Volume Title: NBER Macroeconomics Annual 1994, Volume 9

Volume Author/Editor: Stanley Fischer and Julio J. Rotemberg, eds.

Volume Publisher: MIT Press

Volume ISBN: 0-262-05172-4

Volume URL: http://www.nber.org/books/fisc94-1

Conference Date: March 11-12, 1994

Publication Date: January 1994

Chapter Title: Toward a Modern Macroeconomic Model Usable for Policy Analysis

Chapter Author: Eric M. Leeper, Christopher A. Sims

Chapter URL: http://www.nber.org/chapters/c11008

Chapter pages in book: (p. 81 - 140)

Eric M. Leeper and Christopher A. Sims
FEDERAL RESERVE BANK OF ATLANTA, AND YALE UNIVERSITY

Toward a Modern Macroeconomic Model Usable for Policy Analysis

1. *Introduction*

This paper presents a macroeconomic model that is both a completely specified dynamic general equilibrium and a probabilistic model for time series data. We view the model, perhaps with future refinements, as a potential competitor to existing IS/LM-based models that continue to be used for actual policy analysis in institutions such as the Federal Reserve Board, the Congressional Budget Office, or the International Monetary Fund. Our approach is also an alternative to recent efforts to calibrate real business cycle models. In contrast to these existing models, the one we present embodies all the following characteristics:

1. It generates a complete multivariate stochastic process model for the data it aims to explain, and the full specification is used in fitting the model.
2. It integrates modeling of nominal variables—money stock, price level, wage level, and nominal interest rate—with modeling real variables.
3. It allows for increasing costs in the production of capital goods, breaking the tight relationship of the return on investment with the capital–output ratio.
4. It treats both monetary and fiscal policy explicitly.
5. It is based on dynamic optimizing behavior of the private agents in the model.

The paper displays results of fitting the model that are encouraging, though still highly preliminary. A restricted version of the model fit only to data on three real variables performs approximately as well as an unrestricted vector autoregression (VAR), attributing most cyclical variability to real shocks but not to shocks in the "Solow residual." A 10-variable flexible price version of the model has not yet been successfully fitted, possibly because of fundamental problems with matching data on prices and real variables together with that type of model. A 10-variable sticky price model fits worse than an unrestricted VAR, though the structural model is much more tightly parameterized. It fits about as well as a naive no-change model. The estimated structure implies extreme price stickiness and effective monetary policy but attributes little of observed cyclical variability to monetary policy shocks (and none to fiscal shocks).

Now we discuss in more detail each of the five aspects of the model listed earlier.

(1) We regard the fact that we have a complete stochastic process model as important because it allows us to bring all aspects of the data to bear in generating estimates, improving efficiency relative to instrumental variables approaches that in effect use a narrow band of the available information in estimation. We also can investigate any desired aspect of the discrepancy between our model's implications and the behavior of the data, because we can simulate solutions of it. Any use of a model to trace out the impacts of policy interventions will require use of its full set of dynamic implications. If the model has been estimated by single-equation methods, important aspects of its dynamic structure may never have been confronted with the data, and its policy implications may be correspondingly unreliable. Of course, all these remarks apply a fortiori to a comparison of this model with ones that are largely calibrated informally rather than estimated.

(2) Though our model in many respects follows the spirit of real business cycle (RBC) modeling exercises as pioneered by Kydland and Prescott (1982), we do not follow that literature in paying attention almost exclusively to the behavior of real, rather than nominal aggregates. The RBC approach may be motivated in part by the fact that it has usually started from models in which real and price behavior dichotomizes, so that a complete model for the real variables in the system is possible without any reference to nominal variables. Of course, such models have few interesting implications for monetary policy—indeed, are in a sense aimed at showing that monetary policy is unimportant. Thus, one reason for our emphasis on including nominal variables is our aim of eventually exploring specifications in which price stickiness generates stronger nominal-real interactions. But even for models that do dichotomize, there is information about the model

structure in price as well as real data. RBC modelers sometimes invoke the idea that nominal aggregates are less likely to correspond to the theoretical constructs that appear in their models than are real aggregates. The wage, e.g., is claimed not to be a true market-clearing price as assumed in the theory. But since it is left unspecified what mechanisms produce the results of a market-clearing model in a world where measured price variables are not market-clearing prices, we find the argument for ignoring price variables unconvincing. There are, after all, strong reasons to suppose that measured quantity variables are distant from the corresponding theoretical constructs as well.

(3) The curvature in the transformation curve relating output of investment to output of capital is important in matching some aspects of observed cyclical behavior. We would like the technology to be able to generate fluctuations in real rates of return without corresponding large shifts in the level of the capital stock or output. With a relative price of C and I goods in the model, this can occur, with high rates of return generating above normal I, but only smooth growth in K. In sticky-price models, we would like to allow the possibility that a monetary or fiscal expansion could lower nominal interest rates. Increasing costs of capital goods production provide a mechanism that could contribute to this behavior in the model. Also, as recently shown by Nakornthob (1993), models that make prices and wages sticky in the sense that they cannot move discontinuously may easily have no equilibrium solution unless they include a variable relative price of C and I.

(4) Those few models in the RBC style that have considered "aggregate demand" policy variables have generally focused on monetary or fiscal policy alone. In fact, monetary and fiscal policy are intimately related, as Leeper (1991) and Sims (1994) show theoretically and as becomes evident in the estimation of a model like this. As we explain later, the parameters of monetary and fiscal policy equations must, in order to guarantee existence of a unique equilibrium, lie in a set of complicated geometry. While there are certain conditions under which monetary and fiscal policy dichotomize, with most of the equilibrium derivable from the monetary policy specification alone, these conditions are not generic. Even a model that aims mainly at guiding analysis of monetary or fiscal policy alone needs to treat both together to give reliable results. This is especially true in a period like the recent history of the United States, in which there have probably been changes in beliefs about the political feasibility of keeping taxation in line with government commitments to spending and debt service, at all levels of

government. Such shifts in beliefs could have impacts on prices and, in a model with sluggish prices, on real variables, not captured by models that ignore monetary-fiscal interactions.

(5) Recognizing the implications of dynamic optimizing behavior is important in macroeconomic modeling. But because this point has been emphasized first by natural rate theorists, who aimed to show that dynamic optimization by private agents undermined the effectiveness of aggregate demand management policies, and then by RBC modelers, who model a world without demand managers, Keynesians and monetarists have not embraced it. To be sure, Keynesian textbooks now include treatments of forward-looking theories of consumption and (sometimes) investment accelerator effects arising out of expectations, but these treatments of forward-looking behavior are in themselves incomplete. Furthermore, they are seldom integrated into the general-equilibrium versions of Keynesian models, which usually fall back instead on the ISLM framework, without even a clear distinction of real and nominal interest rates. Expectational elements are, paradoxically, emphasized more in the wage and price-setting components of such models than in their asset accumulation sectors. Yet the Keynesian and monetarist notion of nominal aggregate demand is at its root a theory about the relation of supply to demand for nominal government assets—debt and money. Demand for these assets depends critically on the public's beliefs about future government monetary and fiscal policy. Any model that is to be used to trace out the effects of monetary and fiscal policy needs to consider the implications of dynamic optimization, and this is especially true of a model that intends to explore the implications of price stickiness.

Previous successful attempts to use maximum likelihood to estimate a maximizing equilibrium model, such as that by Altug (1989), dealt with much simpler theoretical structures. Altug estimates a version of Kydland and Prescott's (1982) model, for which the simpler social planner's solution can be supported by a competitive equilibrium. The introduction of money requires solving the decentralized problem and brings with it the difficulties inherent in ensuring that a determinate equilibrium exists. Though we, like Altug, impose stationarity, her approach is to extract deterministic trends from the data, while ours is to allow unit and near-unit roots that imply long-term deviations from steady state. Most importantly, her approach postulates the existence of a measurement error in the data with well-defined stochastic properties but no economic interpretation. Our model's stochastic disturbances are all structural. This means in particular that we have a higher-dimensional vector of structural disturbances than in any previous model of this type. While we may eventually need to introduce something like measurement error in the model, we will do so reluctantly. The allocation of any substantial part of observed variation to such an uninterpreted source raises serious difficulties in using the model for prediction and policy analysis.

McGrattan (1994) and McGrattan, Rogerson, and Wright (1993) use maximum likelihood to estimate general equilibrium models with distorting taxes, so they also cannot rely on solving the social planner's problem. Like Altug, these authors introduce measurement errors as additional sources of uncertainty.

Watson (1993) adds measurement error that is by construction a linear function of the systematic component of the model. Though this unattractive perfect collinearity between error and systematic components is introduced in order to minimize the size of the error, Watson finds that in matching a standard RBC model to data, 40% to 60% of the variance must be attributed to economically uninterpreted sources.

2. *The Model*

2.1 CONSUMERS

Consumers divide their time between work, L, and leisure. They derive utility from consumption net of transactions cost, C^*, and leisure, $1 - L$, and discount utility at the rate of time preference, β. Consumers can hold two types of nominal assets, non-interest-bearing money, M, and interest-bearing government debt, B, and one real asset, capital, K. Income is earned from the capital and labor they rent to firms (which together make up factor income Y) and from the interest received from holding government debt, iB/P. In the sticky-price version of the model, firms make temporary pure profits and losses, and these are assumed to be returned to consumers as dividends. We assume consumers maximize[1]:

$$E\left[\int_0^\infty \exp\left(-\int_0^t \beta(s)\,ds\right)\frac{\left(C^{*\pi}(1-L)^{1-\pi}\right)^{1-\gamma}}{1-\gamma}\,dt\right], \tag{1}$$

1. Note that, though β and (as we will see below) π vary through time, this objective function does not run afoul of the well-known result that time-varying discount rates generate time inconsistency. The usual inconsistency result depends on the discount rate being thought of as indexed by the number of periods into the future at which the discounting is done. We think of consumers as understanding in advance that they will at the absolute date s discount at rate $\beta(s)$, so no time inconsistency is involved.

subject to

$$\lambda: \quad XC + QI + \tau + \frac{\dot{M} + \dot{B}}{P} = Y + \frac{iB}{P} \tag{2}$$

$$\nu: \quad XC^* + \phi VY = XC \tag{3}$$

$$\omega: \quad \dot{K} = I - \delta K \tag{4}$$

$$\xi: \quad Y = rK + wL + S \tag{5}$$

$$\psi: \quad V = \frac{PY}{M}. \tag{6}$$

We assume that $\pi \in (0, 1)$ and $\gamma > 0$. The Lagrange multiplier associated with each constraint is listed at the left. The agents' choice variables are C^*, C, L, I, M, B, K, Y, and V.

Equation (2) is the consumers' budget constraint, where C is gross consumption, I is investment, and τ is the level of lump-sum taxes. Consumption goods and investment goods are distinct from the output good, so they have prices X and Q relative to the output good. Government bonds earn the nominal rate of return i and P is the general price level, i.e., the price in dollars of the output good.

Equation (3) defines consumption net of transactions costs, with total output serving as a measure of the level of transactions at a given point in time. Costs are assumed to be increasing in the volume of transactions and in velocity, V. This simple transactions technology implies that costs approach zero as the level of real money balances approaches infinity, pushing C^* toward C. As the level of real balances approaches zero, transactions costs are unbounded, which implies that no nonmonetary equilibrium exists. This feature of the model could easily be modified by specifying a transactions technology that places an upper bound on transactions costs.

2.2 FIRMS

Equations (4) and (5) are standard. Equation (4) specifies the law of motion for capital, and Equation (5) defines income as the sum of dividends, S, with factor payments to capital and labor, which consumers receive from the firm. Equation (6) defines the income velocity of money.

Firms rent factor inputs from consumers, transform them into "output" according to a production technology, convert "output" into salable C goods and I goods according to another part of the production technology, and sell the C and I goods to consumers and the government. Because the technology is linear homogenous, there are no profits in a market-clearing competitive equilibrium, and we need not keep track of who receives the profits in the flexible price version of the model. In the sticky-price version we need treat profits as part of consumer income and must keep track of the difference between income and factor payments. The net profits from the firms' buying, selling and transforming activities are their maximand, S (written assuming that the number of firms matches the number of consumers so we can again avoid separate explicit market-clearing equations):

$$\max\Big\{X(C+g) + QI^* + A(\alpha K^\sigma + L^\sigma)^{1/\sigma} - rK - wL - \big((C+g)^\mu + \theta I^{*\mu}\big)^{1/\mu}\Big\}, \tag{7}$$

with $C + g$, I^* (defined later), K, and L as choice variables. To keep the production technology concave, $\sigma \leq 1$, and to keep the costs-of-adjustment convex, $\mu \geq 1$. The borderline case $\sigma = 0$ corresponds to Cobb-Douglas production, and $\sigma < 0$ corresponds to low elasticity of substitution. The g term that appears in this problem is the level of government purchases, which shares a relative price with the consumption good. Since government purchases are exogenous, their appearance does not affect the firms' optimization problem.[2]

2.3 GOVERNMENT

The government uses consumption goods in amount g for a purpose that yields no utility to individuals. It also takes responsibility for endowing newly born agents with the same wealth as existing agents and for redistributing equally to living agents the wealth of all those that die. Population grows at the (possibly varying) proportional rate n. With this device, the population can fluctuate while the model can maintain the assumption that there is an infinitely lived representative agent. Thus, the government operates with the budget constraint

$$\frac{\dot{M} + \dot{B}}{P} + \tau = \frac{iB}{P} + gX + QnK, \tag{8}$$

where QnK is net transfers of capital denominated in terms of output

2. The first-order conditions for the consumers and the firms appear in the Appendix.

goods. The variables in this equation are in per capita terms to avoid having to introduce additional market-clearing equations for the policy variables. Aggregate money and debt grow or shrink not only through the $\dot{M}$ and $\dot{B}$ terms in this equation, but also through net issuance of government paper to newborns. Thus, only the real capital that is demanded by the newly born (or turned over by the newly dead) creates a resource drain (or inflow) for the government. Wealth in the form of government paper can be created or destroyed without any effect on per capita M and B simply by the government's issuing or retiring new paper.

Investment goods produced by the firm, I^*, are both those bought by the existing population and those purchased by the government for distribution to the newborns. Thus, a market-clearing condition is

$$I^* = I + nK. \tag{9}$$

The social resource constraint, which is redundant if both firm and government budget constraints are in the system, is

$$X(C + g) + Q(I + nK) = Y. \tag{10}$$

We treat g and n as determined exogenously and P, K, and i as determined by market conditions. Thus, the government has as choice variables M, B, and τ. To define its behavior we need, besides its constraints, two policy equations.

The monetary and tax policy rules are motivated by two consideration: the need to satisfy the intertemporal government budget identity and the pursuit of countercyclical policy objectives. In addition, monetary and fiscal policies must interact to determine the price level. Leeper (1991) and Sims (1994) use simple rules in equilibrium models to compute the regions of the policy parameter space where unique equilibria exist. In those models, the monetary authority obeys a nominal interest rate rule that depends on inflation or money growth, and the fiscal authority adjusts lump-sum taxes in response to the level of real debt held by the public. With systematic policy behavior summarized by the two parameters in the policy rules, there are four qualitatively distinct regions of the policy parameter space: In two of these there exist unique equilibria, in one real debt explodes generically to violate transversality or feasibility, and in one the price level is indeterminate.

