but not twenty-five years" until the completion of such a model seems to reinforce debate on this point.

The purpose of this paper is to discuss the treatment of expectations in policy-oriented empirical models with an emphasis on the use of rational expectations in multicountry models. I take a practical approach that emphasizes feasibility given existing econometric methods, numerical techniques, and computers. The discussion centers on a large, quarterly, rational expectations econometric model that is currently being developed as part of my ongoing research program on econometric policy evaluation. Discussing expectations methods with reference to a particular working rational expectations model has enormous expositional advantages. This particular model has evolved from the smaller econometric rational expectations models mentioned above, and it reflects some of my own theoretical and empirical views: the importance of a staggered wage and price setting, with aggregate demand determining output in the short run; the

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importance of highly mobile capital between countries; term-structure relations within efficient markets; and, of course, numerous accounting identities. The general ideas can be easily translated into other models or frameworks, however, and toward this end I contrast the effects of anticipated and unanticipated money supply increases in this model with those in three other multicountry rational expectations models.

The model I focus on is a quarterly model, estimated over the period of floating exchange rates from the first quarter of 1971 through the last quarter of 1984, that describes economic fluctuations within the United States and six other large industrial economies. It is an empirical version of a smaller, two-country simulation model, described in Carlozzi and Taylor (1985), which was used to evaluate alternative macroeconomic and exchange rate policy rules by using deterministic and stochastic simulation. The model is policy oriented in that it is designed to evaluate the effects of alternative policies under an empirically estimated set of parameters and an empirically estimated distribution of the shocks to the equations. Because expectations are so important in exchange rate determination, a multicountry model raises many more issues about expectations than do closed-economy models. Moreover, it is natural and perhaps more obviously relevant to speak of policy rules—and rational expectations in relation to them—in an international context; questions of international policy reform are central in practical policy discussions today and inherently involve changes in the overall policy rule (for example, flexible versus managed exchange rates). Like other large-scale econometric models, this model is nonlinear, a property that raises serious issues about its ability to handle rational expectations.

To build and use such a model, one obviously needs many approximations. Most of the parameters in the models are estimated econometrically, but for policy analysis these parameters are treated as fixed. Agents whose expectations appear in the model are assumed to share knowledge and use of the model in forecasting the future. The model abstracts from learning over time and from diverse expectations. The equations describing aggregate demand, wage adjustment, and price adjustment are aggregated across many individual agents, and these equations are at best approximations of the complex dynamic decision rules that these agents follow.

Despite all these approximations, I maintain that there is much to be learned about policy from using a multicountry rational expectations econometric model of this type. Such a model is useful (1) for evaluating major macroeconomic and international economic policy reforms—such as rules for exchange rate smoothing, prices, nominal GNP, and cooperation (or lack of it) among countries; (2) for calculating the effects of policy changes, anticipated and unanticipated; (3) for examining counterfactual alternatives to historical policy; and even (4) for conducting the everyday policy analysis needed to maintain or implement an existing policy rule. I argue that such a model has enormous advantages over conventional models or reduced-form models in helping us to evaluate policy. Although still quite computer-intensive when they are stochastically simulated or estimated with maximum-likelihood techniques, rational expectations models are now feasible to build and use. My informed guess is that by 1990 such multicountry rational expectations econometric models will be used for practical policy analysis as extensively as conventional econometric models of the United States are used today.

Feasibility and Usefulness of Rational Expectations in Large Models

Expectations of future variables—prices, wages, output, interest rates, exchange rates—are pervasive in macroeconometric models. In the particular quarterly model discussed here, for example, about half of the behavioral equations contain expectations of future variables. (The equations of this model are listed in the appendix to this chapter, table 7A-1, in a compact form for easy scanning to see the importance of these expectations variables and the form of the model.) In principle even more equations, such as the export and import demand equations, contain expectations of future variables. The same is true of many other models: the annual rational expectations model described by Minford, Agenor, and Nowell (1985), for example, has about the same percentage of behavioral relations containing expectations variables.

It makes a great deal of difference, therefore, how expectations are treated in macroeconomic models. Aggregate demand, aggregate supply, and price adjustment all depend on expectations of the future. Consumption and investment depend on real interest rates and, thereby, on the expectations of prices in the future. Long-term interest rates depend on expectations of future short-term interest rates and, thereby, on expectations of future monetary and fiscal policies. Interest rate differentials among countries depend on expected changes in exchange rates, thereby on expectations of future exchange rates. Finally, current wages and prices depend on expectations of future wages, prices, and demand conditions. In the cases I have examined econometrically, these expectations effects seem to be empirically important as well.

In practice "rational expectations" means that the expectations variables that appear in a model are assumed to be generated by the model itself. This is precisely the way in which Muth (1961) originally defined the term twenty-five years ago in his classic paper. It is a requirement of expectational consistency. The term "model-consistent" expectations might capture the idea more vividly, but Muth's term has now achieved such widespread usage that there is little reason to introduce a new one. Taken literally, rational expectations means that economic agents who are described in the model know the model and use it in forecasting. In using this assumption one hopes that it works as a reasonable approximation of a reality in which most people, of course, are completely unaware of such a model but at least are concerned enough with the future to pay attention to economic forecasts, or to get at least a rough view of macroeconomic events by reading the newspaper and watching television, in which the accounts of such events are in turn influenced by economists and their models. In any case, during periods when the structure of the economy or economic policy is changing one would expect that this simplistic version of rational expectations—in which people are assumed to know the model—might prove inaccurate.

Because of the consistency assumption that the model forecasts are equal to the expectations terms that appear in the model, the rational expectations assumption presents a computational problem that does not exist in reduced-form models or in conventional structural models in which expectations are assumed to be simple functions of past variables (adaptive expectations).

For linear models the assumption of expectational consistency is made operational either by computing explicitly the saddle-point path or by factoring out the expectations variables. Progress in solving linear rational expectations models has been great in the past few years, and the methods are relatively cheap and easy to use. For discrete time applications, Hansen and Sargent (1980, 1981) formulated a rational expectations model in lag-operator notation, and showed how to factor symmetric polynomials in the lag operator to obtain a solution. The polynomials are symmetric when the model is derived explicitly from the optimization problem of a representative agent. As discussed in this paper, such a symmetric polynomial would not emerge from a linear version of the model or from many other models. Dagli and Taylor (1985) described an iterative algorithm to factor nonsymmetric polynomials in the lag operator and have had considerable success using it. Blanchard and Kahn (1980) showed how to solve a general linear model by obtaining the roots directly, eliminating the unstable roots, and thereby placing the model on a saddle-point path. A detailed discussion of these various solution methods, along with an analysis of the calculation of anticipated versus unanticipated shocks and problems of uniqueness, can be found in my recent survey paper (Taylor 1986). Because of the relative ease of using linear models, most of the early small empirical models mentioned in the introduction were either linear or log-linear. The solution methods for linear models are so easy and cheap compared with those for nonlinear models that researchers have a much greater incentive to use linear models when the rational expectations assumption is maintained.

Techniques for Solving Nonlinear Models

Any macroeconomic model that reflects elementary accounting identities and distinguishes between real and nominal magnitudes, however, will be nonlinear. Solving nonlinear econometric models is considerably more complicated than solving their linear counterparts. Yet in the past few years great improvements in solution algorithms have reduced computation time significantly, and current research is likely to improve the methods even further. Two techniques have been used most extensively thus far: the *multiple shooting* method, described in Lipton and others (1982), and the *extended-path* method, described in Fair and Taylor (1983). The multiple shooting technique treats the problem of solving a rational expectations model as a two-point, boundary-value problem in which final as well as initial conditions are given. The final conditions are given by the long-run stationary values of the model, which, as an approximation, are obtained in infinite time. The extended-path method does not require that the final conditions be calculated separately from the dynamic path, and it is similar to methods for solving nonrational simultaneous econometric models. The extended-path approach has apparently become the more convenient one for many users, and I will concentrate on this technique here.

The extended-path method solves a nonlinear rational expectations model through three types of iteration. Consider solving the model for one time period. The first type of iteration takes as given the path of expectations of the model's future variables, starting from a set of initial guesses about those expectations. For these initial estimates the model is solved dynamically forward from the initial time period using the Gauss-Siedel method as in any conventional model. In principle the model will have to be solved into the infinite future because expectations of future variables depend on expectations of the model in future periods, which depend on later expectations, and so on. The process starts, however, with an arbitrary finite horizon for the path of expectations variables.

The second type of iteration is performed on the expectations variables. The solution of the model for the endogenous expectations variables replaces the initial estimates, and a whole new round of type-1 iterations takes place. The expectations variables are then updated again, and the type-1 iterations take place once more.

The third type of iteration is performed on the horizon for the path of expectations. After type-2 iterations have converged, the path is extended, and the whole process is repeated again until convergence is reached. All this procedure is required just to solve the model for one period. Because of these three nested rounds of iteration, the method can be quite expensive. In practice it is usually possible to choose a horizon that is long enough for type-3 convergence of a wide range of policy experiments within a given model. Then the type-3 convergence test might be omitted and replaced by an occasional check of the sensitivity of the solution to horizon length. Although this sensitivity check should be done with some care, great savings in computer time are possible. The simulations with the multicountry model discussed here (reported in the companion volume), for example, were all done with the same horizon length.

The computing requirements for the extended-path algorithm for this multicountry model can be described as follows. A pass through the model (one type-1 iteration) takes about a third of a second of central processing unit (CPU) time on a VAX 780 computer. At least twenty-five periods of dynamic simulation are necessary to ensure type-3 convergence. Solving the model for one period for a given set of expectations takes about 14 type-1 iterations, or a total of 350 passes through the model for the 25 periods of each type-3 iteration. Convergence has required about 33 type-2 iterations, for a total of 11,550 passes through the model. Total CPU time is thus about one hour for a one-period solution. More efficient computer coding and relatively small adjustments in the algorithm can be expected to reduce this time. Fisher, Holly, and Hughes-Hallet (1985) have experimented with various ways to modify the extended-path algorithm to improve speed of computation. (These modifications were not used in the preceding summary of computation times.) Hence, although expensive, solving a nonlinear, large-scale rational expectations model is clearly feasible. Note that the VAX 780 is a relatively slow computer. A larger mainframe computer would greatly reduce computation time.

