Carnegie-Rochester Conference Series on Public Policy 17 (1982) 57-66
North-Holland Publishing Company

PREDICTING THE PRICE LEVEL IN A WORLD THAT CHANGES ALL THE TIME
A Comment

Finn E. Kydland*
Carnegie-Mellon University

In the paper by Bomhoff (1982), an impressive set of data filtering techniques is put to use in various ways for making short-run predictions about the money stock, aggregate output, and, in particular, the price level. These techniques have apparently been used much more in other fields than in economics. It is important, therefore, to have somebody look carefully at their potential for making unconditional economic predictions. I think it is fortunate that Bomhoff resisted the temptation to make the model of the economy too complex, thus enhancing its usefulness as a vehicle for illustrating this potential. Instead, he demonstrates how these filtering techniques can be used at various levels of complexity, from forming forecasts of the money stock when its change is assumed to have unobservable permanent and transitory components with known relative variances to allowing these relative variances, and subsequently also the parameters of the money-demand function, to be updated as well.

One may be concerned about how little economic theory is brought to bear and view these exercises as somewhat ad hoc. I would argue, however, that, for the purpose at hand, it is not clear that the reliance on more economic theory would significantly improve on the predictions.

Within an aggregate context, there may be several motives for conducting empirical research, and it is surely the case that the usefulness of alternative statistical methods depends upon the purpose of the study. Motives other than short-run predictions may be estimating a model within which alternative government policies can be evaluated, or using aggregate data as an aid in determining what model features are essential for explaining the operating characteristics of the economy. The latter task should presumably precede the former. In either case, it is essential that models be specified at a level such that the parameters can be expected to be policy invariant, namely, parameters of preferences, technology, and information sets. Formal statistical methods, such as maximum likelihood methods, for estimating and testing detailed aggregate models at that level are not yet well developed, or at least not compu-

*I am grateful to Edward Prescott for helpful comments and to the National Science Foundation for financial support.

0167-2231/82/0000-0000/$02.75

tationally feasible. Methods such as those of Hansen and Sargent (1980), in which agents' optimization problems are assumed linear-quadratic, are extremely useful for industry studies. It does not appear possible, however, to specify aggregate equilibrium models in detail and still stay strictly within the linear-quadratic framework. One approach currently being pursued is to start with more general nonlinear models for which the long-run or steady-state levels can be determined analytically, and then approximate around these levels to make the structure linear-quadratic. This appears reasonable when the deviations are relatively small as is the case with most aggregate data. An alternative is to work directly with nonlinear first-order conditions (see, e.g., Hansen and Singleton, 1982). It is unclear how far such methods can be pushed in an aggregate context. The applications so far have modelled very limited slices of the economy, such as some elements of consumer behavior, while being nonspecific about the production side, for example.

Even if such methods were available, I would argue that, for the purpose of searching for the essential model features to explain aggregate fluctuations, one would have to exercise a great deal of caution. While we would definitely want to have the model specified at a level where the parameters are policy invariant, formal econometric testing is not without problems. When there are several candidates for model elements that cannot be excluded a priori, these are often not nested. One may argue, also, that initially at least, it is best for this purpose to keep the model fairly abstract so that the contribution of various model elements is as transparent as possible and the results not driven too much by stochastic specifications, including measurement errors, that do not come out of the theory. Such a model may not look very good according to formal testing criteria, say versus the unrestricted vector autoregressive model, even if it contains the right model elements. Alternative methods for summarizing the data and matching the model with the data may be called for. These methods should also enable one, for example, to ascertain the sensitivity of the operating characteristics within ranges of values for parameters that may differ substantially across economies[1], or with respect to timing conventions or other factors that are part of the maintained hypothesis.

In either case, models of economic agents' maximizing behavior would form the basis for the empirical work. If the only purpose is short-run predictions, however, it is not clear that much could be gained from the use of such models in comparison with the approach taken by Bomhoff. This is especially true if predictions involve or hinge in an important way on future policy variables, such as the money stock.

[1]Lucas (1977) makes the point that the principal empirical regularities of the business cycle appear to be common to all decentalized market economies.

Consider a maximizing model of the aggregate economy where the relevant state of the economy at time t can be summarized in a vector of variables S_t (if some variables with time subscript less than t are needed for indexing future preferences, technology, or information sets, these variables are included in S_t as well). Since distributional issues are not essential here, I shall use an abstraction in which there is a large number of households that are all alike. The household-specific state can then be denoted by s_t. Suppose now that one of the decision rules that follow from maximization of households' utility is the demand for money:

$$m_t = d_t(s_t, S_t, P_t) ,$$

where P_t is the aggregate price level, and that this decision rule is linear. At the moment we shall assume that it was derived in the expectation that future prices are given by $P^e_{t+i} = P^e_{t+i}(S_{t+i})$, and that the individual understands the law of motion of the aggregate economy.