If monetary policy fixes the stock of high-powered money or raises the nominal interest rate strongly in response to increases in nominal variables like inflation or money growth, then a unique equilibrium exists only if fiscal policy behaves compatibly by matching any increase in real debt with an equivalent increase in the present value of direct taxes. This policy environment produces the usual monetarist/Ricardian propositions that underlie many economists' views of monetary and tax policy effects. Of course, given the hypothesized monetary policy behavior, refusal of the fiscal authority to increase direct taxes when real debt rises violates the government's intertemporal budget identity, placing the model in the region of the parameter space where no equilibrium exists.

Alternatively, when the fiscal authority refuses to change taxes in the face of real debt expansions, then monetary policy must prevent nominal interest rates from rising and generating explosive growth in government debt. Such a policy mix implies that total government liabilities —high-powered money plus government debt—determine the price level, while the ratio of money to debt is determined by the nominal interest rate. Shocks to lump-sum taxes influence nominal magnitudes when prices are flexible and both real and nominal variables when prices are sticky. The choice between debt- or tax-financing of government spending, therefore, *is relevant,* although the models are "Ricardian" in the sense that private agents fully discount the future tax—direct and inflation—liabilities associated with increases in government debt. This result emerges when debt issue does not imply corresponding future direct taxation, it must instead imply current or future inflation. Moreover, monetary policy shocks can have unexpected effects in this region of the policy parameter space. For example, a disturbance that unexpectedly raises the nominal interest rate can be deflationary or inflationary, depending on the assumed fiscal behavior.[3]

Finally, a policy combination where taxes respond strongly to real debt and nominal interest rates respond weakly to nominal variables leaves the price level indeterminate. Although the ratio of money to bonds is determined, their sum is not: At each date, many different levels of total government liabilities are consistent with an equilibrium, and associated with each level is a different price level. Explicitly modeling fiscal behavior generalizes the well-known Wicksellian view that a pegged nominal interest rate does not determine prices. A pegged rate coupled with direct taxes that do not rise sufficiently when real debt increases can uniquely determine the price level.

3. Leeper (1993) simulates a wide range of policy effects in a simple model with interest rate and tax rules.

Actual policy behavior also contains strong countercyclical components. Monetary policy tends to lower interest rates as unemployment rises and employment falls and to raise rates when inflationary pressures mount. Fiscal policy, through both discretionary tax changes and automatic stabilizers, tends to lower revenues when employment and inflation decline. The policy rules are parameterized to embody both of these reasons for monetary and tax policy changes. In addition to these systematic responses of policy to observable data, the rules contain disturbances reflecting policy responses to unmodeled economic or political developments.

The policy rules in this model are more complex than those studied in earlier papers, so the relevant regions of the parameter space cannot be derived analytically. The underlying economic intuition carries over, however. The monetary policy rule is

$$\frac{\dot{i}}{i} = a_p \log(P/\bar{P}) + a_{\text{inf}}\frac{\dot{P}}{P} + a_i \log(i/\bar{\beta}) + a_L \log(L/\bar{L}) + \varepsilon_i, \tag{11}$$

and the tax policy rule is

$$\frac{d}{dt}\left(\frac{\tau}{C}\right) = b_\tau\left(\frac{\tau}{C} - \frac{\bar{\tau}}{\bar{C}}\right) + b_L \log(L/\bar{L}) + b_{\text{inf}}\frac{\dot{P}}{P} + b_x\left(\frac{B}{PY} - \frac{\bar{B}}{\overline{PY}}\right) + \varepsilon_\tau. \tag{12}$$

The overscored variables denote steady state values. Note that the steady state price level, $\bar{P}$, and the steady-state debt-to-GNP level, $\bar{B}/\bar{Y}$ are free parameters of Equations (11) and (12), just as are the a's and b's.

2.4 POLICY ANALYSIS

The specification of policy behavior in Equations (11) and (12) leads to two types of policy experiments one might conduct with the fitted model: interventions on the out-of-sample paths of the disturbances, ε_i and ε_τ, and once-and-for-all changes in the policy parameters, the a's and b's. We view the first type of experiment as useful for policy analysis of the sort conducted in preparation for Federal Open Market Committee meetings or Congressional debates about fiscal policy. The analyst would choose several candidate paths for, say, ε_i, and present the model's predictions for each path to the policymakers. Most commonly, the ε_i paths themselves would be generated to provide responses to questions such as, "What would happen if the Federal Reserve held interest rates below 4% for the next six months?" To do so, one would solve for ε_i sequences that make the time path of interest rates behave as desired. Because the model implies that there are many potential stochastic influences on interest rates, this kind of projection is generally quite different from simply forecasting conditional on a given time path of the interest rate.

A menu of options generated along these lines would form the basis for the policy discussion. Choices of paths of such shocks in this manner is not a trivial exercise, and the process closely mimics actual policy practices, as has been argued in detail elsewhere (Sims 1982, 1987; Cooley, LeRoy, Raymon 1984; LeRoy 1993). Of course, repeated use of the model in this way for policy choice could eventually be seen by the public as changing the a's and b's, but this is not necessarily true and is in any case likely to take a long time. Even if policymakers announce that they are making permanent changes in the way policy variables are set, the public will for good reason wait for the announcement to be backed by sustained action before accepting the change as even approximately permanent. And in any case, for systematic use of the model to eventually change the a's and b's, it would have to be true both that users of the model had a strong impact on policy debates and that the use of the model changed their conclusions about good policy, rather than simply letting them reach those conclusions more quickly and cheaply.

By construction, changes in policy parameters are rare and permanent events—not the stuff of regular cyclical policy debates. Thus, while it may be interesting to use the model to see whether an alternative set of the a's and b's would deliver a better equilibrium than the historically estimated one, it is internally contradictory to evaluate policy "rules" in this way as if the result were a contribution to the usual year-to-year or decade-to-decade ebb and flow of macroeconomic policy arguments.

2.5 THE STICKY-PRICE VERSION

The sticky-price formulation we are working with does not have the flexible price model as a special case or even as a limit point. In particular, we drop Equations (A4) and (A14) in the Appendix, corresponding to the workers' matching of marginal utility of leisure to the wage and the firm's matching of marginal productivity of labor to the wage. In their place we postulate differential equations relating the rates of growth of $\dot{P}/P$ and W to the discrepancies between the left- and right-hand sides of Equations (A4) and (A14):

$$\frac{d^2}{dt^2}\log(P) = -\chi_P \log\left(A^{\sigma}\left(\frac{Y}{L}\right)^{1-\sigma} \cdot w^{-1}\right). \tag{A4'}$$

$$\frac{\dot{w}}{w} = -\chi_w\left(\log\left((1 - 2\phi V)\frac{w}{X}\right) - \log\left(\frac{1-\pi}{\pi}\frac{C^*}{(1-L)}\right)\right). \tag{A14'}$$

These can be thought of as "markup" and "Phillips Curve" equations. They have no rational expectations elements and, therefore, can be criticized as old-fashioned. However, any element of stickiness is going to violate canons of purity on the rationality front. We are using a modeling framework in which the inflation rate is stationary and do not regard it as unrealistic to treat price dynamics formulated as in Equations (A4') and (A14') as "structural" relative to policy disturbances that come as a stationary time series of shocks. Note also that because Equation (A4') is formulated with the second derivative on the left, it implies that when inflation is at a constant rate, there is no persistent gap between the wage and the marginal product of labor. And since Equation (A14') is in terms of the real wage w, it again does not require any gap between the wage and the marginal utility of labor in the presence of steady inflation.

In principle the speed-of-adjustment parameters χ_w and χ_P can be positive or negative. When negative, they fit an interpretation that requires P and w to have continuous time paths and be predetermined. When positive they are interpreted as allowing discontinuity in P and w paths, with the levels of these variables set to match average expected future values of the right-hand-side forcing variables. We actually do not impose these interpretations directly but instead simply treat Equations (A4') and (A14') as containing endogenous expectational disturbance terms or exogenous disturbances, respectively, according to whether the model as a whole has the right number and location of unstable roots to support the interpretation.[4]

We do not tie Equations (A4') and (A14') to a particular institutional story. They are consistent with many of the stories that have been told

4. As the number of unstable roots in the system formed by the constraints and first-order conditions increases, there are correspondingly increased numbers of stability conditions imposed on the model. A new exact relation among the variables required to suppress an additional unstable root will in general conflict with the specification of the model, unless an additional equation is specified as having an endogenously determined disturbance.

in the literature about price adjustment mechanisms. For example, if we denote the right-hand side of (A4′) as $Z(t)$, then a continuous-time adaptation of John Taylor's[5] 1979 overlapping-contracts pricing mechanism would postulate

$$\dot{p} = \theta(p^* - p), \tag{13}$$

where p is log price, θ is the rate at which the stock of firms is selected to adjust per unit time, and p^* is the value to which they adjust p when they adjust. Then, recognizing that the price they set now will hold over a long future span, they form p^* as

$$p^* = \phi e^{\phi t} E\left[\int_t^\infty e^{-\phi s}(p(s) - \gamma Z(s))\, ds\right]. \tag{14}$$

If $\theta = \phi$, as is reasonable if adjusters average over a time span in the future that corresponds to their actual hazard rate for being selected for price adjustment, exactly Equation (A4′) emerges, though with $\chi_P < 0$.

Another possible story to back up the price adjustment mechanism would be built on search. By explicitly modeling choice of search activity levels by firms and workers, we could create a foundation for modeling unemployment and job vacancy data along with the rest of the model.

Notice that our formulation, though it treats the price adjustment mechanism as an institutional datum, involves no ad hoc or suboptimal behavior by firms or workers. The firms and workers simply treat both the price and quantity of labor as beyond their control. Given the prices and quantities turned out by the labor market mechanism, savings and investment are carried out completely optimally, and with full accounting for expected future paths of inflation and output.

One might think that as the speed with which P and w react to gaps between the left- and right-hand sides of Equations (A4) and (A14) increases, we would smoothly move from a sticky-price world to a flexible-price world. However, as the speeds of adjustment of P and w increase, we converge to flexible-price behavior in a complicated way. This point was shown a year ago by Don Nakornthab in a somewhat simpler version of this model. Its intuitive economic explanation traces

5. Another example of a rational expectations sticky-price model is that in "Money and Business Cycles" (1994) by Robert King. He uses a Taylor-style adjustment mechanism for wages but assumes firms always to be on their labor demand curves and observes that this creates a strongly positive reaction of the nominal interest rate to demand expansions.

back to a point that can be found in Keynes's *General Theory*: Making wages or prices more flexible will not eliminate Keynesian unemployment; indeed, it may make it worse. In a sticky-price model like that we have set up here, quantities respond strongly to fiscal and monetary policy shifts and to technological shocks. But if prices cannot jump downward in response to an initial contractionary demand shock, e.g., the effect on real interest rates of a more rapid deflationary response of prices may actually make the initial impact on quantities greater. The result is that as the speed of adjustment of wages and prices increases, the sensitivity of quantities to shocks increases rather than decreases. What Nakornthab shows that is not obvious from Keynes's informal discussion is that the duration of the quantity responses decreases as their speed increases. The amount of time quantity variables spend away from steady state following a shock decreases with increased price and wage flexibility, but the amplitude of their movement stays about the same and the initial speed of their reaction increases.[6]

2.6 STOCHASTIC SPECIFICATION

The model contains 11 sources of uncertainty in its neoclassical version and 11 to 13 (depending on whether the price-adjustment equations are backward or forward looking) in the sticky-price version. Besides the serially uncorrelated policy disturbances, ε_i and ε_τ, the model is driven by stochastic behavior of some of the parameters and exogenous variables: n, g, π, β, δ, θ, α, A, and ϕ. Each of these is a logarithmic first-order AR in continuous time, except for β, which is a logarithmic first-order AR in unlogged form. Each has a steady-state parameter,[7] a decay parameter and a variance parameter associated with it. The shocks ε_i, ε_τ, n, g, δ, and ϕ are independent, the preference shocks π and β are correlated with each other, but not with any other shocks, and the technology disturbances θ, α, and A are correlated with each other but independent of the other shocks.

Our approach is to carry out inference as an exploration of the shape of the likelihood function. We do not follow the procedure, common in time series inference, of using the likelihood conditional on initial observations, because that loses information and may generate fits that embody large "transients" at the beginning of the sample that are attributed to initial conditions (see Sims 1992). Models that build in

6. In a sticky-price model that differs from that here in a number of important ways, DeLong and Summers (1986) have also made the point that increasing rates of price adjustment do not necessarily reduce volatility of real quantities.
7. As we see later, these "steady-state" parameters need not, if dynamics are nonstationary, correspond to actual means or steady states.

nonstationarity may easily absorb into the statistical "trend" much of what economists think of as business cycle variation. This is true whether the trend is modeled as difference-stationarity, deterministic trend components, or as what is removed by some high-pass filter. At an earlier stage of this work, we used unconditional likelihood based on a stationarity assumption, arguing that a stationary model near enough to the nonstationary boundary of the parameter space could generate arbitrarily strong persistence and, thus, fit even apparently nonstationary data. However, numerical instabilities near the nonstationary boundary were difficult to handle, so we now generate likelihood conditional on an assumption that the model started up from its "steady-state" value 100 years before the initial date of the sample. Well away from the nonstationary boundary, the likelihood formed this way is essentially identical to the unconditional likelihood formed under an assumption of stationarity, but at the boundary it does not have the sharp singularity of the stationary likelihood. It can still show numerical problems if the parameters imply rapidly explosive behavior, but the problems are rarer and easier to deal with than those of the stationary unconditional likelihood.

If the coefficient a_P on the price level in the monetary policy equation is zero, it becomes possible to write the entire model and its first-order conditions as functions of real money balances M/P, real debt B/P, and the inflation rate in place of the variables M, B, and P. In this form, of course, P is by construction nonstationary. In earlier work we did not force a_P to zero and fit to levels of the data. While we have recently switched over to relying mainly on the $a_P = 0$ version, the results we report later for a three-variable fit are for the $a_P \neq 0$ version of the model. The results reported for the 10-variable sticky-price model are for the $a_P = 0$ version.

2.7 SOLVING AND ESTIMATING THE MODEL

The first-order conditions, the constraints, and the policy rules of the model form a system of nonlinear stochastic differential equations. We set the model's disturbances to zero and solve for the steady state as a function of the fixed parameters and the mean values of the disturbances. Since the stochastic specification does not require stationarity, this "steady state" may not correspond to an actual steady state of the deterministic version of the model. It is what the steady state would be if all the exogenously evolving stochastic parameters were fixed at their "steady-state" values, despite the possibility that the dynamic specification may imply that these exogenous parameters do not tend to stay near their "steady-state" values. We then compute a first-order Taylor expansion of the first-order conditions and the constraints around the steady state.