If initial conditions change the next period—as in the case of a stochastic simulation in which new shocks are drawn, or in an estimation problem in which the observations are taken over time—then this entire process must be repeated again in the next period, and so on. If one is doing a deterministic simulation, however, the solutions for the expectations variables will be equal to the solution of the model in the later periods. Because these later solutions will have been computed as part of the solution algorithm, no new computations are necessary if the horizon for the extended path is long enough.

Estimation and Goodness of Fit

Estimation of a nonlinear rational expectations model can be done by using the limited-information techniques developed by McCallum (1976), Hansen (1982), and others. These estimates consider one equation of the model at a time and are much like two-stage, least-squares methods in that instrumental variables must be chosen judiciously. Most of the equations of the model discussed here have been estimated with a McCallum-Hansen estimator.

For assessing how well a model fits the data or for testing the overall model, however, these limited information methods are not entirely satisfactory because the central assumption of a rational expectations model is that the expectations variables are generated by the model. Looking at the residuals from single equations in which the expectations variables have been proxied does not give a good measure of fit. Similarly, dynamic simulations of the model during the estimation period are not revealing because so many of the variables in a rational expectations model are endogenous: as in any time-series model with no exogenous variables, the model will drift from the actual sample data after eight or ten periods. Ideally one would like to estimate the entire model using maximum-likelihood techniques and then use likelihood-ratio measures to judge the adequacy of the model in describing the data. The likelihood function would provide an ideal measure of how well the model fits the data, compared with a fully unconstrained model, and would automatically weigh the errors in each equation according to the estimated covariance matrix. This approach has already been used in small linear models in which maximum-likelihood estimation is less costly. The cross-equation constraints imposed by rational expectations and the structure of the model are tested against the unconstrained reduced form. It is important to make sure that any structural model fits the data in the sense that it delivers a value of the likelihood function that is not significantly different from that of an unconstrained reduced-form model fit to the data. As described below, it is also important to get a good estimate of the variance-covariance matrix of the disturbances to each of the equations, or at least a good estimate of the disturbances themselves, because these estimates are essential to the evaluation of policy.

Two difficulties in using this approach for large nonlinear models present themselves. First, estimating a nonlinear rational expectations model using maximum-likelihood methods is now very computer-intensive. Maximum-likelihood estimation can be performed using nonlinear iterative methods. For these methods the likelihood function can be evaluated by using the extended-path algorithm. Consider again the example of the multicountry model that I and my coworkers have been developing. As shown above, solving the model for one period takes about one hour on a VAX 780. For a sample of fifty periods, one evaluation of the likelihood function therefore takes fifty hours on a VAX 780. An estimation problem that required 100 function evaluations would therefore take 5,000 hours—or over 200 full days of CPU time—to complete on a VAX 780. Maximum-likelihood estimation of a large rational expectations model is thus a task for which supercomputing is almost a necessity.

Second, goodness-of-fit tests based on fully unconstrained reduced forms have an additional difficulty that arises from the lack of degrees of freedom in estimating an unconstrained model for a large number of variables. In multicountry models this problem is most severe because the number of variables can be huge. Estimating a fully unconstrained vector autoregression is impossible for any large-scale model because all the degrees of freedom are exhausted.

What alternatives exist? Ex ante forecasting would clearly be useful, but this takes real time. Looking at the performance of the model during selected subsamples is another possibility, but in principle one should consider all subsamples. A more promising approach would be to examine the behavior of a subset of important variables—such as real output, inflation, the exchange rate—over the entire sample period. Through stochastic simulation the behavior of these variables could be generated during the sample period. Then one could test whether the actual data had stochastic properties that were significantly different from the generated data. By this approach, degrees of freedom could be saved by considering the smaller subset of variables. Another approach would be to place other types of constraints on the coefficients of the reduced form. For example, one could assume that the coefficients on the lagged terms have a smooth shape.

Econometric Policy Evaluation

There are at least four kinds of policy analysis that can be performed with a model in which it is assumed that expectations are rational. In this section I review each in turn. All the methods of policy analysis discussed below take the estimated parameters as given and certain.

One-Time Changes in Policy Instruments

Calculating the effects of "one-time" changes in policy instruments is now straightforward even in large nonlinear rational expectations models. One deterministic simulation suffices to calculate the effects of each such change in the instruments; as discussed above, this simulation requires about an hour on a computer such as the VAX 780. A one-time change in a policy variable simply means that the level of the variable is changed relative to some baseline path, and that subsequently no further changes will occur. A 5 percent once-and-for-all increase in the money supply in the current year is an example of a one-time change in policy. One-time changes are to be distinguished from changes in the policy rule, or reaction function, by which the whole contingency plan for policy is changed. Such one-time changes in policy do occur in reality, but they are rare. Hence in practice this type of policy evaluation is likely to be more useful for illustrating the internal properties of a model than for evaluating alternative policies.

ANTICIPATED OR UNANTICIPATED CHANGES. In any dynamic macroeconomic model it is important to distinguish between one-time policy changes that are thought to be "permanent" (once and for all) and those that are seen to be temporary. In rational expectations models it is also important to distinguish between changes that are anticipated and those that are unanticipated ("shocks"). For linear models this distinction is elaborated in my recent technical survey (Taylor 1986). The distinction between unanticipated and anticipated changes has no operational significance in conventional models with backward-looking expectations schemes, but it is crucial for understanding the properties of rational expectations models. Perfectly anticipated one-time changes in policy instruments are, of course, at least as rare in reality as unanticipated one-time changes. Announced and credible changes in policy—such as enacted changes in tax rates that will come into effect in the future, or declines in the trend rate of money growth—have not seemed to occur often. (In practice the problem of interpreting such simulations is that they rely to great degree on the credibility of policymakers—that such an announced change in the direction of policy will indeed take place. It is possible, of course, to adjust the estimates to account for varying degrees of belief that the policymakers will follow the stated plan, but the rational expectations calculation seems like a good place from which to make such an adjustment.) Again, the main purpose of this type of policy exercise may be to explore the internal properties of a given rational expectations model. Significant information about the properties of a model and how it compares with other models can be obtained from experimenting with the effects of anticipated changes in policy instruments. In comparing rational expectations models, anticipated changes in the policy instruments should definitely be added to unanticipated changes when making a list of useful policy experiments.

Calculating the effects of anticipated policy changes is now standard practice in small linear macroeconomic models (Blanchard 1980, or Taylor 1979c). The techniques for calculating the effects of such changes in large nonlinear rational expectations models require only small modifications of existing solution techniques, such as the extended-path algorithm. Suppose that the effect of an anticipated increase in the money supply three years from now is to be calculated. One simply solves the model dynamically and deterministically, starting in the current period with the money supply taken to be exogenous and equal to the baseline values for the next three years. Then the money supply is increased from the baseline, starting at the end of the third year. This change is built into the exogenous time series for the money supply. The extended-path solution technique then implicitly assumes that people know that this is the path of the money supply, and that this information becomes known to them in the current period when the simulation starts. Because this is a deterministic simulation, it is not necessary to obtain separate rational expectations solutions for each period, so that computation time is again small—about an hour on a VAX 780 for the multicountry model discussed below.

The effects of one-time changes in the policy instruments—whether anticipated or unanticipated—are additive in a rational expectations model, as in a "nonrational" expectations model, if the model is linear. For example, in a linear rational expectations model the combined effect of an increase in the money supply and a decline in government spending, both anticipated three years in advance, can be evaluated by computing the effect of each separately and then adding the effects together. This additivity can easily be shown by using the methods described in Taylor (1986). Of course for nonlinear models this additivity does not hold exactly, whether expectations are rational or not. It is an open question whether the simulation results from nonlinear rational expectations models are approximately additive, as the simulation results from many "nonrational" expectations econometric models appear to be. The experience with the rational expectations model discussed in this paper, however, does indicate that it is nearly additive.

Comparison of Policy Rules

The kind of policy evaluation best suited to a rational expectations model concerns the effect of alternative policy rules. The approach outlined by Lucas (1976) in his well-known critique of policy evaluation in traditional econometric models suggested this type of policy evaluation in rational expectations models. At times the rational expectations approach to policy questions has been identified with this type of policy evaluation, but rational expectations models have many other uses, as emphasized here. Under this kind of policy evaluation, one could calculate, for example, the quantitative effects on the size of business cycle fluctuations of a policy that fixes exchange rates and keeps the growth rate of money in one country (such as the United States) constant. Fixed exchange rates with an accommodative U.S. monetary policy might also be evaluated, or the effects of a policy in which exchange rates are left to float and each country follows an accommodative policy. Exchange rates that fluctuate within a "target zone," but are not perfectly fixed, might be another possibility for analysis. Of course the operating performance of the economy under each of these policies could be compared as part of the process of looking for the best, or at least a good, future policy.

Such policy analyses clearly would seem to be an important quantitative part of the economic research underlying current proposals for more stability in exchange rates. Would such a policy work better than one in which international conditions were ignored in the sense that exchange rates were allowed to fluctuate freely, or better than one in which the money supply reacted to the state of the economy? When made specific, the policy question is whether such reforms would improve macroeconomic performance over the next few decades compared, say, with the past two decades. The cost of reform—what would happen during the year in which the policy rule is being changed—while also an important question, is one that can be logically separated from the longer-run issue.

How would one use a rational expectations model to answer such a question? There are two possibilities. First, one could stochastically simulate an econometric model under alternative monetary, fiscal, and exchange rate rules. The shocks for this stochastic simulation would then be generated from the estimated covariance matrix of the shocks to the estimated equations during the sample period. This stochastic simulation approach has been used in small simulation models by Carlozzi and Taylor (1985) and is logically equivalent to calculating the steady-state distribution of the endogenous variables analytically in linear models, as in Taylor (1979a or 1979c), for example. If such an exercise is viewed as a means of obtaining a close approximation to the stochastic steady-state distribution of a nonlinear model, then many stochastic draws are necessary, and the evaluation could be quite computer intensive.

Second, an alternative approach would simply be to use the actual disturbances from a given sample period. For example, to evaluate alternative monetary policy rules for the next ten years, one could simply use the shocks from the last ten years. If the shocks in the sample period are uncorrelated, then it is appropriate to assume that people do not forecast these shocks in the simulation period. The performance of the system around a baseline forecast for the next ten years could then be examined for different policy rules. For a quarterly model this would entail solving the model for forty periods at least twice—once to obtain the shocks, and again to simulate the economy under a different policy with the same set of shocks. This would be less costly than a stochastic simulation in that more than forty draws would usually be necessary to approximate a steady-state stochastic distribution. Moreover, the empirical distribution of the estimated sample shocks may give a more realistic picture of the type of shocks than simply assuming that the shocks are normally distributed, as is typically done in a stochastic simulation exercise.

SIMS'S COUNTERCRITIQUE. Sims (1982) has argued that such stochastic analysis of policy rules—the same, essentially, as that suggested by Lucas (1976)—is not relevant because changes in the policy rule are rare and occur gradually anyway. Although slow to emerge, such changes do indeed occur, and they are frequently discussed by policymakers. Recently, many conferences have been organized to discuss such reforms of the international monetary system. The U.S. Treasury is currently studying various proposals. Clearly it is important to be able to give as scientific an answer as possible to the question of which type of reform would work best. Currently there appear to be no econometric models that are being used by the staffs of policymakers for this purpose.

Getting such a reform through the policy process is of course difficult and may take years. The situation does not seem to be much different from tax reform, where public finance economists calculate the effect of various reforms by using quantitative estimates of demand and supply elasticities. Tax reform does not occur every day. Many changes in the tax code seem to have evolved gradually. But the slow process does not detract much from the value of getting the best quantitative estimates of the effect of the reforms. Reforms in macroeconomic policy or international finance are similar to tax reform in this respect.

IS THIS ANY WAY TO DEAL WITH LUCAS'S CRITIQUE? Others might question whether a rational expectations model such as the one discussed here adequately deals with Lucas's (1976) critique. In an important sense it does. The reduced form of this model, in which the endogenous variables are a function solely of exogenous variables and past endogenous variables (that is, the function excludes expectations of future variables and current endogenous variables), cannot be computed analytically because the model is nonlinear. Nevertheless, the reduced form does depend on the parameters of the policy rule, as does the reduced form of a linear rational expectations model. Thus, when the policy rule changes, the reduced form changes, but in a way that uses the rational expectations solution method.

If adaptive expectations had been used instead of rational expectations, then this dependence of the reduced form on the policy parameters would be ignored, and one would commit the mistake in policy evaluation pointed out by Lucas. By letting expectations be rational, this type of nonlinear model deals with Lucas's critique in much the same way that I and others have dealt with it in linear models (Taylor 1979a, for example). With respect to expectations, therefore, this approach addresses Lucas's critique.

Still, one might take Lucas's critique further and argue that the behavioral equations of this model are not structural. Consider, for example, the wage equations of the model listed in the appendix to the chapter. These equations are assumed to be structural, but the coefficients might change if a change in policy rule causes workers to index their contracts by a greater or lesser amount. Perhaps more serious, the parameters of what I call structural investment equations might change. For the procedure outlined here to work well, these changes have to be small, and that is the assumption that is being made. If one thought such changes were likely to be large, then it would be necessary to build these other changes into the model. One might use the approach of Hansen and Sargent (1980), which uses the optimization problem of a representative agent to handle these additional changes in behavior. But even these more elaborate approaches can in turn be subjected to Lucas's critique. One might say that the technology is not policy invariant, for example.

Counterfactual Historical Analysis

It is possible to use a rational expectations model to examine how the economy might have performed over a given historical period if the policy rule had been different from the actual policy then in effect. Technically this can be done by simulating the model with the actual estimated shock in the equations during each quarter of the historical period in question. This type of policy evaluation was performed in a linear model by Taylor (1979c) for the period from the first quarter of 1973 through the last quarter of 1977, the period following the first oil shock. Given the nonlinear solution techniques now available, this type of calculation is not difficult for nonlinear models.

There appears to be some controversy about whether such a calculation is legitimate from a rational expectations viewpoint. For example, the impression left by Lucas (1980) is that questions about short periods or isolated shocks are not amendable to serious scientific analysis of any kind. Cooley, LeRoy, and Raymon (1984), for example, seem to have interpreted Lucas in this way and argue strongly against him. For the record, however, Lucas (1981) himself is in general sympathy with the type of simulation and calculation described here, so part of the debate may be due to misinterpretation.

Everyday Policy Analysis to Maintain a Policy Rule

One of the most complex questions in applied policy analysis is how to go from calculations of what is the best, or at least a good, policy rule to actually implementing and maintaining such a rule in practice. In his countercritique, Sims (1982) argued that such implementation is a far better characterization of policy "action" than choosing among rules. Adding to the complexity is that many practical rules—such as nominal GNP targeting—leave vague exactly how the rule is to be implemented. Some analysts feel that the Board of Governors of the Federal Reserve System is currently operating according to a nominal GNP rule. But such a rule clearly does not give simple algebraic equations that tell the open market desk what to do each week. Putting a GNP rule into effect is a difficult task for policymakers and their staffs.

I would argue that rational expectations models can contribute in important ways to making policy rules work. The case can be illustrated through the example of nominal GNP targeting. Suppose that the Federal Open Market Committee (FOMC) of the Federal Reserve System has actually decided that nominal GNP targeting is what they want, and that, although they do not announce the policy explicitly, most analysts will realize what is going on and take a "rational" view of the policy. The task of the Federal Reserve staff is then to make recommendations to the FOMC about target paths for reserves that have the best chance of hitting the nominal GNP target as new information comes in. If expectations about future interest rates, exchange rates, prices, wages, and output are endogenous, then a rational expectations model is likely to be of better assistance to the Federal Reserve staff than a conventional model or a reduced-form model that ignores these expectations or treats them as exogenous or predetermined.

If rational expectations models are useful in such an environment, as I am arguing they are, then why do they not appear to have been used in this way? Put differently, is the lack of empirical analysis using rational expectations at the Federal Reserve Board and other government agencies evidence against the view that the models are useful? For two reasons I think the answer is no. First, the techniques for reliably dealing with large-scale rational expectations models have only recently been developed. The extended-path algorithm, for example, has only received extensive testing in the past three years. Second, the rational expectations approach has frequently been associated with the view that monetary policy is ineffective, a controversial hypothesis that actually has little to do with rational expectations but more to do with the assumption of perfectly flexible wages and prices that appears in some models. For this reason, perhaps, policymakers have not been enthusiastic about investing resources in developing rational expectations models. To be sure, in the early 1980s there was some experimentation with incorporating rational expectations into models at the Federal Reserve Board. Because of the supposed controversial aspects of rational expectations, it is possible that the motivation of the staff in this area was less than enthusiastic. In the United Kingdom, by comparison, rational expectations analysis has not been associated with as much controversy, at least among econometric modelers. As a result several large-scale models with rational expectations have been under development in the United Kingdom—the LIVERPOOL model and the London Business School model among them.

Alternatives to Rational Expectations

The rational expectations approach probably does not work well as an approximation during or shortly after changes in the structure of the economy or in economic policy. If there is great diversity of opinion about the nature of economic models, then it is unclear how close the method is as an approximation. What alternatives are there in these cases? The assumption of adaptive expectations is sometimes used to describe the slow movement of expectations when people are learning, and this is the primary justification for including adaptive expectations in most "nonrational" expectations econometric models that are used today. Although it is reasonable to assume adaptive expectations after a change in policy or structure, these models have adaptive expectations built in for all time periods, whether a policy change has taken place or not. A better approach in principle would be to model the learning more formally. In Taylor (1975), for example, it was assumed that people followed a Bayesian process in learning about the target rate of monetary growth. The equation relating expectations of inflation to actual inflation had the adaptive expectations form in that model, but the coefficient of adaptive expectations was not a constant, as in the typical adaptive expectations assumption. Unfortunately, it has proved very difficult to model learning in analytical frameworks that are at all complicated. Usually researchers focus on only one or a few parameters of a small linear model. Given available techniques it is still difficult to model learning in a large nonlinear structural econometric model, and this is clearly a useful area of research. For the model discussed here, one might assume that individuals are learning about the intercepts of the equations of the model through use of Bayesian updating formulas. Because of the nonlinearities, however, the updating formulas would not have the simple form derived, for example, in Taylor (1975), and computations time would be greatly increased.

Dealing with diverse expectations is also difficult, although recent research by Rudin (1986), using the methods of Townsend (1983), has indicated some possible ways to proceed with estimation and policy analysis in small linear models. In this research individuals are modeled as having different views about parameters of the model. These parameters are also changing, so that opinions never converge. In other words, in the stochastic equilibrium of the model people have diverse expectations, and this changes the dynamics of the reduced form of the model. This research is promising and may eventually generate a significant improvement over the simple assumption of rational expectations in large nonlinear models.

Comparison of Unanticipated and Anticipated Policies

To illustrate the previous discussion of policy evaluation, in this section I show how the rational expectations model described in the appendix can be solved to give the effects of anticipated and unanticipated policy changes—the first type of policy evaluation discussed in the preceding section. I focus on monetary policy shocks and compare this model to three other multicountry rational expectations models that have been compared as part of this conference—the LIVERPOOL model, the McKibbin-Sachs (MSG) model, and the MINIMOD model developed at the International Monetary Fund.