From the resulting system of first-order linear differential equations, we calculate the eigenvalues and eigenvectors. For a determinate equilibrium to exist, the system must have a number of unstable roots[8] that matches the number of forward-looking first-order conditions. The left eigenvectors associated with the unstable roots are the coefficients of linear constraints on the model's variables that must hold to suppress the unstable component of the solution. Combining these relationships with the remaining equations in the model produces a complete linearized solution. Our algorithm allows interpreting the price and wage adjustment equations in the sticky-price version to be either forward or backward looking, depending on the number of unstable roots.

Once the linearized model has been solved, the matrix-valued autocovariance function can be derived as a function of the matrices of coefficients in the linearized system. The autocovariance function is aggregated over time from the continuous time theoretical structure to correspond with quarterly time series observations. The likelihood function for the data can then be computed and estimated over the free parameters of the model. The model consists of 17 endogenous variables and 11 to 13 exogenous shocks. Private and policy behavior and the statistical properties of the exogenous disturbances are summarized by 46 parameters in the flexible-price model and 50 parameters in the sticky-price version. Before being sent through the estimation algorithm, the parameters are transformed to ensure the estimates satisfy some simple a priori bounds (mostly log transformations to ensure positivity).

The model is fit to two different sets of quarterly data over the sample period 1959:1 to 1992:3. Initially, three U.S. time series on real personal consumption expenditures, hours, and real gross private domestic investment less inventory accumulation are used to estimate a subset of the parameters associated with preferences, technologies, and the real exogenous disturbances. These estimates are used to judge the model's ability to replicate some of the calibration exercises performed on real business cycle models. The present work, however, applies a

8. What qualifies as unstable here in principle depends on the detailed structure of the model. Roots that are slightly explosive may still be consistent with transversality conditions. We allow "slightly" explosive roots and hope that our guess at a dividing line between stable and unstable regions does not affect results. If we had guessed wrong, we might have expected to find maxima at the boundary of the allowable region of the parameter space, and this seems not to have occurred.

more stringent set of measures of fit to the data than is typically employed in calibration exercises.

The second data set adds to these three series real wages, the rate of inflation in the GDP deflator, real total government purchases, real total government revenues, the real monetary base, the three-month Treasury bill rate, and working-age population. At this stage the estimation is extended to include all the model's parameters, including those in the policy equations. All series are converted into per capita terms and in the current version of the model, all series are logged except tax revenues, the inflation rate, and the interest rate.[9]

Our approach to inference is based on the likelihood principle, i.e., on the idea that the information in the data about the model is completely captured in the shape of the likelihood function. From this point of view, we need not be concerned with the fact that for parameter values close to the nonstationary boundary of the parameter space, the distribution of maximum likelihood estimators is not well approximated by the usual asymptotic theory for stationary models. The maximum of the log likelihood function and the second-order Taylor expansion of it around the maximum carry the same sort of information about the function's shape regardless of the presence of near-non-stationary behavior. This point is elaborated in a simple example model in Sims and Uhlig (1991).

3. *Numerical Considerations*

Estimation of this model presents some numerical difficulties. In addition to the usual requirement that most economic variables be positive, a determinate solution requires there to be the proper number of unstable roots in the linearized system of differential equations and that they generate a well-behaved mapping between exogenous disturbances and expectational error terms. These requirements create complex and generally unknown boundaries to the set of feasible parameters in the parameter space. The model, and particularly the policy behavior, is specified to make the boundaries as simple as possible. But without implausibly simple policy rules and a dichotomy between the real and nominal sectors of the economy, it is difficult to characterize the boundaries analytically.

The economics of the model implies that when parameters fall outside the feasible boundaries, either no equilibrium exists (too many unstable roots) or the equilibrium is underdetermined (too few unstable

9. Detailed descriptions appear in a data Appendix.

roots).[10] In either case, the likelihood function is not defined. This puts the numerical optimization problem into somewhat uncharted waters because it is neither an unconstrained maximization nor a constrained maximization with a separate routine that checks if the constraint is satisfied. Penalty function methods associated with constrained optimization typically assume the objective function is defined in "bad" regions of the parameter space and tack on to that function a smooth, continuously differentiable function that penalizes the objective function when the algorithm tries parameter values that violate the constraint. If, as in our case, "bad" parameter values imply that the likelihood function is not defined, the usual penalty function methods cannot be applied.

As an alternative, our likelihood-evaluation algorithm checks whether the candidate parameter vector implies nonsensical steady-state values or the wrong number of unstable roots and returns a large negative likelihood value in these cases. This approach introduces discontinuities in the likelihood function, which can create difficulties for some gradient-based algorithms. There are two kinds of difficulties. Some algorithms may try to take a gradient of the objective function at points where the function value is worse than that at the beginning of the iteration. If such a point happens to be in the region where the objective function is flat at a large negative value because of nonexistence of equilibrium, this obviously creates a problem. Other routines attempt sophisticated line searches that interpolate polynomials across function values obtained in the line search. When the function is discontinuous, these methods may not only fail to be useful, they may also fail to find an improved value even when a less sophisticated line search would easily find it. Our routine that avoids these difficulties is available as a Matlab m-file.

Our procedure is to linearize the model's first-order conditions and constraints about the steady state and to use the resulting model to generate first and second moments for the full data matrix. With 134 (when we use filtered data) observations and 3–10 variables, the covariance matrix we are using is of order 402–1340. Such a matrix cannot even be stored on PCs with the most common memory endowments.

10. More precisely, when there are too many unstable roots, an equilibrium exists only if the exogenous stochastic processes are linearly related, which violates the maintained assumption that they are uncorrelated. When there are too few unstable roots, the price level is not determined. We can sometimes pick an equilibrium in this case by treating the largest stable root as if it were unstable. Then we can use penalty-function methods by using this equilibrium to calculate the implied distribution of the data, adding on to the likelihood a penalty term that depends monotonely on the degree to which the largest stable root falls below zero.

We are nonetheless able to compute the likelihood by using recursive methods to factor and invert the covariance matrix, therefore never having to store the entire matrix.

At early stages of our work, numerical difficulties in evaluating the likelihood led us to focus attention on fitting to quasi-differences, i.e., $Y(t) - \rho Y(t-1)$ for some ρ in $(0,1)$, where these difficulties lessened. This allows deviation of initial levels from steady state to influence the fit, though the influence is diminished relative to use of levels data.[11] Note that this does not mean we are modeling in quasi-differences, constraining the model to imply nonstationarity as would be the case if we fit a VAR in quasi-differences. We are modeling in levels, using the result to generate implications about the second-order moments of the time series of quasi-differences. It is true that as ρ approaches unity, using the differenced data will make the fit emphasize higher-frequency characteristics of the data, and in particular will pay less attention to the distance of the initial value from the steady state.

Our method for solving the linearized model, based on the QZ decomposition, is somewhat nonstandard and probably competitive or superior in efficiency with standard methods. It makes no use of the fact that the model comes from optimization problems, working only off boundary conditions limiting the size of unstable roots. It handles singularities in the matrix of coefficients on derivatives automatically and does not require explicit casting of the model into state-space form. (The algorithm must be told how many unstable roots to squash, however.) Though we can make the code available, this part of our code is model-specific in its current form.

4. *Results*

In judging the model's goodness of fit, we are not simply testing the model to see whether it is true. We do use statistical measures of fit and compare, with likelihood-based test statistics, our model to others, including naive no-change predictions and VARs. Like many RBC researchers, we are not ready to cast our model aside as soon as we find

11. We have greatly reduced our model's numerical difficulties by four main techniques. We have found a way to double the accuracy of Matlab's Ricatti equation solver lyap.m by essentially applying it twice. We have truncated the triangular orthogonalization generated by the block Levinson algorithm at a fixed lag length in every function evaluation. At some stages of our work, we used a Bayesian hill-climbing algorithm that can be adjusted to make it insensitive to modest levels of rounding error in likelihood evaluation. And finally we have used the likelihood conditioned on the data being at "steady state" at a distant past point, as described in the text. A separate paper or papers describing these numerical innovations is in preparation.

a VAR that clearly fits better. On the other hand, we are also not ready to make excuses for our model that imply we are ready to rely on it for policy conclusions even though it clearly misses or contradicts patterns of behavior observed in the data. Our model has been formulated with enough sources of random disturbance and enough free parameters that it is not implausible that it could match the observed time-series variation in the 10 variables we aim at explaining. While the model does not yet fit quite as well as an unrestricted VAR with a similar number of parameters, it comes close enough to suggest that with a little more work and a few judicious modifications of the model structure, a fit as good as a VAR fit may be attainable.

4.1 THE THREE-VARIABLE DATA SET

First we report the parameter estimates implied by fitting the flexible-price model to quasi-differences of time series on consumption, hours, and investment. Table 1 reports the estimated values for the 33 free parameters associated with the version of the model that is formulated in the levels of nominal variables.[12] Because at this stage we are not using data on 7 of the 10 variables, and policy shocks are neutral in the flexible-price model, the values for the remaining 12 parameters from the policy rules have no effect on the likelihood value and are not reported. Most of the estimated parameters look reasonable. The risk aversion parameter, γ, is estimated to be 8.82, which is in line with some previous estimates. There is some slight convexity to the technology that transforms output goods into consumption and investment goods ($\mu = 1.025$), and the elasticity of substitution between labor and capital is estimated to be quite low ($\sigma = -.32$). Point estimates for two important parameters—the discount rate, β, and the depreciation rate, δ—are less reasonable but so imprecisely estimated that they are within one standard error of plausible values. Most of the exogenous processes have roots away from the unit circle: Only the shock to total factor productivity has a root above .95.

Table 2 compares the forecast errors from the estimated model with those implied by naively assuming no change in the data and by fitting an unrestricted VAR to the three quasi-differenced time series. The VAR is estimated with two lags of each variable and a constant term. The

12. We actually maximize the likelihood concentrated with respect to a scale factor for the variances. Thus, we can fix the variance of one of the exogenous processes as a normalization, and the standard errors we compute on the variances are actually standard errors on their ratios to the pegged variance parameter. This follows from the fact that the concentrated likelihood is almost exactly the same as the likelihood integrated over the same parameter, so that the concentrated likelihood can be interpreted as an approximate marginal posterior p.d.f. The standard errors of the estimates are computed using a BFGS-update of the inverse of the Hessian matrix.

Table 1 THREE-VARIABLE DATA SET: ESTIMATED PARAMETERS FOR FLEXIBLE PRICE MODEL
(Standard errors in parentheses)

Preferences			
$\bar{\pi} = 0.341$	$\rho_\pi = -2.912$	$\sigma_\pi^2 = 3.961e-4$	
(.060)	(.194)	(2.730e − 1)	
$\bar{\beta} = 0.165$	$\rho_\beta = -0.635$	$\beta_\pi = -4.019$	$\sigma_\beta^2 = 5.277e-6$
(.288)	(.153)	(.206)	(3.209e − 2)
$\gamma = 8.882$			
(.145)			
Technologies			
$\bar{\theta} = 0.528$	$\rho_\theta = -3.191e+3$		
(.082)	(.240)		
$\bar{\alpha} = 0.352$	$\rho_\alpha = -0.324$	$\alpha_\theta = 1.186$	
(.092)	(.126)	(.088)	
$\bar{A} = 96.794$	$\rho_A = -8.715e-5$	$A_\alpha = 2.520$	$A_\theta = 0.559$
(.105)	(.094)	(.147)	(.205)
$\sigma_\theta^2 = 2.137e-2$	$\sigma_\alpha^2 = 1.995e-5$	$\sigma_A^2 = 6.847e-6$	
(.369)	(0.363)	(.216)	
$\bar{\phi} = 2.934e-4$	$\rho_\phi = -0.673$	$\sigma_\phi^2 = 1.962e-2$	
(.182)	(.105)	(3.194e − 2)	
$\bar{\delta} = 0.250$	$\rho_\delta = -1.821$	$\sigma_\delta^2 = 8.169e-2$	
(.135)	(.232)	(fixed)	
$\mu = 1.025$	$\sigma = -0.315$		
(.324)	(.037)		
Government Spending and Population			
$\bar{g}/Y = 7.731e-2$	$\rho_g = -5.428e-2$	$\sigma_g^2 = 4.823e-6$	
(.292)	(0.114)	(3.165e − 2)	
$\bar{n} = 1.400e-2$	$\rho_n = -5.930$	$\sigma_n^2 = 4.894e-6$	
(.292)	(.047)	(3.186e − 2)	
Log likelihood value = 1545.48			

ρ_x is the first-order AR coefficient on the continuous-time process x, y_x is the coefficient determining how y depends on x, and σ_x^2 is the variance of the process. Policy parameters do not affect the likelihood and were fixed arbitrarily to ensure a unique equilibrium exists.

number of free parameters in the VAR, then, (including the 6 free parameters in the covariance matrix of the innovations) is 27.

By the log determinant criterion, the model fits the data about 22% better than does the assumption of no change, and it fits only 1.8% worse than the unrestricted VAR.[13] The model also comes close to

13. To see this, divide one-half of the difference in the relevant log determinants by the number of variables. For the likelihood values, the same sort of estimate of "average percentage difference in standard errors of forecast" is the difference in likelihoods divided by sample size times number of variables.

Table 2 THREE-VARIABLE DATA SET: FIT OF THE FLEXIBLE PRICE MODEL

Covariance / Correlation matrices

First difference of data
Log Det = −24.926 Likelihood = 1469.04

Choleski decomposition

	C	L	I
C	.0169		
L	.0026	.0106	
I	.0072	.0048	.0215

VAR innovations (2 lags plus constant, 27 free parameters; estimated using quasi-differenced data)

Log Det = −26.339 Likelihood = 1563.71

Choleski decomposition

	C	L	I
C	.0124		
L	.0016	.0089	
I	.0080	.0048	.0173

Model residuals (33 free parameters)

Log Det = −26.229 "Likelihood" = 1556.34

Choleski decomposition

	C	L	I
C	.0128		
L	.0015	.0092	
I	.0087	.0045	.0171

The model's steady state versus means of the data

	U.S. data means	Model steady state
C	13.96	20.48
L	0.353	0.350
I	2.292	3.110
L/C	0.025	0.017
I/C	0.164	0.152

matching the contemporaneous correlations among the VAR innovations.

On the other hand, the log determinant criterion is proportional to the maximized likelihood for the VAR and for the naive no-change model for which the covariance matrix of first differences is the innovation covariance matrix. For our structural model, the log determinant criterion is not proportional to the maximized likelihood. For direct comparison of likelihood, we should compare $-.5 \times 134 \times$ (log determinant of the covariance matrix) or $-.5 \times 134 \times 3$ for the two naive models to our fitted log likelihood of 1545.48. The two naive models have, by this calculation, log likelihoods of 1469.04 and 1563.71, respectively. The "likelihood" reported in Table 2 for the model is computed from the log det covariance matrix just as it was for the two naive models. The model's actual likelihood is slightly lower. This is partly because, unlike the reduced-form models, it does not leave the covariances among the innovations unrestricted. However, the model fits the data unconditionally, while the VAR is fitting only conditional on the initial observations, so the two likelihoods are not strictly comparable.[14]

For convenience, Table 2 also reports Choleski decompositions of the covariance matrices, which make comparisons by variable across models easier. The model improves on a random walk for consumption, hours, and investment. In the case of investment, the model produces an error variance below that of the VAR.