To simulate the effects of an unanticipated increase in the money supply, I take money and government spending in each country as exogenous. The model consisting of the equations listed in the

Table 7-1. Effects of a 4 Percent, One-Time Increase in the U.S. Money Supply in the Taylor Multicountry Rational Expectations Model
Percent change from baseline unless otherwise noted

	United States				Japan				ROECD			
Year	Y^a	P^b	RS^c	E^d	*Y*	*P*	*RS*	*E*	*Y*	*P*	*RS*	*E*
					Increase unanticipated							
1985	0.83	0.23	−0.61	−4.1	0.01	−0.01	−0.01	4.4	0.04	0.02	0.02	4.2
1986	0.50	0.85	−0.50	−3.4	−0.08	−0.08	−0.02	3.7	−0.06	−0.10	−0.04	3.6
1987	0.45	1.42	−0.34	−3.1	−0.21	−0.22	−0.05	3.3	−0.11	−0.23	−0.07	3.2
1988	0.33	1.83	−0.31	−2.9	−0.31	−0.41	−0.07	3.1	−0.13	−0.36	−0.10	3.0
1989	0.19	2.11	−0.30	−2.7	−0.31	−0.61	−0.08	2.8	−0.12	−0.46	−0.10	2.8
1990	0.13	2.27	−0.29	−2.5	−0.24	−0.76	−0.08	2.6	−0.07	−0.52	−0.09	2.6
					Increase anticipated three years in advance							
1985	0.32	0.12	0.12	−2.5	−0.01	−0.01	−0.01	2.7	0.00	−0.02	0.00	2.5
1986	0.37	0.50	0.24	−2.7	−0.07	−0.07	−0.02	2.8	−0.04	−0.08	−0.02	2.7
1987	0.46	0.99	0.36	−3.0	−0.16	−0.18	−0.03	3.2	−0.08	−0.17	−0.05	3.1
1988	0.45	1.48	−0.44	−3.2	−0.23	−0.34	−0.05	3.4	−0.10	−0.29	−0.07	3.3
1989	0.26	1.85	−0.39	−2.8	−0.27	−0.51	−0.07	2.9	−0.12	−0.40	−0.10	2.9
1990	0.18	2.08	−0.31	−2.6	−0.25	−0.67	−0.07	2.7	−0.09	−0.48	−0.09	2.6

Source: Author's simulations.
a. Output.
b. Output deflator.
c. Percentage-point change from baseline short-term interest rate.
d. The exchange rate, measured as weighted units of foreign exchange per unit of domestic currency.

appendix can then be solved in each period for the endogenous variables. The solution is performed numerically, using the extended-path algorithm as discussed in the first section of the chapter. Each such simulation takes about an hour on a VAX 780. For these simulations the time horizon for the type-3 iterations was taken to be forty-five quarters beyond the first quarter. Because the model is simulated dynamically for twenty periods, this horizon leaves about 25 periods beyond the last sample point.

In the top panel of table 7-1 is shown the effect on a small selected group of U.S., Japanese, and non-U.S. OECD variables of a one-time *unanticipated* increase in the U.S. money supply of 4 percent, phased in gradually over four quarters starting in the first quarter of 1985. The other countries are assumed not to alter their money supplies at all, in effect letting exchange rates fluctuate freely. Note that this is a level shift in the money supply of 4 percent relative to the baseline. The behavior of real output *Y*, the output deflator *P*, the short-term nominal interest rate *RS*, and the exchange rate *E* is shown. The exchange rate is reported in output-weighted units of foreign exchange per U.S. dollar. All the data are reported in percentage deviations from a baseline path except the short-term interest rate, which is reported in percentage-point deviations from the baseline path. The results are aggregated over four quarters for each year to allow comparison with annual models.

The bottom panel of table 7-1 reports the results for an *anticipated* 4 percent increase in the U.S. money supply with the same phase-in starting in 1988 rather than in 1985. The increase is assumed to be known from the first quarter of 1985, three years in advance. The computations were done by setting the exogenous increase in money to begin in 1988 but solving the model starting in 1985. The extended-path algorithm thereby lets the increase in money enter people's information sets in 1985. Again, the other countries are assumed to keep their money supplies and government spending unchanged.

As is clear from table 7-1, there is a great difference between the anticipated increase and the unanticipated increase in money (top panel of the table). In the case of the unanticipated increase, U.S. real output expands by almost 1 percent and then returns gradually to normal as prices adjust. The dollar exchange rate depreciates and then begins to appreciate in typical Dornbusch overshooting fashion. In this case output in all the other countries declines (after the first year). Except for a small positive effect at impact, an expansionary U.S. monetary policy will depress output abroad for a while. The decline is larger in Japan than in the other countries.

Note that real interest rates fall by more than nominal rates because of the increase in the expected rate of inflation. This feature of this type of model was noted by Carlozzi and Taylor (1985). It occurs because wages and prices are sticky: wages and prices can adjust in the long run but not in the short run. Under rational expectations investors realize this feature and therefore expect a period of inflation after the increase in the money supply. Nominal

Table 7-2. Effects of a 4 Percent, One-Time Increase in the U.S. Money Supply in the Liverpool Multicountry Rational Expectations Model
Percent change from baseline unless otherwise noted

Year	United States				Japan				ROECD			
	Y^a	P^b	RS^c	E^d	Y	P	RS	E	Y	P	RS	E
					Increase unanticipated							
1985	0.60	1.8	0.40	−2.2	0.00	−0.20	−0.20	2.4	0.10	−0.10	−0.10	2.4
1986	0.10	3.7	−0.30	−3.9	0.00	−0.10	−0.10	4.3	0.00	0.00	−0.10	4.2
1987	−0.10	3.9	−0.10	−4.0	0.00	0.00	0.00	4.3	0.00	0.00	−0.00	4.2
1988	−0.20	4.1	−0.10	−4.1	0.00	0.00	0.00	4.4	0.00	0.10	−0.00	4.5
1989	−0.20	4.4	−0.00	−4.3	0.00	0.00	0.00	4.6	0.00	0.10	−0.00	4.5
1990	−0.20	4.5	−0.00	−4.4	0.00	0.00	−0.00	4.6	0.00	0.10	−0.00	4.6
					Increase anticipated three years in advance							
1985	0.02	0.31	−0.15	−0.68	0.01	−0.19	−0.02	0.76	0.01	−0.13	−0.01	0.55
1986	−0.04	0.58	−0.20	−1.0	0.03	−0.26	−0.06	1.1	0.00	−0.10	−0.05	0.96
1987	−0.08	0.80	0.51	−1.3	0.04	−0.32	−0.09	1.3	0.02	−0.23	−0.08	1.2
1988	−0.10	2.8	0.43	−3.1	0.06	−0.39	−0.18	3.4	0.03	−0.22	−0.16	3.2
1989	−0.11	4.5	−0.31	−4.7	0.07	−0.43	−0.21	5.2	0.03	−0.18	−0.22	4.9
1990	−0.10	4.3	−0.26	−4.4	0.07	−0.44	−0.18	4.9	0.03	−0.16	−0.20	4.6

Source: Data provided by Patrick Minford.
a–d. As defined in notes to table 7-1.

interest rates do not fully adjust to keep the real interest rate constant because wages and prices are sticky and real demand increases. Hence changes in the nominal interest rate are not a good sign of the effects of monetary policy in this model. Put another way, the slope of the LM curve measured by looking at the money demand equations is not particularly flat. In contrast, the LM curve traced by looking at the paths of the nominal interest rate and output will look very flat.

An anticipated increase in the U.S. money supply causes U.S. output and prices to rise as soon as the increase is anticipated. Note that the rise is much less than in the case of an unanticipated increase in the money supply. Anticipated money increases are less powerful than unanticipated money increases. This is a property unique to rational expectations models. Note also that anticipated money increases are not neutral (so long as they are not anticipated infinitely far in the future). The effect of anticipated U.S. money increases in other countries is smaller than in the case of unanticipated increases, but the difference is not so marked.

Table 7-2 shows the results of exactly the same simulation for the LIVERPOOL model described by Minford, Agenor, and Nowell (1985). The LIVERPOOL model is an annual model, so comparison with the above quarterly model is difficult, despite aggregation of the quarterly data in table 7-3. In the annual model the unanticipated increase in money is a surprise for a full year; in a quarterly model the unanticipated increase is a surprise for only one quarter.

In any case the results of the two models are quite different. In the case of unanticipated increases in U.S. money, the LIVERPOOL model indicates that U.S. output expands by about 0.5 percent in the first period and then by a negligible amount. In the case of the unanticipated increase in the money supply, output in the other countries hardly changes at all. The price level increases almost completely to its new equilibrium level after the first year.

In the case of anticipated increases in money there is only a negligible effect. In essence, anticipated increases in the money supply are neutral in this model. The price level jumps in the year that the increase in the money supply is announced, with no noticeable effect on output. This is a feature of new classical models that distinguishes them from staggered wage and price models with rational expectations.

Tables 7-3 and 7-4 show the results of the same anticipated and unanticipated money supply increases in the linearized version of the MSG model and in the MINIMOD model. Japan is not shown in tables 7-2–7-4 because the MINIMOD model does not have separate equations for Japan. Both of these models assume that prices or wages (or both) are sticky, but neither model is fit directly to the data. The parameters of the MSG model are calibrated to correspond to annual time periods. The MINIMOD model is a two-country aggregate (over variables and across countries) of a quarterly multicountry model. (Note that the unanticipated increases are not comparable with the simulation results reported in the supplemental volume of this conference proceedings. The MINIMOD model uses a tighter type-3 convergence criterion than in the conference pro-

Table 7-3. Effects of a 4 Percent, One-Time Increase in the U.S. Money Supply in the MSG Rational Expectations Model

Percent change from baseline unless otherwise noted

	United States				Japan				ROECD			
Year	Y^a	P^b	RS^c	E^d	Y	P	RS	E	Y	P	RS	E
					Increase unanticipated							
1985	2.6	0.4	−6.7	−7.0	−0.9	−0.3	−0.8	n.a.	−1.1	−0.4	−0.9	n.a.
1986	0.5	1.4	−0.7	−1.2	0.4	−0.6	−1.2	n.a.	0.6	−0.8	−1.3	n.a.
1987	0.5	2.3	−0.9	−2.0	0.3	−0.6	−0.5	n.a.	0.3	−0.7	−0.5	n.a.
1988	0.2	3.0	−0.2	−1.7	0.4	−0.5	−0.3	n.a.	0.5	−0.6	−0.3	n.a.
1989	0.0	3.7	0.3	−1.9	0.3	−0.3	0.1	n.a.	0.4	−0.4	0.1	n.a.
1990	−0.2	4.3	0.7	−2.1	0.3	0.0	0.4	n.a.	0.3	−0.1	0.4	n.a.
					Increase anticipated three years in advance							
1985	0.3	0.1	0.2	−2.0	−0.2	−0.1	−0.2	n.a.	−0.3	−0.1	−0.2	n.a.
1986	0.2	0.3	0.7	−2.4	−0.1	−0.3	−0.5	n.a.	−0.1	−0.3	−0.5	n.a.
1987	0.3	0.6	1.1	−3.7	−0.1	−0.5	−0.7	n.a.	−0.1	−0.5	−0.7	n.a.
1988	2.0	1.1	−5.7	−5.7	−0.3	−0.8	−1.1	n.a.	−0.4	−0.8	−1.3	n.a.
1989	0.2	1.9	−0.5	−1.3	0.5	−0.9	−1.0	n.a.	0.7	−0.9	−1.1	n.a.
1990	0.3	2.4	−0.7	−2.1	0.3	−0.8	−0.5	n.a.	0.4	−0.7	−0.4	n.a.

Source: Data provided by Warrick McKibbin.
a–d. As defined in notes to table 7-1.

Table 7-4. Effects of a 4 Percent, One-Time Increase in the U.S. Money Supply in the MINIMOD Two-Country Rational Expectations Model, Excluding Japan

Percent change from baseline unless otherwise noted

	United States				ROECD			
Year	Y^a	P^b	RS^c	E^d	Y	P	RS	E
				Increase unanticipated				
1985	0.82	0.13	−0.39	−8.4	0.05	0.02	−0.23	8.4
1986	1.4	0.58	−1.2	−7.7	−0.16	0.10	−0.10	7.7
1987	1.3	1.1	−0.79	−6.6	−0.37	0.22	−0.08	6.6
1988	0.94	1.7	−0.71	−5.9	−0.54	0.37	−0.06	5.9
1989	0.64	2.2	−0.63	−5.2	−0.67	0.48	−0.04	5.2
1990	0.36	2.5	−0.62	−4.6	−0.78	0.57	−0.62	4.6
				Increase anticipated three years in advance				
1985	0.04	0.03	0.38	−3.7	0.08	−0.00	−0.10	3.7
1986	0.38	0.22	0.81	−4.4	0.17	−0.01	−0.03	4.4
1987	0.72	0.63	1.5	−5.4	0.25	−0.05	−0.04	5.4
1988	1.1	1.3	−0.64	−6.4	0.20	−0.07	−0.04	6.4
1989	0.89	2.0	−0.60	−5.4	−0.00	−0.00	−0.00	5.4
1990	0.46	2.6	−0.45	−4.7	−0.12	0.11	0.03	4.7

Source: Data provided by Paul R. Masson.
a–d. As defined in notes to table 7-1.

ceedings, and the MSG results are from a linearized version of the nonlinear model used for the conference proceedings.) The results from the linear MSG model were provided by Warwick McKibbin.

Note that with both of these models there is a large difference between the effects of anticipated and unanticipated increases in the money supply. The effect on output is smaller when the increase is anticipated because the advance notice of the money shock increases prices and wages before the shock takes place. This is a common feature of all rational expectations models and is what makes the policy implications of these models so different from "nonrational" expectations models. The difference also holds for government spending simulations (not shown here). For unanticipated changes in policy, the differences between rational expectations models and more traditional models are not so marked.

Conclusions

The aim of this paper has been to discuss the treatment of expectations in policy-oriented empirical multicountry models. I have argued that the most promising way to treat expectations, at least within the context of structural models, is to try the rational expectations approach. This view is based largely on my own experience with a new multicountry econometric model, and I feel that the discussion of the solution and estimation of the model in this chapter, although in a preliminary form, and the simulation results are convincing evidence.

The rational expectations approach is not without its own drawbacks, which include the implicit assumption of common knowledge of the model and the policies that are being followed by each country, as well as the omission of a formal learning mechanism. But computational complexity is no longer a serious drawback of the rational expectations approach. Except for computing full-information, maximum-likelihood estimates, the computation time required to accommodate rational expectations in a large multicountry model, even when half of the equations have future expectations terms, is not at all prohibitive. Because existing large conventional econometric models are rarely if ever estimated with full-information methods anyway, this exception is irrelevant for many users.

Four of the twelve multicountry models examined at this conference are rational expectations models. Given that the methods (such as the extended-path algorithm) for estimating and solving large rational expectations models such as these have been fully developed and tested only in the past two or three years, a third of the total representation seems like a large proportion for rational expectations models. Although some of the rational expectations models in the group are pure simulation models not intended to serve as econometric models with estimated parameters and error variances, this large fraction indicates that the rational expectations approach might have more use in practical econometric policy evaluation in the years ahead.

Appendix: A Multicountry, Econometric Rational Expectations Model

In this appendix I briefly describe the quarterly econometric model used to illustrate many of the points made in the main text of the chapter. Although the number of equations in the model is fairly large, it is possible to list them in a compact way that aids intuitive understanding of how the model works. By scanning through the equations in table 7A-1, one can assess such things as how structural the model is, how nonlinear it is, how important are expectations, how the model is solved using the extended-path algorithm, and other issues discussed in the text. The variables are defined in table 7A-2. Note that an "L" before a symbol indicates the logarithm of that variable.

The model is based on quarterly data from national income accounts. In addition to the United States, quarterly models were estimated for Canada, France, Italy, Germany, Japan, and the United Kingdom. If there is no numerical suffix to a variable, the variable refers to the United States; a number suffixed to a variable refers to one of the other countries: Canada, 1; France, 2; Germany, 3; Italy, 4; Japan, 5; and the United Kingdom, 6. The estimation period is from the first quarter of 1971 through the last quarter of 1984, covering the period of floating exchange rates. Note in interpreting table 7A-1 that the units of the variables differ greatly across countries because of different currency units and different base years for computing real magnitudes. In the reports of the simulation results I have translated to a common base year and currency.

In this model aggregate demand determines output in the short run because the aggregate wage and price level is in essence predetermined in each quarter—only a fraction of the workers adjust their wages each quarter. Aggregate demand is built up from disaggregated spending decisions—consumption, investment, government, and net export. The important price variables in these demand equations are the real long-term interest rate *RRL* (rational expectations of future inflation are a factor here) and the relative price of domestic goods to foreign goods (the exchange rate is a factor here).

Income and the real rate of interest are the two factors assumed to affect consumption. The real interest rate is defined as the nominal long-term rate on bonds (*RL*) less the expected rate of inflation over a period of four quarters. This type of equation was estimated for consumer durables, and, with the capital term omitted, for services and nondurables for the United States. For Canada, Japan, France, and the United Kingdom a similar group of three equations was estimated. For Germany and Italy only total aggregate consumption was estimated. Hence a total of seventeen consumption equations appear in the model. Hansen's estimator was used to estimate the equations with the real rate of interest. Strong negative effects from the real interest rate were estimated for durables in the United States, Canada, and Japan and for total consumption in Germany. (For the United States, disposable income appears in the consumption equation; currently the income side of the model is not complete—instead, a simple auxiliary equation relating real GNP to real disposable income was used.)

The investment equations include output lagged one and two periods ("accelerator" effects) and the real rate of interest (long-term) as previously defined. This general form of the equation was estimated for equipment, nonresidential structures, residential structures, and inventory investment in the United States as well as in Canada, France, and the United Kingdom. Total fixed investment equations were estimated for Germany, Italy, and Japan. No inventory equation was estimated for Italy because of data limitations. With the exception of equipment investment in France, the real interest rate had a strong negative effect on investment for every country and every type of investment, including inventory investment. The accelerator terms relating to output were also strong. The lagged output terms in general had opposite signs of about the same magnitude.