The estimated parameters imply a steady state that matches the means of the data in some but not all respects. Except for consumption, the steady-state values of the three series are near their means, as are the ratios of hours and investment to consumption. The model also implies a labor share of income equal to .90, which is higher than the two-thirds typically cited.

Figure 1 shows time series charts that compare the model's output with the innovations from the VAR. The shaded areas correspond to NBER business cycle peaks and troughs. For consumption, the model keeps pace with the VAR in the middle of the sample and during most recessions, but performs less well than the VAR in the 1960s and outperforms the VAR in the 1980s. In the second panel, the model performs remarkably well in predicting hours fluctuations, though it has a slight tendency to exaggerate declines in hours during recessions. The model also predicts investment as well as the VAR.

Figure 2 contrasts the reduced-form moving average representations over 20 quarters from the VAR (solid lines) with those from the model (dashed lines). The covariance matrices are orthogonalized in the order consumption, hours, and investment. Estimating the VAR in quasi-differences eliminates most of the dynamics in the response functions, with the responses of the three series dying out quickly following their

14. It is also true that the model implies that the covariance matrix of innovations varies over time, so that in computing its likelihood, errors at different dates are weighted differently. But it appears that this effect is not strong here compared with the effect of restrictions on the covariances at a point in time.

Figure 1 THREE-VARIABLE FLEXIBLE PRICE MODEL

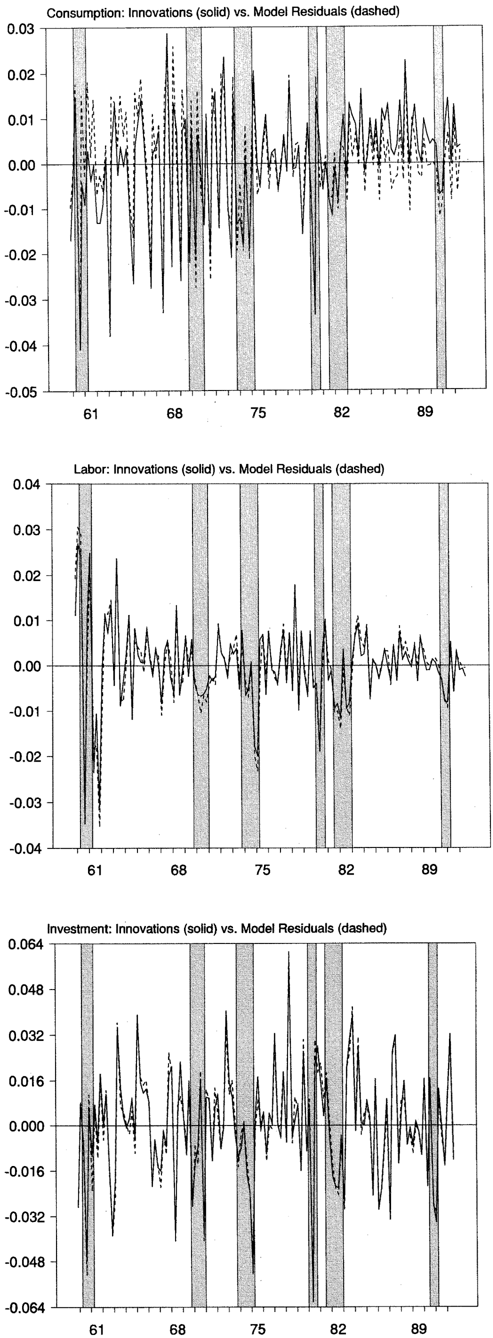


Figure 2 THREE-VARIABLE FLEXIBLE PRICE MODEL

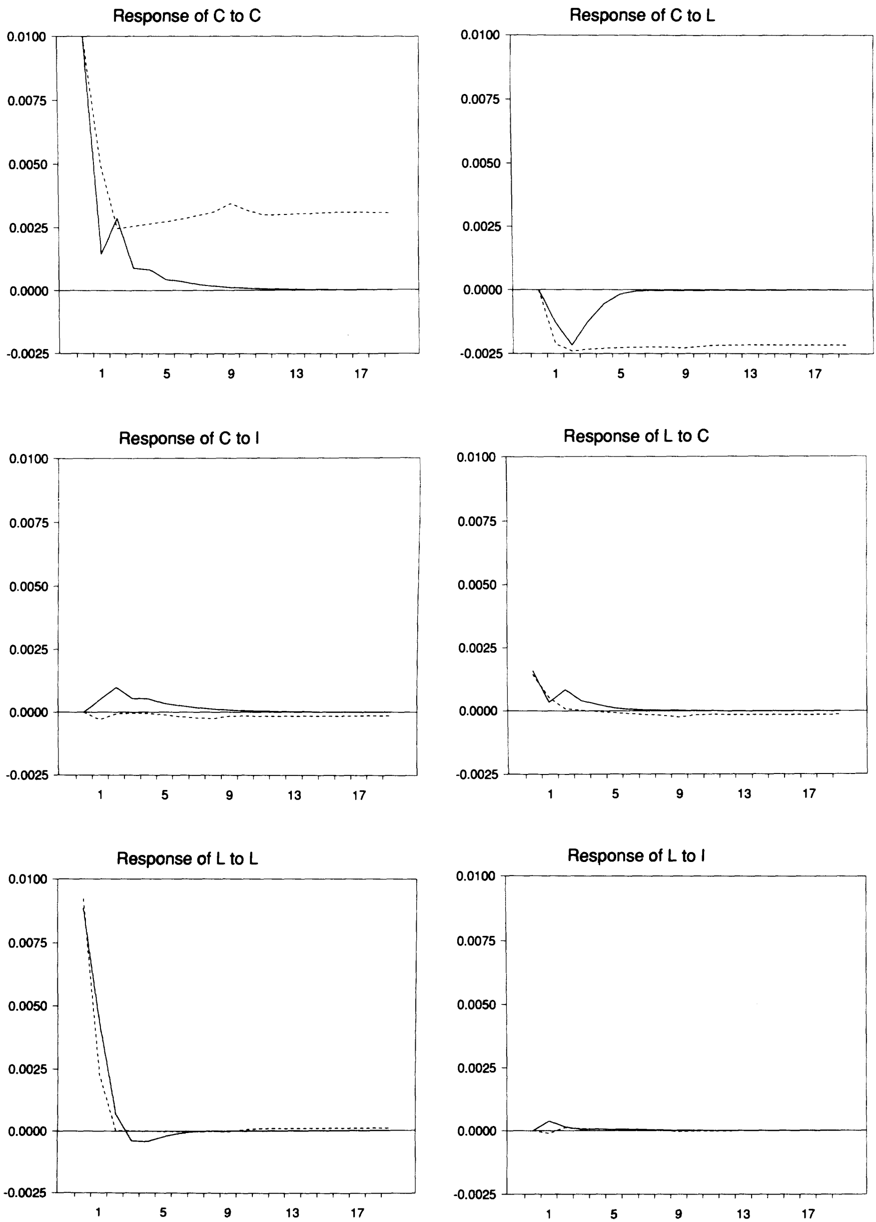
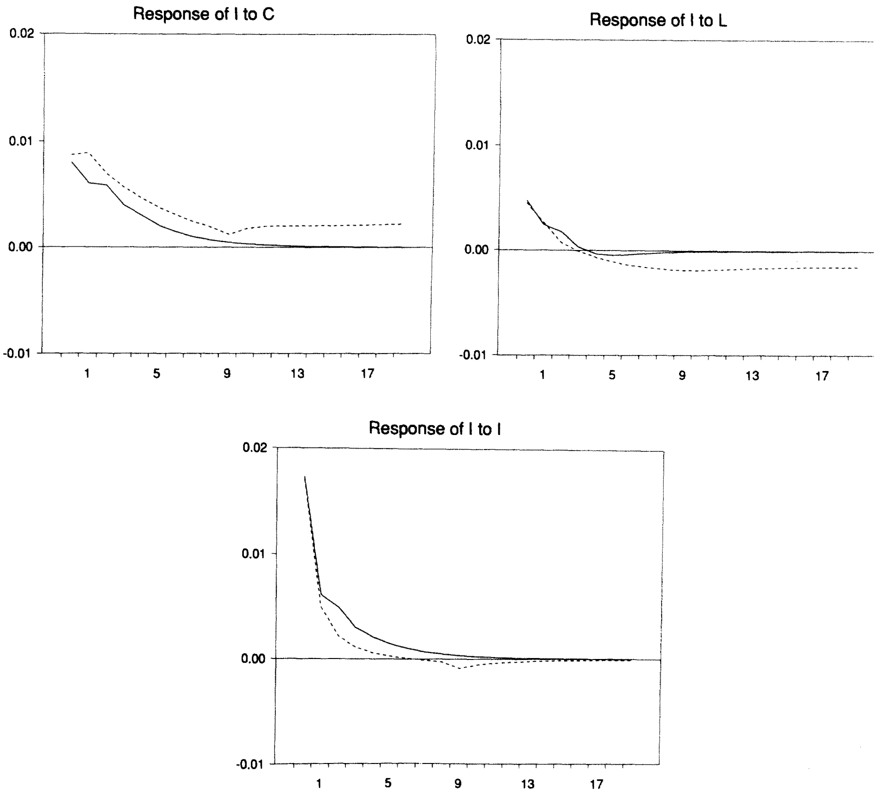


Figure 2 (continued)



own disturbance. The model appears to reproduce the contemporaneous correlations among innovations well, but it implies more persistent responses in consumption to consumption and hours innovations than observed in the data.

Once estimated, the model can be used to evaluate the underlying exogenous sources of fluctuations in consumption, hours, and investment over the sample period. It turns out that shocks to only 3 of the 11 exogenous processes in the model account for all the fluctuations in the three endogenous series. The three important disturbances are π, a shock to consumption's share in utility, θ, a shock to investment in the cost-of-adjustment technology, and α, a shock to the marginal product of capital in the production function.

Table 3 reports the percentage of each variable's forecast error variance due to the three shocks in the short and medium runs. In the short

Table 3 THREE-VARIABLE DATA SET: VARIANCE DECOMPOSITION

	Percentage of forecast error variance attributable					
	After 6 months to			After 3 years to		
	π	θ	α	π	θ	α
C	35	42	22	8	83	8
L	68	32	0	67	32	0
I	1	98	1	10	85	2

run, all three shocks contribute to consumption fluctuations, with π and θ accounting for over one-third of the variance each and α accounting for one-quarter. As the forecast horizon extends, however, θ becomes the dominant source of fluctuations in consumption. Two-thirds of the error variance of hours is due to the preference shock, and one-third is due to the cost-of-adjustment shock, regardless of the forecast horizon. Finally, fluctuations in investment arise almost entirely from shocks to the technology that transforms output goods into consumption and investment goods.

For the model's implications to be credible, the estimates must produce sensible dynamic responses to the exogenous shocks. Figure 3 reports the responses of consumption, hours, and investment to the three important structural disturbances.[15] The first row shows that a transitory preference shock that makes consumption more desirable raises consumption and lowers leisure contemporaneously. Investment rises gradually, reaching a peak after about one year before declining smoothly. Responses to a shock to θ appear in the second row. Higher θ, making investment goods relatively more expensive, can be thought of as a decline in the productivity of the capital goods sector. Because θ is serially uncorrelated ($\rho_\theta = -3191$ implying almost no persistence), the shock lowers the one-period return to investment, causing investment to fall precipitously and return immediately to its normal level. Hours worked fall with the capital stock but then rise to compensate for the decline in capital. Consumption drops to a permanently lower level consistent with the one-time decline in the capital stock. The shock to the marginal product of capital, α, raises the rental price of capital and drives down investment and hours worked initially. The serial correlation of the shock (estimated root of .72) generates a smooth decline in

15. The responses are plotted over a five-year period as monthly samplings of the underlying continuous response function, not as responses of the time-aggregated actual data.

Figure 3 THREE-VARIABLE FLEXIBLE PRICE MODEL

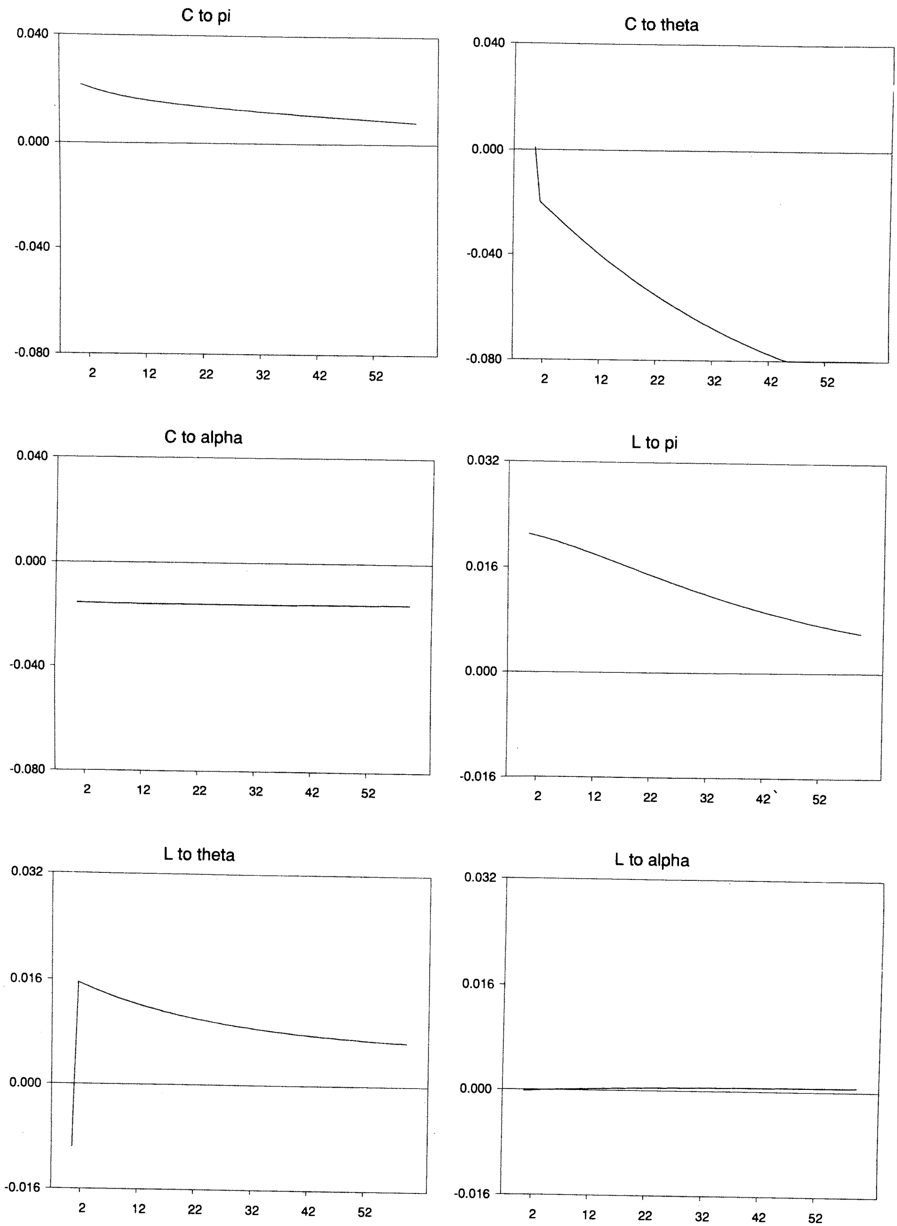
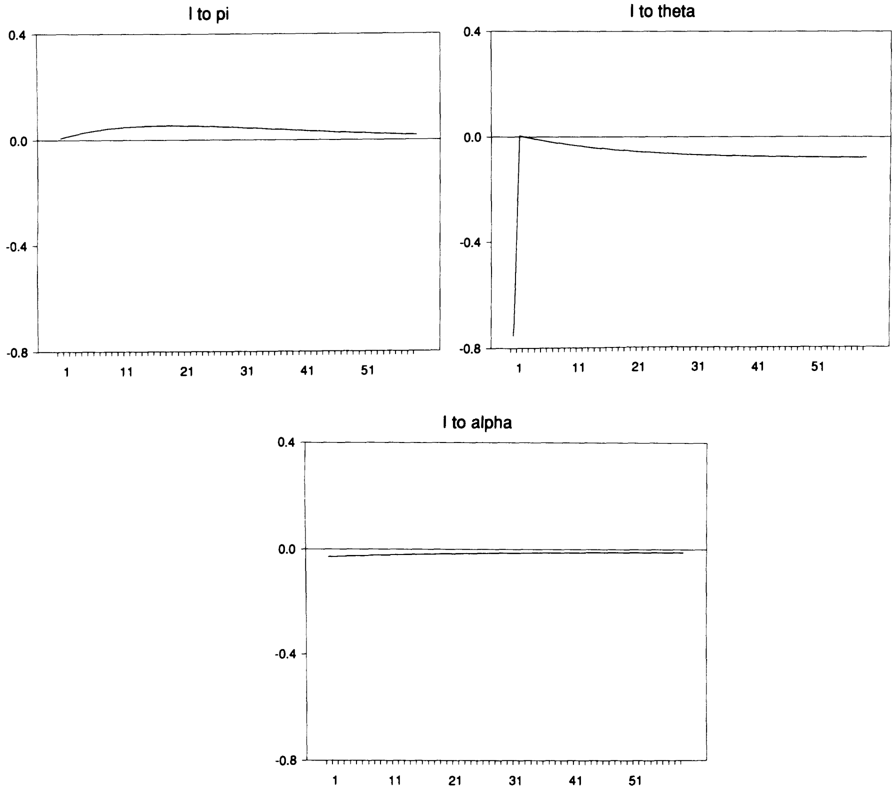


Figure 3 (continued)



consumption, which bottoms out after about two years. As noted in Table 3, disturbances to α are unimportant sources of fluctuations in hours and investment, but they are relatively important for short-run movements in consumption.

4.2 THE 10-VARIABLE DATA SET

We had substantial numerical difficulties with the 10-variable neoclassical version of the model and did not achieve a respectable fit with it. The fit remained particularly bad for the price variables. We do not take these difficulties as proof that this version of the model cannot fit the data—we had substantial numerical difficulties with each version of the model at one point or another, so that the fact that we do not have results to display for this version of the model at the deadline for this manuscript could be simple misfortune. But the difficulty with the

Table 4 ESTIMATED PARAMETERS FOR 10-VARIABLE STICKY-PRICE MODEL

1 $\overline{g/Y}$	0.0681	2 ρ_g	−0.00147
3 $\bar{n}$	0.0149	4 ρ_n	−9.63
5 $\bar{\pi}$	0.614	6 ρ_π	−0.000285
7 $\bar{\beta}$	0.06	8 ρ_β	−0.000488
9 β_π	−1.56	10 $\bar{\theta}$	1.81
11 ρ_θ	−1.28	12 $\bar{\alpha}$	0.624
13 ρ_α	−0.000754	14 α_θ	0.412
15 $\bar{A}$	107	16 ρ_A	−0.000306
17 A_α	−0.612	18 A_θ	−1.089
19 $\bar{\phi}$	0.00532	20 ρ_θ	−0.00165
21 $\bar{\delta}$	0.465	22 ρ_δ	−0.0107
23 μ	25.8	24 σ	−25.0
25 γ	5.65	26 a_{inf}	0.00748
27 a_r	−1.06	28 a_L	1.66
29 b_τ	−5.47	30 b_L	1.36
31 b_x	2.41	32 b_{inf}	1.82
33 $\bar{P}$	0.563	34 $\overline{\text{BGNP}}$	0.118
35 χ_P	0.00804	36 χ_w	0.00019
Equation variances			
37 mpol	0.0188	38 fpol	0.0209
39 Padj	0.0283	40 wadj	0.00166
41 g	0.0175	42 n	0.00372
43 π	0.00196	44 β	0.00107
45 θ	0.00786	46 α	0.00722
47 A	0.00301	48 ϕ	0.0986
49 δ	0.401		

Note: The parameters are as they appear in the text, except that bars over the parameters indicate steady-state values and the double greek letter parameters refer to responses in the exogenous dynamics. For example, A_α is the coefficient on the level of α in the differential equation with $\dot{A}$ on the left.

neoclassical model fit to price data does accord with speculation by one of the authors (Sims, 1989) and may yet turn out to be a robust result.

For the sticky-price model, we obtained apparently converged results, reported in Table 4. The likelihood value at the best fit is 5348.91, quite a bit lower than the 5742.26 obtainable with a first-order VAR containing constant terms and with an unrestricted covariance matrix of disturbances. The VAR in this case, however, has 165 parameters compared with 49 for the model. The difference in likelihoods is still large relative to degrees of freedom, but again we must recognize that we cannot draw firm conclusions from comparing conditional and unconditional likelihoods. The log determinants of the residual covariance

Table 5 STANDARD DEVIATIONS OF ERRORS

	Model	*First Differences*	*VAR*
C	0.0130	0.0119	0.0114
L	0.0101	0.0102	0.0084
I	0.0234	0.0238	0.0195
tx/Y	0.0119	0.0108	0.0096
infl	0.0201	0.0174	0.0143
W	0.0047	0.0048	0.0045
M/P	0.0146	0.0111	0.0126
r	0.0092	0.0090	0.0084
g	0.0161	0.0154	0.0146
n	0.0029	0.0029	0.0026

matrices are -95.705 for the VAR and -92.651 for the model, and these are on a comparable sample. The difference corresponds to an average improvement by the VAR over the model of 15% of the standard error of forecast. The model has almost the same log determinant of the covariance matrix of errors as does the naive no-change forecast. Table 5 shows that, in constrast to the three-variable data set, here the model's fit is closer to that of a naive no-change forecast than to that of a VAR.

While the fit achieved here leaves plenty of room for improvement, it is still interesting to explore what sort of economic interpretation this model supplies. Tables 6 and 7 give most of the story. The model is converged to a parameter value in the purely Ricardian region of the parameter space. Shocks to the tax equation (the Fpolicy column) have no effect on any of the 10 variables other than taxes themselves. Monetary policy looks weak, judged by the size of the entries in column 1. However this reflects a low estimate of the variance of shocks to monetary policy, and the tendency of larger shocks to dominate variance decompositions, where squared responses matter. In Table 7, which shows cumulative percent responses to sustained one-time shifts of one "standard error unit,"[16] we see that responses of C, L, and I to a monetary contraction are substantial and of reasonable signs. Because the model is so tightly parameterized, it does not produce fancy dynamics in the impulse responses. Figures 4–6 show four typical

16. Since this is a continuous time model, a sustained shift in the disturbance (which is modeled as white noise) is even more atypical of realizations of the model than it would be in a discrete model. The sizes of the responses look large because the typical disturbance is so little sustained that it never builds nearly this much cumulative response.

Table 6 VARIANCE DECOMPOSITION, 10-VARIABLE STICKY PRICE MODEL

	Mpolicy	*Fpolicy*	*Padj*	*Wadj*	g	n	π	β	θ	α	A	ϕ	δ
C	0.01	0.00	0.00	0.00	0.00	0.00	0.26	0.06	0.42	0.12	0.13	0.00	0.00
L	0.02	0.00	0.00	0.00	0.00	0.00	0.80	0.18	0.00	0.00	0.00	0.00	0.00
I	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.02	0.05	0.02	0.02	0.00	0.79
tax/C	0.00	0.52	0.31	0.00	0.01	0.00	0.04	0.01	0.04	0.01	0.01	0.03	0.00
Infl.	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	0.00	0.00	0.00	0.98	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00
M/P	0.03	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.22	0.06	0.07	0.56	0.00
r	0.20	0.00	0.00	0.00	0.00	0.00	0.65	0.14	0.00	0.00	0.00	0.00	0.00
g	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
n	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 7 CUMULATIVE RESPONSES ($\times 100$)

	Mpolicy	*Fpolicy*	*Padj*	*Wadj*	g	n	π	β	θ	α	A	ϕ	δ
C	−16	0	−0	−0	−7	0	67	31	77	41	42	0	0
L	−15	0	−0	−0	0	0	63	29	1	0	0	0	0
I	−16	0	−0	−0	0	2	80	37	47	27	27	−0	141
tax/C	0	24	25	−0	1	0	7	3	−5	−3	−3	−4	0
Infl.	0	0	121	0	0	0	0	0	−0	−0	−0	0	0
W	−0	0	0	29	−0	0	1	1	0	0	0	0	0
M/P	−45	0	−0	−0	0	0	47	22	71	38	39	110	0
r	39	0	0	−0	0	0	20	9	0	0	0	0	0
g	0	0	0	0	94	0	0	0	0	0	0	0	0
n	0	0	0	0	0	8	0	0	0	0	0	0	0

response shapes. In all three graphs the x axis is in monthly units. In Figures 5 and 6, the responses have not yet begun to die away after three years.

Inflation responds to nothing, but the price adjustment shock, while wages respond to nothing but the wage adjustment shock. This is a model in which most fluctuations in prices are persistent, generating no expectation of inflation or deflation, and in which the rest of the

Figure 4 TEN-VARIABLE STICKY PRICE MODEL

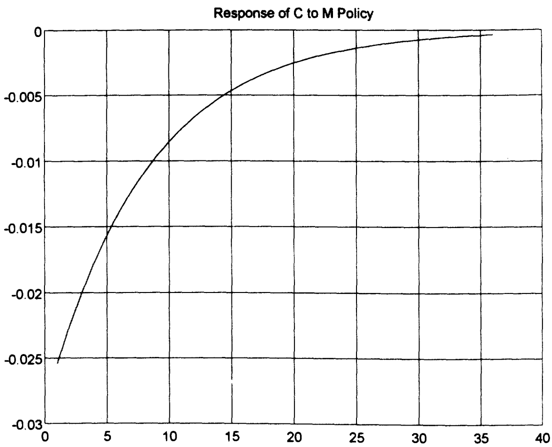
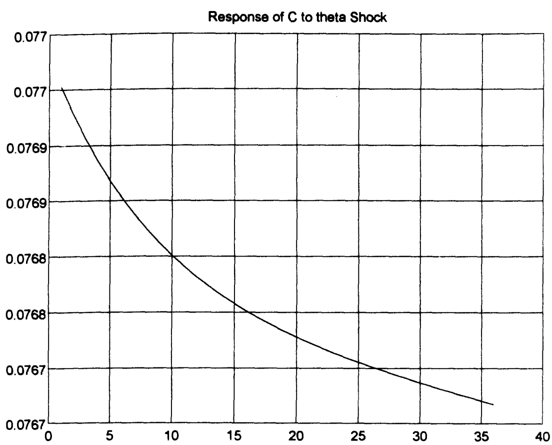


Figure 5 TEN-VARIABLE STICKY PRICE MODEL



economy has little impact on price movements. In this sense the fitted model is showing extremely sticky prices, with none of the expectational instability we have noted is in principle possible in these models.

An open question is whether in this fitted model the extreme price stickiness and strong influence of real shocks is dependent on the particular monetary and fiscal policy rules that are estimated here. We could simulate the model with alternative policy rules to check this.

Appendix: The First-Order Conditions

The first-order conditions for the firm are

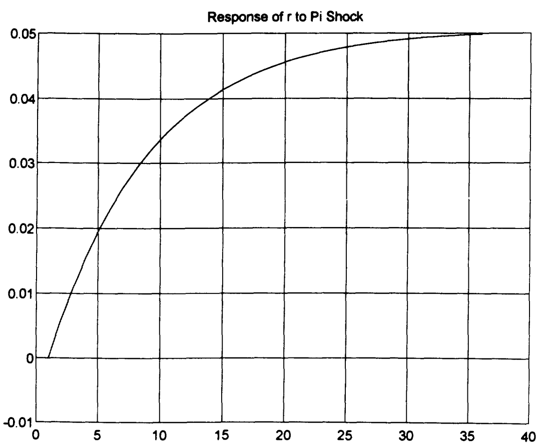
$$X = \left(\frac{Y}{C+g}\right)^{1-\mu} \tag{A1}$$

$$Q = \theta\left(\frac{Y}{I^*}\right)^{1-\mu} \tag{A2}$$

$$r = A^{\sigma}\alpha\left(\frac{Y}{K}\right)^{1-\sigma} \tag{A3}$$

$$w = A^{\sigma}\left(\frac{Y}{L}\right)^{1-\sigma}. \tag{A4}$$

Figure 6 TEN-VARIABLE STICKY PRICE MODEL



For the agent they are

$$\partial C^*:\quad \pi Z^{-\gamma}\left(\frac{1-L}{C^*}\right)^{1-\pi} = \nu X \tag{A5}$$

$$\partial L:\quad (1-\pi)Z^{-\gamma}\left(\frac{C^*}{1-L}\right)^{\pi} = \xi w \tag{A6}$$

(where $Z = C^{*\pi}(1-L)^{1-\pi}$)

$$\partial I:\quad Q\lambda = \omega \tag{A7}$$

$$\partial C:\quad \lambda = \nu \tag{A8}$$

$$\partial M:\quad -\frac{\dot{\lambda}}{\lambda} = -\frac{P^2Y}{M^2}\frac{\psi}{\lambda} - \beta - \frac{\dot{P}}{P} \tag{A9}$$

$$\partial B:\quad -\frac{\dot{\lambda}}{\lambda} = i - \beta - \frac{\dot{P}}{P} \tag{A10}$$

$$\partial Y:\quad \lambda + \frac{\psi P}{M} = \xi + \phi V \nu \tag{A11}$$

$$\partial V:\quad \phi Y \nu = -\psi \tag{A12}$$

$$\partial K:\quad -\frac{\dot{\omega}}{\omega} = r\frac{\xi}{\omega} - \delta - \beta. \tag{A13}$$

Here are the agent's FOCs manipulated to get rid of Lagrange Multipliers:

$$(1-2\phi V)\frac{w}{X} = \frac{1-\pi}{\pi}\frac{C^*}{(1-L)} \tag{A14}$$

$$i = \phi V^2 \tag{A15}$$

$$\begin{aligned}(1-\pi(1-\gamma))\frac{\dot{C}^*}{C^*} &+ (1-\gamma)(1-\pi)\frac{\dot{L}}{1-L} \\ &= i - \beta - \frac{\dot{X}}{X} - \frac{\dot{P}}{P} + \frac{\dot{\pi}}{\pi} + \dot{\pi}(1-\gamma)\log\left(\frac{C^*}{1-L}\right)\end{aligned} \tag{A16}$$

$$(1-2\phi V)\frac{r}{Q} + \frac{\dot{Q}}{Q} - \delta = i - \frac{\dot{P}}{P}. \tag{A17}$$

Data Appendix

Consumption: Personal consumption expenditures, NIPA, deflated by the PCE deflator.