In the current version of the model, government spending is exogenous, so that the remaining component of aggregate demand in the model is net exports. The import and export equations include

Table 7A-1. Equations of the Model[a]

Equation	*LHS*	*Coefficient*	*RHS*	*Equation*	*LHS*	*Coefficient*	*RHS*	*Equation*	*LHS*	*Coefficient*	*RHS*
						Short- and long-term interest rates[b] *and exchange rate parity*					
1	*RS*	−0.234	*CNST*	6	*RS5*	0.770	*CNST*	12	LE5	1.000	LE5(+1)
		−0.770	LM			−0.766	LM5			0.250	*RS5*
		0.570	LM(−1)			0.696	LM5(−1)			−0.250	*RS*
		0.770	LP			0.766	LP5				
		−0.570	LP(−1)			−0.696	LP5(−1)	13	LE6	1.000	LE6(+1)
		0.194	LY			0.004	LY5			0.250	*RS6*
										−0.250	*RS*
2	*RS1*	−0.757	*CNST*	7	*RS6*	−1.217	*CNST*				
		−0.509	LM1			−0.568	LM6	14	*RL*	0.100	*RS*
		0.447	LM1(−1)			0.444	LM6(−1)			0.900	*RL*(+1)
		0.509	LP1			0.568	LP6				
		−0.447	LP1(−1)			−0.444	LP6(−1)	15	*RL1*	0.100	*RS1*
		0.207	LY1			0.322	LY6			0.900	*RL1*(+1)
3	*RS2*	0.359	*CNST*	8	LE1	1.000	LE1(+1)	16	*RL2*	0.100	*RS2*
		−0.677	LM2			0.250	*RS1*			0.900	*RL2*(+1)
		0.182	LM2(−1)			−0.250	*RS*				
		0.677	LP2					17	*RL3*	0.100	*RS3*
		−0.182	LP2(−1)	9	LE2	1.000	LE2(+1)			0.900	*RL3*(+1)
		0.356	LY2			0.250	*RS2*				
						−0.250	*RS*	18	*RL4*	0.100	*RS4*
4	*RS3*	−2.202	*CNST*							0.900	*RL4*(+1)
		−0.654	LM3	10	LE3	1.000	LE3(+1)				
		0.188	LM3(−1)			0.250	*RS3*	19	*RL5*	0.100	*RS5*
		0.654	LP3			−0.250	*RS*			0.900	*RL5*(+1)
		−0.188	LP3(−1)								
		0.666	LY3	11	LE4	1.000	LE4(+1)	20	*RL6*	0.100	*RS6*
						0.250	*RS4*			0.900	*RL6*(+1)
5	*RS4*	−2.518	*CNST*			−0.250	*RS*				
		−0.569	LM4								
		0.399	LM4(−1)								
		0.569	LP4								
		−0.399	LP4(−1)								
		0.394	LY4								
						Consumption demand equations[c]					
21	*CD*	−145.173	*CNST*	27	*CD2*	−4.866	*CNST*	33	*CN5*	4,549.568	*CNST*
		0.486	*YD*			0.826	*CD2*(−1)			0.818	*CN5*(−1)
		−0.338	*KNCD*(−1)			0.015	*Y2*			0.021	*Y5*
		−72.656	*RRLC*								
				28	*CN2*	25.572	*CNST*	34	*CS5*	355.022	*CNST*
22	*CN*	0.282	*CNST*			0.620	*CN2*(−1)			0.733	*CS5*(−1)
		1.004	*CN*(−1)			0.102	*Y2*			0.068	*Y5*
		0.000	*YD*								
				29	*CS2*	−6.666	*CNST*	35	*CD6*	−1.479	*CNST*
23	*CS*	1.937	*CNST*			0.927	*CS2*(−1)			0.783	*CD6*(−1)
		0.995	*CS*(−1)			0.025	*Y2*			0.019	*Y6*
		0.003	*YD*								
				30	*C3*	3.378	*CNST*	36	*CN6*	8.140	*CNST*
24	*CD1*	−2.524	*CNST*			0.751	*C3*(−1)			0.683	*CN6*(−1)
		0.508	*CD1*(−1)			0.143	*Y3*			0.064	*Y6*
		0.074	*Y1*			−84.390	*RRLC3*				
		−3.573	*RRLC1*					37	*CS6*	−0.534	*CNST*
				31	*C4*	858.480	*CNST*			0.971	*CD6*(−1)
25	*CN1*	1.801	*CNST*			0.919	*C4*(−1)			0.009	*Y6*
		0.925	*CN1*(−1)			0.043	*Y4*				
		0.006	*Y1*								
		−0.641	*RRLC1*	32	*CD5*	−1,209.743	*CNST*				
						0.507	*CD5*(−1)				
26	*CS1*	0.469	*CNST*			0.024	*Y5*				
		0.960	*CS1*(−1)			−2,359.463	*RRLC5*				
		0.007	*Y1*								

Table 7A-1 (*continued*)

Equation	*LHS*	*Coefficient*	*RHS*	*Equation*	*LHS*	*Coefficient*	*RHS*	*Equation*	*LHS*	*Coefficient*	*RHS*
					U.S. investment demand						
38	*INE*	−41.742	*CNST*	41	*II*	−13.486	*CNST*	44	*IR*1	1.341	*CNST*
		0.578	*INE*(−1)			0.267	*Y*(−1)			1.019	*IR*1(−1)
		0.120	*Y*(−1)			−0.251	*Y*(−2)			−0.414	*IR*1(−2)
		−0.057	*Y*(−2)			−213.851	*RRL*			0.074	*Y*1(−1)
		−45.648	*RRL*							−0.066	*Y*1(−2)
				42	*INE*1	−1.187	*CNST*			−3.615	*RRL*1
39	*INS*	−3.541	*CNST*			0.817	*INE*1(−1)				
		0.953	*INS*(−1)			0.054	*Y*1(−1)	45	*II*1	−1.774	*CNST*
		0.038	*Y*(−1)			−0.027	*Y*1(−2)			0.484	*II*1(−1)
		−0.034	*Y*(−2)			−4.543	*RRL*1			0.445	*Y*1(−1)
		−7.471	*RRL*							−0.430	*Y*1(−2)
				43	*INS*1	−1.183	*CNST*			−11.749	*RRL*1
40	*IR*	43.159	*CNST*			0.982	*INS*1(−1)				
		0.289	*Y*(−1)			0.012	*Y*1(−1)				
		−0.283	*Y*(−2)			−5.762	*RRL*1				
		−163.475	*RRL*								
					Non-U.S. investment demand						
46	*INE*2	−6.962	*CNST*	51	*II*3	−66.486	*CNST*	56	*INE*6	−2.291	*CNST*
		0.762	*INE*2(−1)			0.091	*Y*3(−1)			0.354	*INE*6(−1)
		0.128	*Y*2(−1)			−1,132.849	*RRL*3			0.062	*Y*6(−1)
		−0.098	*Y*2(−2)							−6.865	*RRL*6
				52	*IF*4	835.585	*CNST*				
47	*INS*2	15.827	*CNST*			0.859	*IF*4(−1)	57	*INS*6	8.599	*CNST*
		0.762	*INS*2(−1)			0.014	*Y*4(−1)			0.425	*INS*6(−1)
		−9.552	*RRL*2			−1,575.515	*RRL*4			0.023	*Y*6(−1)
										−0.023	*Y*6(−2)
48	*IR*2	9.940	*CNST*	53	*IN*5	−3,401.796	*CNST*			−12.709	*RRL*6
		0.845	*IR*2(−1)			0.800	*IN*5(−1)				
		0.013	*Y*2(−1)			0.034	*Y*5(−1)	58	*IR*6	2.322	*CNST*
		−0.013	*Y*2(−2)			0.023	*Y*5(−2)			0.738	*IR*6(−1)
		−26.967	*RRL*2			−13,900.496	*RRL*5			0.015	*Y*6(−1)
										−0.015	*Y*6(−2)
49	*II*2	1.213	*CNST*	54	*IR*5	2,192.522	*CNST*			−4.181	*RRL*6
		0.690	*II*2(−1)			0.776	*IR*5(−1)				
		0.386	*Y*2(−1)			0.153	*Y*5(−1)	59	*II*6	0.102	*CNST*
		−0.386	*Y*2(−2)			−0.153	*Y*5(−2)			0.530	*II*6(−1)
		−5.063	*RRL*2			−305.174	*RRL*5			0.206	*Y*6(−1)
										−0.206	*Y*6(−2)
50	*IF*3	7.365	*CNST*	55	*II*5	281.755	*CNST*			−10.242	*RRL*6
		0.752	*IF*3(−1)			0.300	*II*5(−1)				
		0.058	*Y*3(−1)			0.006	*Y*5(−1)				
		−329.282	*RRL*3			−9,352.189	*RRL*5				
					Export and import demand equations						
60	LEX	−2.753	*CNST*	63	LEX3	−2.196	*CNST*	66	LEX6	−3.434	*CNST*
		0.688	LEX(−1)			0.465	LEX3(−1)			0.292	LEX6(−1)
		−0.189	LPEX			−0.599	LPEX3			−0.260	LPEX6
		0.189	LPIM			0.599	LPIM3			0.260	LPIM6
		0.553	LYW			0.693	LYW3			0.802	LYW6
61	LEX1	−4.066	*CNST*	64	LEX4	−2.075	*CNST*	67	LIM	−7.232	*CNST*
		0.535	LEX1(−1)			0.626	LEX4(−1)			0.432	LIM(−1)
		−0.369	LPEX1			−0.058	LPEX4			0.381	LPEX
		0.369	LPIM1			0.058	LPIM4			−0.381	LPIM
		0.731	LYW1			0.764	LYW4			1.370	LY
62	LEX2	−5.496	*CNST*	65	LEX5	−0.501	*CNST*	68	LIM1	−1.350	*CNST*
		0.449	LEX2(−1)			0.837	LEX5(−1)			0.525	LIM1(−1)
		−0.382	LPEX2			−0.154	LPEX5			0.133	LPEX1
		0.382	LPIM2			0.154	LPIM5			−0.133	LPIM1
		1.109	LYW2			0.323	LYW5			0.625	LY1

Table 7A-1 (*continued*)