Investment: Residential plus nonresidential fixed investment, NIPA, deflated by their respective deflators, NIPA.

Employment: Civilian employment times weekly hours index for total goods production, scaled to lie in the unit interval.

Real wages: Index of compensation per hour in the nonfarm business sector, deflated by the GDP deflator.

Price level: GDP deflator, NIPA.

Government purchases: Total federal plus state and local purchases, NIPA, deflated by the GDP deflator.

Government tax revenues: Total federal plus state and local tax receipts, less transfer payments, with federal grants to state and local governments netted out, NIPA, deflated by the GNP deflator.

Money: The Federal Reserve Board's monetary base, not adjusted for reserve requirement changes.

Interest rate: Three-month Treasury bill rate, secondary market, in basis points.

Population: Quarterly growth rate of the civilian noninstitutional population, at annual rates.

Per capita series are obtained by deflating by the population. All series seasonally adjusted except the interest rate and population. Monthly series are time-averaged to quarterly frequencies.

REFERENCES

Altug, S. (1989). Time-to-build and aggregate fluctuations: Some new evidence. *International Economic Review* 30:889–920.

Cooley, T. F., S. F. LeRoy, and N. Raymon. (1984). Econometric policy evaluation: Note. *American Economic Review* 74:467–470.

De Long, J. B., and L. H. Summers. (1986). Is increased price flexibility stabilizing? *American Economic Review* 76:1031–1044.

King, R. (1994). Money and business cycles. *Journal of Monetary Economics*, in press.

Kydland, F., and E. Prescott. (1982). Time-to-build and aggregate fluctuations. *Econometrica* 50:1345–1370.

Leeper, E. M. (1991). Equilibria under "active" and "passive" monetary and fiscal policies. *Journal of Monetary Economics* 27:129–147.

______. (1993). The policy tango: Toward a holistic view of monetary and fiscal effects. Federal Reserve Bank of Atlanta *Economic Review* 78:1–27.

LeRoy, S. F. (1993). On policy regimes, Manuscript, University of Minnesota, August.

McGrattan, E. R. (1994). The macroeconomic effects of distortionary taxation, forthcoming *Journal of Monetary Economics* 71:573–601.
______, R. Rogerson, and R. Wright. (1993). Household production and taxation in the stochastic growth model. Federal Reserve Bank of Minneapolis Working Paper 521 (October).
Nakornthob, D. (1993). The study of a deterministic Keynesian model with perfect foresight in asset markets. Yale College Senior Essay (April).
Sims, C. A. (1982). Policy analysis with econometric models. *Brookings Papers on Economic Activity* 1:107–164.
______. (1987). A rational expectations framework for short-run policy analysis. In *New approaches to monetary economics*, W. A. Barnett and K. J. Singleton (eds.). Cambridge, England: Cambridge University Press.
______. (1989). Models and their uses. *American Journal of Agricultural Economics* 71:489–494.
______. (1992). Bayesian inference for multivariate time series models with trend. Mimeo (November).
______. (1994). A simple model for study of the determination of the price level and the interaction of monetary and fiscal policy. *Economic Theory*, 4:381–399.
______, and H. Uhlig. (1991). Understanding unit rooters: A helicopter tour. *Econometrica* 59:1591–1599.
Taylor, J. (1979). Staggered wage setting in a macro model. *American Economic Review* 69:108–113.
Watson, M. (1993). Measures of fit for calibrated models. *Journal of Political Economy* 101:1011–1041.

Comment

ROBERT G. KING
University of Virginia, Federal Reserve Bank of Richmond, and NBER

1. *Introduction*

Titles of macroeconomic papers sometimes bear little relationship to contents. However, Eric Leeper and Christopher Sims (LS) give an honest assessment of their work and the more general state of current research with the title of their contribution to this volume. Nearly two decades after the publication of Robert E. Lucas's "Econometric Policy Evaluation: A Critique," we are still not close to having small-scale modern macroeconomic models that we can use for monetary policy analysis. From the perspective of 1975, it is perhaps surprising that it has taken so long to go so small a distance. However, after the diversions of the last decade, it is also notable that our profession is back on the path of constructing small-scale macroeconomic models that can be used for monetary policy analysis in a post-Lucas critique fashion.

When attending sessions like this and thinking about my role as a discussant, I sometimes contemplate the strategies that conference organizers appear to use in choosing discussants. One model that appears appropriate at times is that discussants are selected to bracket the research efforts of the author(s) in interesting ways. At times, this means that an author looks like a baseball player caught in a rundown.

With some discussant pairs, Sims and Leeper could perhaps have been caught between a conventional macroeconomic modeler and a real business cycle adherent, with one discussant demanding that LS produce a model that could more adequately capture the quarter-to-quarter variation in a larger number of series and the other asking for additional deep economic structure. But that is not going to happen here. Instead, I have broad sympathy for the LS program: To continue my baseball analogy, reading the LS paper is for me like talking to the first-base coach from another team in a postseason setting, considering the conditions under which it is best to "hit and run." As I have in some of my own recent research, LS are struggling with how best to introduce some short-run nonneutralities of money into a small-scale macroeconomic model, which otherwise makes heavy use of neoclassical modeling. In terms of the econometric analysis, LS are also struggling with how best to compare alternative macroeconomic models, while recognizing that each is relatively primitive.

Since it is clear that the LS paper is a progress report on an ongoing research project, I am not going to focus on the details of the model or on the parameter estimates. Rather, I am going to consider where this research project fits into the broad sweep of post-1975 macroeconomic research and thus, isolate the general contributions of the paper. My discussion will thus focus on four questions related to this research program:

1. Why should the construction of small-scale macroeconomic (SSMM) models be a goal?
2. Why has it taken us so long to start to do this systematically?
3. How is the LS approach distinctive?
4. What are we learning about real theories of economic fluctuations?

2. *Expectations and Macroeconomic Models*

The class of macroeconomic models that LS suggest that we should study has four key characteristics. First, it makes extensive use of dynamic choice theory to model the consumption, investment, and portfolio decisions of private agents. Second, it builds in certain nominal rigidities and associated real consequences of these incomplete adjustments. While the nature of these nominal rigidities is necessarily ad hoc, they are motivated by various prominent economic hypotheses about the wage and price adjustment process. Thus, the class of models advocated by LS blends aspects of the modern neoclassical approach to macroeconomics—most fully developed in modern real business cycle theory—with the older approaches utilized by Keynesian and Monetarist economists. Third, simple ad hoc decision rules are used to represent the monetary and fiscal behavior of the government. Fourth, the models are cast in the approximate linear form that Chow (1975) and Sargent (1979, 1981) taught us is the natural first-order framework for thinking about macroeconomics: In this case, the linear systems framework (1) makes it possible to rapidly compute rational expectations solutions, and (2) provides a natural basis for macroeconometric analysis.

Why do I think that SSMM models are important for thinking about the positive and normative analysis of monetary policy? We now have a range of evidence that the expectational channels stressed by Lucas are quantitatively significant: SSMM models are a means of systematically building these channels into macroeconomic analysis and policy discussions. Expectations are important empirically, and the incorporation of rational expectations yields major changes in how macroeconomic models work. Particularly in the area of interest rate determination, it is simply central to take into account how expectations are formed.

2.1 EXPECTATIONS AND THE TERM STRUCTURE

In an important early paper on the implications of rational expectations for the macroeconomic model, Poole (1976) focused attention on the term structure equation of then-existing large macroeconometric models: This specified that the long-term rate was a fixed distributed lag of the short-term interest rate. He noted that incorporating rational expectations in the term structure equation would have major implications. It is now clear that Poole's intuition was right in three important ways. First, if one looks at monetary policy in the first half of 1994 and other particular historical episodes in the United States and other countries, it is clear that the long rate is not a fixed distributed lag of short rates. This spring, the Federal Reserve raised its short-term interest rate target three times so as to produce a deceleration of money growth: The first two times long rates rose, and the third time long rates fell. Most observers interpret these varying responses as related in important ways to expectations about future policy that were very different across the events. Second, we now know that most modern macroeconomic models could capture this time-varying response in principle, while conventional term structure equations could not. Third, with respect to variations in policy regimes, we know from the work of Mankiw, Miron, and Weil (1987) that changes in the monetary regime—the founding of the Federal Reserve and the departure from the gold standard—induced major changes in the linkage of a short rate to a longer term rate.

2.2 EXPECTATIONS AND THE SHORT-TERM RATE

It is also clear that our standard models feature a process of interest rate determination that is highly sensitive to expectations. For example, theories of financial market frictions (gradual adjustment of portfolios) and commodity market frictions (sticky prices and wages) are typically taken to imply that increases in money growth lower nominal interest rates, at least temporarily. But two recent examples show that standard models work otherwise. In a rational expectations version of the financial market friction model, Christiano (1991) found that increased money growth increased nominal interest rates: Expected inflation effects on the nominal rate dominated a temporary liquidity effect on the real interest rate. He traced this to a key feature of the behavior of post-war U.S. monetary aggregates: Positive serial correlation in money growth means that a current increase in money growth is typically followed by a future increase in money growth. In my own work on sticky-price and wage models, I reached the same conclusion (King, 1994): Increases in money growth led to higher nominal interest rates. Further, in these models of gradual nominal price adjustment, the conclusion held even without positive serial correlation in money growth: Stickiness of prices necessarily means that one time increases in the level of the money stock will raise expected inflation, since current prices do not move and the long-run price level increases.

These conclusions are not inescapable: They can be altered by various structural modifications of each model. But they do testify to the likely power of expectations in SSMM models. Further, if applied in an attempt to summarize these small-scale models, the basic IS-LM model simply does not give a good account of the outcomes: The basic IS and LM curves are subject to expectations-induced shifts that are simply more important than the effects highlighted in the IS-LM analysis. It is for this reason that I've argued that the New Keynesian Macroeconomics is unlikely to resurrect the IS-LM model (King, 1993). Thus, I agree with Leeper and Sims that we need a new generation of models to replace the IS-LM apparatus.

2.3 CHOICE OF MODELING STRATEGY

The modeling strategy of Leeper and Sims is to take these expectational channels seriously and, accordingly, to build macroeconomic models with nominal frictions that take into account the Lucas critique. While I view it as natural, it is a controversial choice. Indeed, it is fair to say that it is viewed as obviously wrong in Cambridge and in Minneapolis, albeit for different reasons.

Real business cycle models incorporate the dynamic optimization in consumption and investment, which is a key element of the class of models that SL advocate. But, for unswerving adherents to the real business cycle (RBC) approach, it is obvious that most of economic fluctuations arise from productivity shocks (the estimate in Kydland and Prescott (1991) is over two-thirds) and that the dynamic response of the economy is well captured by models without frictions in labor, product, or financial markets.

Since the pioneering efforts of Fischer (1977) and Phelps and Taylor (1977), modern Keynesian macroeconomists have focused the bulk of their energies constructing microeconomic rationalizations of the sorts of nominal rigidities that SL are incorporating. But there is little current support in Cambridge for the models of the SSMM program. Notably, Mankiw (1990) is confident that when his "New Keynesian" research program is completed, the result will be very much like the conventional IS-LM model. Blanchard (1991) calls for a return to the "pragmatic" macroeconometric research program of the 1960s and early 1970s. The view in Cambridge seems to be that it is better to use DRI than an SSMM model.

In different ways, each of these viewpoints is the outcome of a crisis in the methodology of macroeconometrics.

3. *Macroeconometrics*

In 1976, Lucas defined a successful modern macroeconomic model as one that captured the comovements of real and nominal variables within an equilibrium framework. He also forecast that it would be developed in the relatively short term, guessing that its arrival would be "five but not twenty-five years off." We are now closer to the latter figure than the former.

3.1 THE RATIONAL EXPECTATIONS CONSENSUS IN 1978

Lucas's optimistic forecast was made during an era in which there was an emerging consensus on the importance of the SSMM program at least among active younger researchers: It is unlikely that Lucas foresaw the emergence of a major disparity of viewpoints. The consensus and its devolution is well illustrated by considering the classic 1978 volume on "Rational Expectations and Economic Policy," edited by Stanley Fischer, in which there were two promising models.

3.1.1 The Prototype Neoclassical Model As developed by Kydland and Prescott, a prototype neoclassical model was used to investigate the "feasibility and desirability of stabilization policy." The theoretical model was one in which output fluctuations were driven by real shocks and also by temporary misperceptions of monetary shocks (as in the theoretical study of Lucas, 1972). Notably, this early Kydland–Prescott model contained explicit intertemporal choice problems for determination of consumption, expenditures on durables, investment, etc. Perhaps most important in terms of subsequent research, Kydland and Prescott learned that the weak internal propagation mechanisms of their model could not deliver protracted business cycles.

3.1.2 The Prototype New Keynesian Model As developed by Olivier Blanchard, the prototype new Keynesian model was used to study "the monetary mechanism in the light of rational expectations." This sophisticated model contained staggered wage setting, a dynamic investment sector (of the "q" theory form), etc. The new Keynesian model was used to explore the real and nominal effects of monetary policy shocks and monetary policy rules. Technically, it was far more sophisticated that the Kydland and Prescott model: It computed a Pareto inefficient dynamic equilibrium using methods detailed later in Blanchard and Kahn (1980).

There were important common features of these research projects. First, each of the models was largely "calibrated" rather than being estimated using the full set of time series under investigation: The authors chose "plausible" parameters from other studies or simply invented numbers. This was a natural research strategy—one that we now call quantitative theory—because the dynamic properties of such models were then largely unexplored. Second, the authors compared the dynamic multipliers arising from their models with empirical estimates of such multipliers, either obtained from their own empirical research or from models constructed by others.

To those of us that studied the papers from this conference, it seemed that there would be a natural parallel exploration of the empirical properties of a range of macroeconomic models. Notably, leading young researchers from "salt water" and "fresh water" schools of macroeconomics were using broadly similar models and strategies.