Equation	LHS	Coefficient	RHS	Equation	LHS	Coefficient	RHS	Equation	LHS	Coefficient	RHS
69	LIM2	-3.765	CNST	71	LIM4	-13.356	CNST	73	LIM6	-1.815	CNST
		0.656	LIM2(-1)			0.161	LIM4(-1)			0.630	LIM6(-1)
		0.225	LPEX2			0.564	LPEX4			0.016	LPEX6
		-0.225	LPIM2			-0.564	LPIM4			-0.016	LPIM6
		0.811	LY2			1.912	LY4			0.610	LY6
70	LIM3	-3.637	CNST	72	LIM5	-2.586	CNST				
		0.359	LIM3(-1)			0.889	LIM5(-1)				
		0.420	LPEX3			0.159	LPEX5				
		-0.223	LPIM3			-0.159	LPIM5				
		1.033	LY3			0.308	LY5				
						Income identities					
74	Y	1	=CD	77	Y3	1	=C3	79	Y5	1	=CD5
		1	+CN			1	+IF3			1	+CN5
		1	+CS			1	+II3			1	+CS5
		1	+INE			1	+G3			1	+IR5
		1	+INS			1	+EX3			1	+IN5
		1	+IR			-1	-IM3			1	+II5
		1	+II							1	+G5
		1	+G	78	Y4	1	=C4			1	+EX5
		1	+EX			1	+IF4			-1	-IM5
		-1	-IM			1	+II4				
						1	+G4	80	Y6	1	=CD6
75	Y1	1	=CD1			1	+EX4			1	+CN6
		1	+CN2			-1	-IM4			1	+CS6
		1	+CS1							1	+INE6
		1	+INE1							1	+INS6
		1	+INS1							1	+IR65
		1	+IR1							1	+II6
		1	+II1							1	-G6
		1	+G1							1	+EX6
		1	+EX1							-1	-IM6
		-1	-IM1								
76	Y2	1	=CD2								
		1	+CN2								
		1	+CS2								
		1	+INE2								
		1	+INS2								
		1	+IR3								
		1	+II2								
		1	+G2								
		1	+EX2								
		-1	-IM2								
						Contract wage equations[4]					
81	LX	0.125	LW	82	LX1	0.125	LW1	83	LX2	0.125	LW2
		0.125	LW(+1)			0.125	LW1(+1)			0.125	LW2(+1)
		0.125	LW(+2)			0.125	LW1(+2)			0.125	LW2(+2)
		0.125	LW(+3)			0.125	LW1(+3)			0.125	LW2(+3)
		0.125	LP			0.125	LP1			0.125	LP2
		0.125	LP(+1)			0.125	LP1(+1)			0.125	LP2(+1)
		0.125	LP(+2)			0.125	LP1(+2)			0.125	LP2(+2)
		0.125	LP(+3)			0.125	LP1(+3)			0.125	LP2(+3)
		0.250	YGAP			0.250	YGAP1			0.250	YGAP2
		0.250	YGAP(+1)			0.250	YGAP1(+1)			0.250	YGAP2(+1)
		0.250	YGAP(+2)			0.250	YGAP1(+2)			0.250	YGAP2(+2)
		0.250	YGAP(+3)			0.250	YGAP1(+3)			0.250	YGAP2(+3)

Table 7A-1 (*continued*)

Equation	*LHS*	*Coefficient*	*RHS*	*Equation*	*LHS*	*Coefficient*	*RHS*	*Equation*	*LHS*	*Coefficient*	*RHS*
84	LX3	0.125	LW3	86	LX5	0.125	LW5	87	LX6	0.125	LW6
		0.125	LW3(+1)			0.125	LW5(+1)			0.125	LW6(+1)
		0.125	LW3(+2)			0.125	LW5(+2)			0.125	LW6(+2)
		0.125	LW3(+3)			0.125	LW5(+3)			0.125	LW6(+3)
		0.125	LP3			0.125	LP5			0.125	LP6
		0.125	LP3(+1)			0.125	LP5(+1)			0.125	LP6(+1)
		0.125	LP3(+2)			0.125	LP5(+2)			0.125	LP6(+2)
		0.125	LP3(+3)			0.125	LP5(+3)			0.125	LP6(+3)
		0.250	YGAP3			0.250	YGAP5			0.250	YGAP6
		0.250	YGAP3(+1)			0.250	YGAP5(+1)			0.250	YGAP6(+1)
		0.250	YGAP3(+2)			0.250	YGAP5(+2)			0.250	YGAP6(+2)
		0.250	YGAP3(+3)			0.250	YGAP5(+3)			0.250	YGAP6(+3)
85	LX4	0.125	LW4								
		0.125	LW4(+1)								
		0.125	LW4(+2)								
		0.125	LW4(+3)								
		0.125	LP4								
		0.125	LP4(+1)								
		0.125	LP4(+2)								
		0.125	LP4(+3)								
		0.250	YGAP4								
		0.250	YGAP4(+1)								
		0.250	YGAP4(+2)								
		0.250	YGAP4(+3)								
Average wage and domestic price equations											
90	LW	0.250	LX	97	LP	0.012	CNST	103	LP6	0.038	CNST
		0.250	LX(−1)			0.883	LP(−1)			0.792	LP6(−1)
		0.250	LX(−2)			0.092	LW			0.168	LW6
		0.250	LX(−3)			0.024	LPIM			0.039	LPIM6
						−0.0003	T			−0.0007	T
91	LW1	0.250	LX1								
		0.250	LX1(−1)	98	LP1	0.022	CNST	104	LPIM	0.346	CNST
		0.250	LX1(−2)			0.875	LP1(−1)			0.854	LPIM(−1)
		0.250	LX1(−3)			0.036	LW1			0.145	LFP
						0.088	LPIM1				
92	LW2	0.250	LX2			−0.0004	T	105	LPIM1	0.219	CNST
		0.250	LX2(−1)							0.881	LPIM1(−1)
		0.250	LX2(−2)	99	LP2	0.012	CNST			0.118	LFP1
		0.250	LX2(−2)			0.854	LP2(−1)				
						0.112	LW2	106	LPIM2	0.025	CNST
93	LW3	0.250	LX3			0.033	LPIM2			0.941	LPIM2(−1)
		0.250	LX3(−1)			−0.0012	T			0.058	LFP2
		0.250	LX3(−2)								
		0.250	LX3(−3)	100	LP3	0.026	CNST	107	LPIM3	0.012	CNST
						0.883	LP2(−1)			0.940	LPIM3(−1)
94	LW4	0.250	LX4			0.090	LW2			0.060	LFP3
		0.250	LX4(−1)			0.025	LPIM2				
		0.250	LX4(−2)			−0.0006	T	108	LPIM4	−0.397	CNST
		0.250	LX4(−3)							0.905	LPIM4(−1)
				101	LP4	0.015	CNST			0.094	LFP4
95	LW5	0.250	LX5			0.873	LP4(−1)				
		0.250	LX5(−1)			0.073	LW4	109	LPIM5	−0.468	CNST
		0.250	LX5(−2)			0.053	LPIM4			0.908	LPIM5(−1)
		0.250	LX5(−3)			−0.0007	T			0.091	LFP5
96	LW6	0.250	LX6	102	LP5	0.045	CNST	110	LPIM6	0.320	CNST
		0.250	LX6(−1)			0.914	LP5(−1)			0.816	LPIM6(−1)
		0.250	LX6(−2)			0.069	LW5			0.183	LFP6
		0.250	LX6(−3)			0.015	LPIM5				
						−0.0013	T	111	LPEX	0.081	CNST
										1.103	LP

Table 7A-1 (*continued*)

Equation	LHS	Coefficient	RHS	Equation	LHS	Coefficient	RHS	Equation	LHS	Coefficient	RHS
112	LPEX1	0.052	CNST	114	LPEX3	−0.020	CNST	116	LPEX5	−0.091	CNST
		1.074	LP1			1.044	LP3			0.563	LP5
113	LPEX2	−0.034	CNST	115	LPEX4	0.026	CNST	117	LPEX6	0.023	CNST
		1.952	LP2			0.978	LP4			0.983	LP6

Source: National income accounts and author's calculations.

a. "LHS" denotes left-hand-side variables, and "RHS" denotes right-hand-side variables: for the latter, the number of lags (−) or leads (+) is indicated in parentheses. An "L" preceding a variable indicates logarithm: a number suffixed to a variable indicates the country—other than the United States (which takes no suffix)—referred to (1, Canada; 2, France; 3, Germany; 4, Italy; 5, Japan; 6, United Kingdom); *CNST* denotes a constant. Definitions of the variables appear in table 7A-2.

b. Real long-term interest rate definitions:

RRL = *RL* − L*P*(+4) + L*P*
*RRL*1 = *RL*1 − L*P*1(+4) + L*P*1
*RRL*2 = *RL*2 − L*P*2(+4) + L*P*2
*RRL*3 = *RL*3 − L*P*3(+4) + L*P*3
*RRL*4 = *RL*4 − L*P*4(+4) + L*P*4
*RRL*5 = *RL*5 − L*P*5(+4) + L*P*5
*RRL*6 = *RL*6 − L*P*6(+4) + L*P*6
RRLC = *SCALE***RRL*
*RRLC*1 = *SCALE*1**RRL*1
*RRLC*3 = *SCALE*3**RRL*3
*RRLC*5 = *SCALE*5**RRL*5
SCALE = Exponential trend.

c. U.S. durable stock and disposable income equation: *KNCD* = *KNCD*(−1) + (*CD*/4) − *DCD*(−1); every fourth quarter, *DCD* = *KNCD**0.0515, with *DCD* = *DCD*(−1) for other quarters; *YD* = −60 + 0.741**Y*.

d. Definitions of *YGAP*:

YGAP = L*Y* − 7.034 + 0.00657**T*
*YGAP*1 = L*Y*1 − 4.595 + 0.0069**T*
*YGAP*2 = L*Y*2 − 6.747 + 0.0065**T*
*YGAP*3 = L*Y*3 − 6.906 + 0.0052**T*
*YGAP*4 = L*Y*4 − 11.08 + 0.0059**T*
*YGAP*5 = L*Y*5 − 11.72 + 0.0108**T*
*YGAP*6 = L*Y*6 − 5.301 + 0.0036**T*.

the price of imports and the price of exports. Domestic output is included in the import equations for each country, and a trade-weighted average of foreign outputs is included in the export equation. These two equations were estimated in logarithmic form for each country, with the coefficients of import price and export price constrained to be equal but with opposite signs. For each equation, an increase in the relative price of exports to imports increases import demand and lowers export demand. These equations are dynamic in that lagged dependent variables are included in the estimated equations.

Wages in the model are determined according to the staggered contract approach used in Taylor (1979c). That is, wages are assumed to be bid up relative to expected future wages and prices if aggregate demand (as measured by actual output) is above potential output. Potential output is assumed to grow at a constant rate. In this version of the model there is no effect on potential output from increases in the capital stock. In addition, all countries are assumed to have a four-quarter wage setting with no synchronization. This simplifying assumption will be relaxed in future work. The parameters of the wage equation are not estimated separately for each country but are simply taken as representative values from previous research. Prices are set according to a markup over wages and import prices, with an allowance for trend increases in productivity. The equations are estimated for all seven countries, with allowance for slow adjustment so that margins fall in the short run after an increase in wages or import prices. Eventually the full wage and import price increase is passed through. The coefficient on wages is about 3.5 times as large as the coefficient on import prices for the United States. With the exception of Canada, the coefficient on wages is larger than the coefficient on import prices.

For each of the seven countries import prices are assumed to relate directly to an average of prices in the rest of the world, converted into domestic currency units by using the exchange rate between each country. The effect of exchange rates on domestic prices occurs through this channel in that domestic prices are affected by import prices as described above. Export prices are assumed to move with a geometric lag in response to domestic prices.

Long- and short-term interest rate and exchange rate equations for the different countries are shown in the first part of table 7A-1. Standard partial-

Table 7A-2. Definitions of Variables

Variable	Definition
	Financial variables
RS	Short-term interest rate
RL	Long-term interest rate
RRL	Real long-term interest rate
RRLC	Exponential trend times real long-term interest rate
E(i)	Exchange rate (dollars per unit of foreign exchange); $i = 1, 2, \ldots 6$
M	Money supply (M1 definition)
	Real GNP and its spending components[a]
Y	Real GNP (or GDP)
C	Total consumption
CD	Consumption of durable goods
CS	Consumption of services
CN	Consumption of nondurable goods
YD	Disposable income
INS	Investment in nonresidential structures
INE	Investment in nonresidential equipment
IR	Residential investment
II	Inventory investment
IF	Fixed investment
EX	Exports in national income accounts
IM	Imports in national income accounts
G	Government purchases of goods and services
	Wages and prices
X	Unobservable "contract" wage
W	Average wage
P	GNP (or GDP) deflator
PIM	Import price deflator
PEX	Export price deflator
YGAP	Proportional gap between real GNP and potential GNP
PW	Trade-weighted average foreign price
EW	Trade-weighted average exchange rate
FP	Trade-weighted foreign price level in domestic currency units
YW	Trade-weighted average of foreign outputs
T	Time term

a. Billions of local currency units; base year varies.

adjustment, money demand equations were estimated for each country and inverted to give an equation for the short-term interest rate *RS*. The money supply is exogenous in the current version of the model. The short-term interest rates are then used to determine long-term rates through forward-looking term-structure equations as shown in table 7A-1. These equations have not yet been estimated. The coefficient of future short-term rates is assumed to decline geometrically at the same rate in all countries. Finally, the exchange rate *E* is related to the differential between interest rates in each country.

In table 7A-1 the equations are listed in the order in which they are solved in the Gauss-Siedel iterations. The interest rates and exchange rates are determined first, followed by the components of aggregate demand—consumption, investment, and net exports. Next, the equations for wages and prices in each country are solved. The world weighted averages of prices and output (not shown here) are solved last.

Comment by Bennett T. McCallum

John Taylor's paper is, as anyone who knows him would anticipate, well thought out and clearly presented. The model that it develops is a relatively small one that is unusually clean and comprehensible in its specification. In terms of its properties, the simulation results reported by Bert Hickman (see chapter 5) evidently include no cases in which the responses seem implausible or are outliers relative to those of the other models. This encouraging performance is a consequence not only of Taylor's skill but also of his basic approach—that is, to use a relatively small model that is firmly grounded in sound theoretical ideas. As it happens, I have in the past argued that the precise way in which money wages are set, in the most idiosyncratic and crucial equation of Taylor's model (see the appendix to his paper), has some undesirable theoretical properties (McCallum 1982). In comparison with its counterpart in other working macroeconometric models, however, even this feature looks rather good.

The main purpose of Taylor's paper is to focus on the role of expectations and especially the use of the rational expectations hypothesis in macroeconometric modeling. In this regard, his work clearly demonstrates that it is feasible to incorporate rational expectations in a moderately large model. I have no major disagreements with his discussion, but my emphasis would be different in several ways. These will be discussed in what follows.

First, it is quite useful in discussing rational expectations econometrics to keep in mind the distinction between the two activities of *estimation* and *simulation*. Usually researchers will adopt rational expectations either in both of these activities or in neither. But it is logically possible for someone to estimate a model using some other expectational hypothesis and then to simulate it using rational expectations. (In fact, it is even possible to go the other way, though such an approach does not seem sensible.) This assertion might appear to contradict the argument that it is not possible to "patch up" econometric models by putting in rational expectations after the fact. But what adherents of that argument actually have in mind is not, I believe, a denial of my proposition as a matter of logic, but rather a judgment that in practice most models that have been estimated without rational expectations have had specifications in which distributed-lag ex-

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pectational proxies are not clearly distinguished from distributed lags that enter for other reasons (for example, adjustment costs). That distinction is, of course, crucial. Unless it is observed, the econometrician will muddle together structural parameters and the coefficients of agents' forecasting formulas—with consequences that can be highly undesirable. Explicitness with regard to expectational variables is necessary for useful simulations of models that assume rational expectations.

My reason for emphasizing the distinction between estimation and simulation is that the basic rationale for using rational expectations is different in these two activities. Specifically, at the estimation stage one wants to use the rational expectations assumption if agents have in fact formed expectations during the sample period in a manner that approximates the substantive condition implied by this assumption—namely, that expectational errors are uncorrelated with variables known to agents at the time they formed their expectations. When conducting simulations, by contrast, one wants to use the rational expectations assumption if the policy experiment that the simulation depicts is one that would be likely to bring about a significant change in the time-series properties of the model's variables (a change, that is, relative to the sample period). The point, of course, is that such changes will tend to induce purposeful agents to change their expectational rules of thumb—that is, the coefficients in their forecasting formulas. Because of this basic difference in rationale, it seems entirely possible that a careful researcher might want to use rational expectations in policy simulations even if he believes that rational expectations would provide a bad description of actual expectational behavior during the utilized sample period.

Second, I find Taylor's discussion of four main types of simulation exercises to be quite useful. It was the second of these, termed "comparison of policy rules," that Lucas (1976) had in mind in his famous "critique" and that was implicit in my foregoing comments. I am pleased that Taylor has not adopted the currently fashionable stance of denigrating that type of analysis on the grounds that, in actuality, one rarely sees clean-cut and long-lasting changes in policy rules—that is, regime changes. The claim about actuality in this critique of Lucas's critique is correct, of course, but it simply does not follow that this type of analysis is therefore unimportant. Developing knowledge of how an economy's operating characteristics would differ, on average, under different policy rules or institutional settings is what economics is primarily about and has been since the time of Ricardo. Lucas (1980) has argued to this effect on the basis of comparative advantage: this type of analysis is what professional economists can do better than others. Taylor's example of alternative exchange rate regimes makes the point nicely.

Third, Hickman (see chapter 5) and others have mentioned that simulations involving a one-time change in a policy instrument—the first of the four types of simulation listed by Taylor—should be regarded as useful mainly in describing the internal properties of the model at hand, as Taylor himself cautions. That is, the responses should not be construed as indicating reactions to policy, when the policy changes are unanticipated, because a policymaker cannot generate surprises at will. I quite agree with this view but would suggest (as Taylor seems to) that it also applies to the one-time changes that Taylor describes as "anticipated." At the time that future changes are announced, they come as totally unanticipated surprises (according to the simulation procedure). But anyone sympathetic to the basic idea of rational expectations should doubt the possibility that policymakers can systematically generate surprises even at the announcement stage.

My fourth point concerns "counterfactual historical analysis," the third type of simulation on Taylor's list. Although such exercises have considerable psychological appeal, from a logical perspective they would seem to amount to a limited type of policy-rule comparison. This item, in other words, seems to be a subset of Taylor's second type.

Finally, I should add a few words regarding estimation. As Taylor says, he estimated his model one equation at a time by means of an instrumental-variable procedure. His reason for doing so was that a full-information, maximum-likelihood procedure, which he would have preferred, remains computationally infeasible. Now this is certainly a defensible point of view, but it can be argued that the instrumental-variable approach has other advantages besides computational simplicity. One is the generic advantage of using "limited-information" estimators, namely, that they tend to "quarantine the effects of specification error" (Fisher 1970, 8). A second, more germane to the present discussion, supposes that a researcher wants to weaken the rational expectations assumption as applied to the sample period. In this case the researcher can assume that expectational errors are orthogonal to only a *subset* of the model's variables, with the subset possibly different for expectations of different variables, and then readily proceed with the instrumental-variable method. Thus the single-equation, instrumental-variable approach facilitates the use of assumptions positing various forms of "partial rationality."

There is, however, a desirable feature *not* possessed by instrumental-variable estimators that needs to be mentioned. What I have in mind is the notion that instrumental-variable estimation of rational expectations models does not require the absence of regime changes during the sample period. The idea is that, as long as expectational errors are orthogonal to the instruments, instrumental-variable estimators should be consistent even if there is a regime change that is not recognized. But the usual proof of consistency and the derivation of large-sample inference formulas both involve matrices of moments such as $T^{-1}Z'u$ and $T^{-1}Z'x$, where X, Z, and u refer to variables, instruments, and composite disturbances (inclusive of expectational errors), respectively, with T the sample size. Moreover, if a change in policy regime occurs, it would be remarkable if there were no change in the population counterparts of these moments. Consequently, unless that change is somehow accounted for, the sample moments will not be related to fixed population counterparts in the manner presumed by the standard analysis. Thus the instrumental-variable procedure will break down, certainly with respect to computed standard errors. The instrumental-variable procedure is not worse in this regard than the full-information, maximum-likelihood technique, but both apparently require either one regime throughout the sample or a model specification that takes explicit account of any regime change that takes place.

The foregoing summarizes my principal thoughts regarding Taylor's paper and the use of rational expectations in large multicountry econometric models. I should add one last point in closing: a recommendation that Taylor's paper be carefully read and studied.

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