3.2 ECONOMETRIC EVALUATION OF BASIC MODELS

The next phase of research on SSMM models was slow, painful, and led to a major bifurcation of research activity. After some initial exercises in quantitative theory, the natural next stage of research was to subject the basic models of Kydland and Prescott (1978, 1982) and Blanchard (1978) to empirical tests. The emerging technology of Hansen and Sargent (1980) was chosen for that purpose: It was a natural method, given that it fit neatly into linear systems econometric theory, which also included Sims's influential work on VARs (1980). Indeed, in the Hansen–Sargent program, the natural benchmark for any single macroeconomic model was the VAR as an unrestricted reduced form.

The rejections of these basic dynamic models were decisive, recurrent, and painful. It was not uncommon to attend an NBER conference in the early 1980s and to watch a sophisticated young researcher trying to explain the unexplainable. The researcher had written down an interesting and relevant economic model, had estimated its parameters using the Hansen–Sargent maximum likelihood procedure, and had determined that the data liked an unrestricted VAR so much better that the relevant likelihood ratio statistic indicated that the model was rejected at any P value one cared to name.

There were basically three reactions to this outcome. One was to argue that econometrics was an intrinsically useless business, as Kydland and Prescott have on many occasions (including [1991]). A second was to turn away from the program of constructing small-scale modern macroeconomic models, as has become Blanchard's practice. Instead, his work has turned to experimentation with structural VARs as in Blanchard and Watson (1984) and to more traditional interpretations of reduced form models (Blanchard, 1991). These two very different reactions have dominated research in Minnesota and in Cambridge.

A third interpretation was that there is something deeply wrong with the Hansen–Sargent program or, at least, in its practical application. My own thinking is that I go into an empirical investigation knowing that SSMM models are incomplete; they are also sure to perform worse than an unrestricted VAR. Using the old rule that "it takes a model to beat a model," I take the relevant issues to be:

1. Which of our current SSMM models performs best empirically in some overall sense?
2. Along what dimensions do specific SSMM models perform relatively better or worse?
3. Along which specific dimensions do VARs outperform a particular SSMM model?

In making progress toward the goal of an SSMM model usable for monetary policy-making, our rate of growth will be maximized if these questions are kept squarely in front of us.

4. *The LS Approach*

The LS project takes a particular line on evaluating SSMMs, which is notable and distinct from the recent effort of Christiano and Eichenbaum (1992) or that in my recent joint work with Mark Watson (King and Watson, 1993a, b). In many ways, it is closer to the Hansen–Sargent methods than this other work, but it also represents a substantial departure from the earlier practical applications of these ideas.

LS specify *fully articulated* models of the economy, i.e., ones in which there are as many behavioral shocks as VAR forecasting errors. The implication of this strategy is most clear when we consider their benchmark model, which is essentially a real business cycle model with a money demand function (transactions technology), a Fisher equation, and a specification of monetary policy. One approach would be to start with a small number of shocks (such as those to technology, money demand, and money supply) and to compare the implications of the model economy to some aspects of the U.S. economy, ignoring the stochastic singularity that is present in such a basic model.[1] Another alternative adopted by Altug (1989) would be to add some additional shocks interpreted as measurement error. By contrast, LS add additional behavioral shocks. In large part, this modeling choice apparently reflects their interest in replacing one monetary policy rule with another and comparing the system's operating characteristics: They argue that consideration of such policy interventions requires that we undertake a structural interpretation of disturbances.

With this structural model specification in hand, LS estimate their model using a system method based on the likelihood principle. Without going into the details, it is clear that the approach is solidly in the Hansen–Sargent tradition with respect to estimation of parameters. LS are critical of other approaches that rely on estimating parameters off subsets of the moment restrictions of the model, including instrumental variables estimates of individual equations. However, it is also clear that the unconstrained maximum likelihood point estimates need not correspond well with other prior information that would be typically employed in selecting parameters.

1. This is essentially the approach of Christiano and Eichenbaum (1992) or King and Watson (1993b).

However, the LS procedure of *model evaluation* is very distinct from the practice of the Hansen–Sargent methodology that developed in the early 1980s. In particular, LS articulate their approach as follows: "Like many RBC researchers, we are not ready to cast our model aside as soon as we find a VAR that clearly fits better." Their practice is to look across a range of different models; they explore the relative successes and failures of each using a battery of techniques. Importantly, relative to a straightforward application of the HS methodology, they have moved away from simple reliance on likelihood ratio tests and toward a broader-based evaluation of the absolute performance of an individual model and the relative performance of alternative structural models.

Let's see how the LS style of investigation would likely answer the questions that were posed at the end of the previous section.

Overall empirical performance (#1) and comparison with VARs (#3): LS use relative likelihood values to describe the comparative empirical performance of models. However, they supplement these with many other types of information on the empirical performance of a model. Notably, they compare an estimated model's impulse responses with those from a VAR, requiring that the estimated model's comparative dynamics "make sense" and are close to those from the VAR. They also explore how the fitted values of the model's endogenous variables perform relative to actual data, examining both overall correlation and the performance in specific episodes (e.g., recessions).

Comparisons across macroeconomic models (#2): The comparison of (a) structural model with VAR impulse responses and (b) fitted model values with data also provides a natural means of making comparisons across structural macroeconomic models.

Empirical research on small-scale macroeconomic models will need to make use of methods such as these if it is to make rapid progress. A variety of different approaches to parameter selection and model evaluation will likely be useful, as each may shed light on different aspects of the models' successes or failures.

5. *Implications for the RBC Model*

It is sometimes argued (e.g., King and Plosser, 1984) that real business cycle models with endogenous money supply can capture the major features of nominal and real interactions. However, my perspective, based on some recent work with Mark Watson (1993b), is that this is not such an easy task. A plausible interpretation of the LS results is that they also find that it is not easily accomplished. Hence, while these two investigations use quite different methodologies in terms of selection of model parameters and procedures for evaluating models, there is a single message that comes through.

King and Watson (1993b) show that a benchmark real business cycle model that is permitted to fit the "Solow Residual" very well can also do a very good job of accounting for fluctuations in real activity. But, even with a specification that makes the money supply endogenous and allows for generous shifts in the demand for money, the benchmark RBC model has great difficulty in capturing the cyclical variability and co-movement of nominal wages, prices, and interest rates. This difficulty occurs even though the model is assumed to capture the cyclical variation in money supply exactly, in part as a response to macroeconomic conditions.

LS show that a slightly different benchmark real business cycle model can also do a very good job in accounting for fluctuations in output, consumption, investment, and labor input. Their model does not place the same stress on "productivity residuals" but finds additional sources of real cyclical fluctuations in preferences and investment technologies. But LS have great difficulty using the same model to fit cyclical fluctuations in nominal variables even with (1) the introduction of additional nominal shocks and real shocks, and (2) a monetary policy rule that makes the money stock endogenous.

Taken together, these two studies thus challenge the idea that it is easy to use "endogenous money" as a rationalization of the interplay of real and nominal variables. They also illustrate the idea, discussed in the previous section, that a range of different styles of methods of parameter selection and model evaluation will aid us in determining the robust implications of small-scale macroeconomic models.

6. *Conclusions*

The research program of Eric Leeper and Christopher Sims is a promising one. It promises development of small-scale macroeconomic models that are usable for monetary policy purposes. It also promises the evaluation of alternative models in this class with a battery of formal statistical and other diagnostic methods.

REFERENCES

Altug, S. (1989). Time to build and aggregate fluctuations: Some additional evidence. *International Economic Review* 30:889–920.

Blanchard, O. J. (1978). The monetary mechanism in the light of rational expectations. In *Rational expectations and economic policy*, S. Fischer (ed.). Chicago: University of Chicago Press for National Bureau of Economic Research, pp. 75–102.

______ (1991). New classicals and new Keynesians: The long pause. Federal Reserve Bank of St. Louis conference paper.

______ and C. Kahn. (1980). The solution of linear difference systems under rational expectations. *Econometrica* 48:1305–1311.

______ and M. W. Watson. (1984). Are business cycles all alike? In *The American Business Cycle: Continuity and Change*, R. J. Gordon (ed.). Chicago, IL: University of Chicago Press for NBER, pp. 123–156.

Chow, G. (1975). *Analysis and control of dynamic economic systems*. New York: John Wiley and Sons.

Christiano, L. J. (1991). Modeling the liquidity effect of a money shock. *Federal Reserve Bank of Minneapolis Quarterly Review* 15:1–34.

______ and M. Eichenbaum. (1992). Liquidity effects, monetary policy and the business cycle, manuscript, Northwestern University.

Fischer, S. (1977). Long-term contracts, rational expectations, and the optimal money supply rule. *Journal of Political Economy* 85:191–205.

______ (ed.). (1978). *Rational expectations and economic policy*. Chicago: University of Chicago Press.

Hansen, L. P., and T. J. Sargent. (1980). Formulating and estimating dynamic linear rational expectations models. *Journal of Economic Dynamics and Control* 2:7–46.

King, R. G. (1993). Will the new Keynesian macroeconomics resurrect the IS-LM model? *Journal of Economic Perspectives* 7:67–82.

______ (1994). Money and business cycles. *Journal of Monetary Economics*, in press.

______, and C. I. Plosser. (1984). Money, credit and prices in a real business cycle. *American Economic Review* 74:363–380.

______, and M. W. Watson. (1993a). On the econometrics of comparative dynamics. Manuscript, University of Virginia.

______, and ______ (1993b). Money, interest rates, prices and the business cycle. Manuscript presented at the October 1993 NBER Economic Fluctuations meeting.

Kydland, F., and E. C. Prescott. (1978). On the feasibility and desirability of stabilization policy. In *Rational expectations and economic policy*, S. Fischer (ed.). Chicago, IL: University of Chicago Press for National Bureau of Economic Research.

______, and ______ (1982). Time to build and aggregate fluctuations. *Econometrica* 50:1345–1370.

______, and ______ (1991). The econometrics of the general equilibrium approach to business cycles. *Scandanavian Journal of Economics* 93:161–178.

Lucas, R. E., Jr. (1972). Expectations and the neutrality of money. *Journal of Economic Theory* 4:103–124.

______ (1976). Econometric policy evaluation: A critique. In *The Phillips Curve and labor markets*. K. Brunner and A. Meltzer (eds.). Carnegie-Rochester Conference Series on Public Policy, no. 1, pp. 19–46.

Mankiw, N. G. (1990). A quick refresher course in macroeconomics. *Journal of Economic Literature* 28:1645–1660.

______, J. A. Miron, and D. N. Weil. (1987). The adjustment of expectations to a change in regime: A study of the founding of the Federal Reserve. *American Economic Review* 77:358–374.

Phelps, E. S. and J. B. Taylor. (1977). Stabilizing powers of monetary policy under rational expectations. *Journal of Political Economy* 85:163–190.
Poole, W. W. (1976). Rational expectations in the macro model. *Brookings Papers on Economic Activity* 2:463–505.
Sargent, T. J. (1979). *Macroeconomic Theory*. New York: Academic Press.
______ (1981). Interpreting economic time series. *Journal of Political Economy* 83:213–248.
Sims, C. A. (1980). Macroeconomics and reality. *Econometrica* 48:1–48.

Comment

LAURENCE H. MEYER
Washington University and Laurence H. Meyer & Associates

Robert Lucas's 1976 critique of econometric policy evaluation dramatically undermined the credibility of large-scale macroeconometric models in the academic community and pointed in the direction of what has become modern macroeconomics, models that incorporate explicit optimizing behavior of economic agents, explicit rules governing policy instruments, continuous market clearing, and rational expectations. As Greg Mankiw (1988) has pointed in his "refresher course" article, neither the critique of existing practice nor the development of the alternative paradigm affected the still widespread use of large-scale macroeconometric models for policy analysis in the private sector or within the government.

Eric Leeper and Chris Sims, however, tell us that modern macro is now ready to graduate from the classroom and the journals to the CEA, OMB, CBO, etc., where it will initially compete with and presumably ultimately replace large-scale macroeconometric models for policy analysis. In other words, they want to put me out of business!

You can understand, therefore, that I was amused when Stan and Julio asked me to comment on this paper. It was like being invited to your own wake! In defense of Stan and Julio, I am, I expect, an excellent choice as a representative of the old macro. My license plate reads IS-LM, a gift from the Economics Department at Washington University when I retired as chairman. My consulting firm has built and maintains a large-scale macroeconometric model, and this model is indeed in use at CEA, OMB, CBO, and IMF.

Let me not keep you in suspense about my conclusion. To paraphrase Mark Twain (appropriate because I am also from Missouri): The reports of the demise of large-scale macroeconometric models for policy analysis are greatly exaggerated!

The Leeper and Sims paper does represent scientific progress. Macroeconomics has now labored for nearly two decades in the direction pointed at by Robert Lucas. For too long, practitioners of the modern macroeconomics comforted themselves in their neat first-order conditions and elegant mathematical solutions. Some sought imaginary "validation" from calibration exercises. Some satisfied their empirical inclinations with atheoretical vector autoregressions. But gradually techniques have evolved that allow estimation of the deep structural parameters of taste and technology that define modern macro models, allowing a direct empirical assessment of the validity of modern macro. I have always been fond of the scientific method, and, if it's making a comeback now, I am all for it. I think this is the spirit of the Leeper and Sims paper—to estimate the deep structural parameters of a modern macro model and assess whether that model is broadly consistent with the data.

Leeper and Sims conclude that it is not and don't seem that surprised: They "doubt that a market clearing, rational expectations model of this sort is consistent with the observed price and quantity data." This conclusion appears somewhat unexpected given the hopes raised at the outset.

But I like the conclusion. My expectations were apparently rational after all. The key questions we must ask about this paper are, Is it a legitimate test of modern macroeconomics? And if so, where do we go from here?

My comments on the Leeper and Sims paper fall into two broad areas. First, I want to make some comments on the details of the specification of their model. These are relevant to assessing whether this paper can be seriously defended as a test of modern macroeconomics and whether it provides a satisfactory framework for policy analysis. Given the conclusions that Leeper and Sims reach, I also want to wonder out loud whether modern macroeconomics can and should be taken seriously, or whether an enormous gap has developed between modern macroeconomics and reality that demands a serious rethinking of the direction of research in macroeconomics.

1. *Comments on the Leeper and Sims Model*

Let me start then with some comments on details of the specification of the Leeper and Sims model. I have seven specific issues I want to address.

(1) *They make up the data:* While I could not possibly implement the impressive model solution and estimation techniques that Leeper and

Sims marshall in this paper, I do know a GDP identity when I see one, and I can make identities ident! Leeper and Sims define GDP to exclude inventory investment and net exports. Therefore, GDP is not GDP.

Why do they do this? I expect this decision reflected the necessity of keeping the model as small and simple as possible, given the demanding techniques required for solution and estimation. So technique dominates, likely at the expense of realism. I believe we could use less technique and more realism.

What they leave out is, of course, very important. Their model is for a closed, stationary, and, given the contribution of inventory investment to cycles, almost a noncyclical economy. This is not a sound foundation for a model "usable for policy analysis."

How can you redefine output and test the fit of the model? C is really consumption, I is really investment, but Y is not really income. I am at a loss here to understand how the results of this procedure can be viewed meaningfully as a test of modern macroeconomics, as much as I would like to believe their findings.

(2) *The model lacks sufficient disaggregation:* The same considerations that encouraged leaving out inventory investment and net exports undoubtedly also led Leeper and Sims to avoid disaggregation of consumption and investment. They have a single consumption and a single investment aggregate. Investment is gross private domestic investment less inventory investment and, thus, includes equipment purchases, spending on nonresidential structures, and residential construction. Most practical macro models separate spending on durable goods from spending on nondurables and services, an important disaggregation to capture the short-run dynamics of consumption and aggregate spending. And these models would also separate out equipment and structures (with different depreciation rates and different tax treatment and dramatically different patterns in relative prices) and also separate residential construction (more closely tied to demographics) from business fixed investment. There is some minimum amount of disaggregation that I believe is required to capture both the short-run dynamics output movements and to allow for an meaningful link between policy instruments and the economy. This model, I believe, falls way short of that level of disaggregation. But again the techniques applied are very demanding and can only be applied, I expect, to small and, hence, highly aggregated models. So simplicity rules, technique dominates, and realism suffers.

(3) *A static maximizing model for the firm:* Leeper and Sims model specifies a static maximizing problem for the firm, in contrast to the intertemporal maximization problem for the household. Firms, in effect,

rent capital each period, depending on the desired level of production and the relative price of renting capital and labor. Therefore, there is no problem of irreversibility in decisions involving the purchase of capital goods. Hence, firm decisions do not require knowledge of the path of output and relative prices over the life of the capital they are purchasing. Expectations are rational but irrelevant. This is particularly important because investment demand is central to understanding the short-run dynamics of output. The overly simplistic modeling of investment, therefore, may further undermine any success at explaining short-run dynamics.

(4) *A paucity of policy levers:* Leeper and Sims begin with the objective of constructing a model for use in policy analysis. You might expect, therefore, that they made a careful attempt to incorporate into their model a variety of policy levers. They did not. For tax levers, we have a single lump sum tax parameter. There are no personal or corporate taxes that vary with income, no average or marginal tax rates, no capital gains tax preference, no indirect business taxes, etc. Simplicity rules. Realism suffers.

Time does not permit a full elaboration, but most of the policy issues we have been asked to study in recent years could not even be attempted in this framework.

(5) *Arbitrary and ad hoc policy rules:* Modern macroeconomics has emphasized that policy ought to be modeled not as arbitrary changes in policy instruments but as systematic rules followed by the policy authorities. There is certainly some validity to this.

But it seems Leeper and Sims want to have it both ways. They tell us that policymakers follow rules, and households take these rules into account in their formation of expectations. But when Leeper and Sims discuss how to do policy analysis with this model, they tell us to pretend we are the Fed and try a variety of different interest rate paths (imposed by ad factoring the policy rule) and see which we like the best in terms of outcome. Don't get me wrong. I am used to precisely that type of policy analysis. But it seems out of place in modern macroeconomics and in this model.

I was also surprised by the arbitrary, simplistic, and ad hoc rules that policymakers follow, especially relative to the optimizing behavior for households. Why is there no optimizing framework for policy authorities?

In addition, I was puzzled by why a policy authority operating in a world of continuous market clearing would try to carry out countercyclical policy. Does this make sense? Apparently consumers are rocket scientists, and policy authorities are dummies. Indeed, I believe that neither assumption is tenable.

I can understand a policy rule for the Fed that governs their adjustment of short-term interest rates in response to economic developments. I have much more difficulty with the quarterly policy rule Leeper and Sims pretend the fiscal authorities follow. You can do damage by failing to incorporate into your model rules when policy is systematic, and you can do damage by imposing an arbitrary and unrealistic rule when you may not otherwise be sure how to model the systematic behavior of the policy authority.

(6) *A bizarre explanation for the trend in productivity:* Old macro models explain growth in part via an exogenous trend in multifactor productivity. This is certainly subject to a criticism that it contributes to the too sharp separation between the growth and cycle components of the model. In the Leeper and Sims model, there is no exogenous rate of growth of multifactor productivity. The model is in fact described as one of a stationary state. How then is growth of per capita output explained? We are told that variables that are in fact trendless (like productivity apparently) can nevertheless exhibit what appears to be trend growth (as is observed in historical productivity data) "if the models have roots near the unit circle in the right configuration." As I understand it, postwar growth is the result of a productivity shock that has persisted for quite some time and has apparently taken us rather far from the steady (make that stationary) state. I hope this isn't modern macroeconomics's answer to neoclassical growth theory.

(7) *A strange modeling of sticky prices:* Leeper and Sims introduce at the end of their paper a sticky-price version of their model. As a believer in sticky prices, however, I had a difficult time feeling comfortable with their modeling of this vision. Their so-called Phillips Curve makes the rate of nominal wage change proportional to the difference between the real wage and the marginal disutility of labor. Their so-called markup equation makes the rate of change in the price level proportional to the difference between the real wage rate and the marginal product of labor. The driving force for the adjustment of prices and wages, therefore, is not some measure of output or labor *market disequilibrium* (gaps between market supplies and demands) but rather some measure of the degree to which either households or firms are off their respective labor supply or demand curve.

There are at least two problems with this approach. First, it fails to capture the role of *market* disequilibrium in driving nominal price change and, therefore, appears to have painfully little relation to traditional sticky-price models. Second, it yields wage change and price change equations that are not expectations-augmented. Thus, Leeper and Sims swing wildly from rigidly imposing extraordinarily tight theoretical restrictions on their model earlier to failing in their sticky-price version to impose a restriction that almost all macroeconomists would insist upon.

2. *The Leeper and Sims Conclusions*

The Leeper and Sims findings suggest that there is a tension, to put it mildly, between the data and modern macroeconomics—hardly a surprise from those of us still clinging to the old macro.

It was useful for Leeper and Sims to compare the fit of their model with naive no-change predictions and time series benchmarks from an unrestricted VAR. It would, however, have put their results in better perspective if they compared them with forecasts from a more traditional structural macroeconometric model. That is not easy, because the reported forecasts from those models generally have powerful judgmental elements. However, Ray Fair maintains a record for his large-scale macroeconometric model based on forecasts generated without any judgmental adjustments and with exogenous variables replaced with time series forecasts. This procedure provides a useful comparison to the forecasts generated with the Leeper and Sims model.

Although they do not report significance tests for the parameter estimates, Leeper and Sims find that their modern macro model yields implausible parameter values and a lousy fit and conclude that the data soundly rejects the model. They conclude, for example: "We had substantial difficulties with the 10-variable neoclassical version of the model and did not achieve a respectable fit with it."

This leaves me a little confused. Leeper and Sims begin by telling us that modern macro models are about to replace the current generation of large-scale macro models. They note that they still may need "future refinements" to accomplish this feat. But their results suggest that the modern macro models are fundamentally in conflict with the data. It appears that modern macro is need of more than "future refinements." How about a whole new direction, a thorough reconsideration of the vision on which these models are founded?

3. *More Fundamental Questions*

Given the Leeper and Sims conclusion, I believe we may want to ask some more fundamental questions about their model in particular and the direction of modern macroeconomics in general. I will focus on three broad issues that differentiate the old macro from the modern:

whether to assume continuous market clearing or sticky prices, how to handle expectations and expectations formation, and how tightly to impose theoretical restrictions on model specifications and how much room to leave to allow the data to speak.

3.1 CONTINUOUS MARKET CLEARING VERSUS STICKY PRICES

The old macro is fundamentally concerned with explaining empirical regularities. It begins from sticky prices because observation demands such an assumption. But modern macro often seems to march to a different drummer. It begins from a simple optimizing model and carries it to its logical conclusion. If there is no optimizing story for sticky prices, then prices must clear markets continuously, period.

While theory has its role, so does simple observation. Let me make a prediction (something I am not half bad at): When the old macro rolls over and is replaced with something new, it won't be a model with perfectly flexible prices and continuous market clearing.

The Leeper Sims paper begins with a market clearing model and then offers a sticky-price alternative. But moving from a continuous market clearing model to one with sticky prices requires more than allowing an equilibrium condition to lapse and replacing it with a disequilibrium adjustment equation. Of course, Leeper and Sims don't even go that far. But doing justice to sticky prices requires a more thorough adjustment of the underlying foundations of the model, as suggested by the effective demand literature.

3.2 EXPECTATIONS AND EXPECTATIONS FORMATION

The old macro does a lousy job with expectations. I am interested in work under way to incorporate rational expectations into models with sticky prices.[1]

But, alas, I have some serious reservations about the rigid implementation of rational expectations. Rational expectations is, I hope, a testable hypothesis, not a religion. It is, in my view, as extreme in its assumptions as adaptive expectations is in its own right. It is not at all obvious, in a world with costly information, learning, heterogeneous information

1. This is a direction toward which Bob King seemed to point in his recent article, "Will the New Keynesian Macroeconomics Resurrect the IS-LM Model?" in the *Journal of Economic Perspectives*, Winter 1993. Some work by Evan Koenig at the Dallas Fed also follows this line. See, e.g., "Rethinking the IS in IS-LM: Adapting Keynesian Tools to Non-Keynesian Economies," in *Economic Review*, Federal Reserve Bank of Dallas, Third Quarter 1993.

and beliefs, and great uncertainty about the structure of the economy, that rational expectations correctly captures the decision making of real economic agents.[2]

3.3 HOW TIGHTLY SHOULD THEORETICAL RESTRICTIONS BE IMPOSED ON THE DATA?

The old macro is not devoid of theory. It builds, for example, on the life cycle model of consumption, the neoclassical model of optimal capital accumulation, and inventory theoretic models of money demand. But it would never try to make the data conform to an explicit intertemporal utility function of very specific form for an infinitely lived representative agent under rational expectations. The life cycle model would be used to define a more loosely specified equation with more room allowed for the data to speak about the dynamics of the response of consumption to changes in income and wealth.

How much restriction should be imposed on model specification by theory, and how much should the data be allowed to speak? That depends, I suspect, on how confident we are about theory. Given the confidence I have in our collective understanding of the structure of the economy, I feel more comfortable with imposing less tightly the restrictions suggested by theory and allowing more room for the data to speak. This continues to be the strategy used in building large-scale macroeconometric models.

4. *Conclusion*

The Leeper and Sims paper is a valuable effort to test the success of the revolution in macroeconomics that has been under way for about two decades. My reading is that modern macro fails this test. I believe it will take more than "future refinements" to remedy the mess.

Modern macro theorists may indeed be the new Copernicans, as Greg Mankiw has suggested, but I really doubt it. I expect, therefore, that policy analysis will be left, for better or worse, to the likes of me for some time to come. That is comforting from a business perspective but less so intellectually. I believe the profession could make a more certain contribution to policy analysis by refining the current generation of structural macroeconometric models than by continuing down the road of modern macroeconomics.

2. For a discussion of the limitations of imposing rational expectations in macro models, see Pesaran (1987) and Phelps (1988).

I suppose that leaves me at the end where I started at the beginning —identifying with and clinging to the old macro. So let me conclude by associating myself with a comment by James Tobin in a recent article in the *Journal of Economic Perspectives*: "Considering the alternatives, I do not mind being billed as a Keynesian, an old Keynesian at that."[3]

REFERENCES

King, R. G. (1993). Will the new Keynesian macroeconomics resurrect the IS-LM model? *Journal of Economic Perspectives*, Winter: 67–82.

Koenig, E. F. (1993). Rethinking the IS in IS-LM: Adapting Keynesian tools to non-Keynesian economies. *Economic Review*, Federal Reserve Bank of Dallas, Third Quarter 1993, pp. 33–49.

Lucas, R. E. (1976). Econometric policy evaluation: A critique. In *The Phillips Curve and labor markets, vol. 1*. K. Brunner and A. Meltzer (eds.). Carnegie Rochester Conferences on Public Policy, *Journal of Monetary Economics*, 1976 (Suppl.), 19–46.

Mankiw, N. G. (1988). Recent developments in macroeconomics: A very quick refresher course. *Journal of Money, Credit, and Banking* August: 437–449.

Pesaran, H. H. (1987). *The limits to rational expectations*. Oxford, UK: Basil Blackwell.

Phelps, E. (1988). Comment. *Journal of Money, Banking and Credit*, August: 456–458.

Discussion

Sims responded to Meyer and King's comments on the fit of the model. Sims noted that although the current version model was outperformed by an unrestricted VAR, the fit was close enough to be optimistic that later versions could match the VAR, adjusting for the number of free parameters. Existing Keynesian models, however, are much further away by this criteria.

Sims also clarified several points raised by Meyer. On the modeling of sticky prices, Sims said that although the adjustment equations are expressed in terms of gaps between either marginal costs or marginal utility and real wages, rather than as functions of goods or labor market disequilibrium, the variables are consistent with a standard Phillips curve and markup equation.

3. James Tobin, "Price Flexibility and Output Stability: An Old Keynesian View," *Journal of Economic Perspectives*, Winter 1993, pp. 45–65.

On the modeling of investment, Sims explained that investment is solved dynamically. Instead of being solved by firms, investment is determined by the households' intertemporal optimization problem. This assumption was made for convenience, to avoid having to track equity prices and dividends. However, Sims noted that in the sticky-price version of the model, the distinction between firms and households is relevant, in which case it might be more appropriate to have firms solve the investment problem.

On the model's potential for conducting policy analysis, Sims agreed with Meyer that the current model is too aggregated. In order to compete with existing large-scale macroeconometric models, more policy instruments are required, consumption and investment should be disaggregated into several components, and a foreign sector should be included. However, Sims observed that the cost of introducing more detail would be increased complexity and difficulty in obtaining reliable parameter estimates.

Olivier Blanchard pointed out that there are also conceptual problems in addition to the obvious technical problems in using full information maximum likelihood models with many variables. He noted that three variable systems are convenient to work with and interpret; however, in a 10-variable system, it is difficult to understand exactly what is happening.

Stanley Fischer asked what money demand specification came out of the model. Sims responded that there is a standard LM curve, where money demand depends on the interest rate. Fischer also questioned the application of the model to the data. For example, it is unclear why the monetary base should be used instead of M1. Leeper answered that there is no banking sector in the model, and the monetary base is what belongs in the government budget constraint. Sims agreed that M1 belongs in the money demand equation, and that adding a banking sector and allowing for a distinction between M1 and the base should be considered.

Miles Kimball observed that the flexible price version of the model was similar to a model of Kydland's that incorporated a similar money demand specification in a real business cycle model. Leeper responded that the monetary sector was similar, but that Kydland's model did not allow for fiscal policy, ruling out any interaction between fiscal and monetary policy.

On the issue of fiscal policy, Alan Auerbach asked why the model predicts any real effects, since all taxes are lump sum and agents have infinite horizons. Sims explained that in the flexible price version, the economy is completely Ricardian with respect to real variables. However, for nominal variables, there are strong interactions between prices and fiscal policy shocks that result when the monetary authority tries to maintain an interest rate target. In the sticky-price version, fiscal policy is not neutral in the real variables.

Greg Mankiw asked Sims what model he would use if the CBO asked him to make policy recommendations. Sims answered that in a previous paper, he had used a VAR to make deficit forecasts and that it had performed very well.