If we aggregate across individuals, we get

$$M_t = D_t(S_t, P_t) .$$

Suppose now that the money supply is governed by a policy rule $M^S_t = M^S_t(S_t)$. Then, the equilibrium price level must satisfy

$$D_t(S_t, P_t) = M^S_t(S_t) ,$$

that is, P_t is some function $P_t(S_t)$. Only if the expectations, on the basis of which individuals' decisions were made, are consistent with what is obtained from aggregation and market clearing do we have an equilibrium.

We know that if the monetary rule were to change, the coefficients of the decision rules d_t and of the corresponding aggregate money-demand function D_t would change because of the effect on future prices.[2] If agents think the policy rule is likely to change again in the future, then price behavior even in the current period will be affected. Thus, the effect of an announced policy rule $M^S(S_t)$ could be determined only if it were credible. Otherwise, depending upon agents' perceptions of the likelihood and expected extent of change, the

[2]If it were not for the monetary feedback rule, the competitive equilibrium could, under quite general assumptions, be determined by solving the utility maximization problem of the price-taking representative household (see Prescott and Mehra, 1980), and the distinction between individual and aggregate variables would not have been necessary.

resulting behavior could be anything. In such a situation, even a good model, in the sense of having the elements needed for explaining business cycles and accurate estimates of the policy-invariant parameters, would not be helpful in making predictions.

These problems complicate not only the use of economic theory in making predictions but also attempts at determining from past data the effects of government policies on the economy. Good examples are the studies by Barro (1977, 1978) of the effects of unanticipated monetary shocks. These shocks were defined as the deviations from a monetary growth rule estimated once and for all for the entire sample period. Kantor (1979, p. 1432) argued that it would be more in the spirit of rational expectations theory to use only data up until period $t - 1$ to determine the unanticipated monetary shock in period t. I would disagree with this view and suggest that Barro's implicit hypothesis, namely, that the predictable part of monetary policy has been stable over the sample period, was a reasonable one for his purpose. The reliability of the results depends, of course, on how accurate this hypothesis is. It follows from my discussion above, however, that the procedure suggested by Kantor is unlikely to be of help in guarding against its failure.

The methods in Bomhoff's paper represent more elaborate ways of using data up until period t for making predictions about period $t + 1$. I do not share Bomhoff's optimism about the potential usefulness of his model for purposes other than short-run predictions, such as evaluation of alternative (and credible) monetary policies. My reasons are implicit in the above discussion. The paper may possibly be suggestive to economists trying to incorporate unobservable elements and learning processes into models with maximizing agents. Theories based on learning have been particularly useful in providing insights on many phenomena within cross-sectional contexts. An example is the work by Jovanovic (1979) in which workers and firms learn the unobserved worker-job match over time. There are aggregate models with permanent and transitory shocks where only the sum is observable.[3] Simple Kalman filtering methods can be used for determining the conditional expectations of these shocks when their variance-covariance matrix is known. If this matrix also is subject to learning over time as in Bomhoff's model of Type 2, then models based on maximizing behavior become difficult to solve. In that case, the separation between estimation and control is lost.[4]

[3] See Brunner, Cukierman, and Meltzer (1980), Crawford (1979), and Kydland and Prescott (1982).

[4] For an excellent exposition, see Zellner (1971).

In the last ten years or so, much of the work on aggregate equilibrium models, inspired by the seminal papers by Lucas (1972, 1975) and carried further by Barro (1976) and others, has dealt with the possible effects of various information structures on aggregate fluctuations. This research was particularly important because it demonstrated the potential for monetary shocks to create persistent real fluctuations in equilibrium. One of the most recent papers in that spirit is by Townsend (1981). Kalman-filtering techniques are central to his analysis. The paper shows that further work incorporating interesting information structures still can provide many insights. I think, however, that, at least relatively speaking, the propagation mechanisms deriving from preferences and technology have been neglected. High priority must be given to determining the role of productive capital, inventories, durable consumption, and perhaps capital-like elements in preferences as well, in the propagation of aggregate fluctuations.

In most equilibrium models, there is a sense in which learning has already taken place. We usually impose upon agents knowledge of agents' behavior in the aggregate and of autonomous processes generating shocks. Admittedly, such a degree of perfection in understanding the way the economy works could realistically be obtained only after some learning. Rational learning behavior of this kind, that is, about the structure of the economy, is hard to model, however. The difficulties in trying to model optimal learning about autonomous processes are discussed in Sargent (1981). One could also imagine economic agents learning about the aggregate behavioral relations that are of importance for their individual decisions. This is even harder to model rationally because the aggregate of agents' behavior will be the actual laws of motion that they are trying to learn about.[5] There may even appear to be a potential for instability in this situation. For that reason, results are sometimes presented suggesting that the economy, if it were located away from the equilibrium laws of motion, would tend towards the equilibrium under reasonable learning or adjustment assumptions. This, in effect, is a check for stability and provides a justification for the equilibrium concept being used in the model that is confronted with the data.[6]

[5]For example, in the simple abstraction above, say under stable and well-understood monetary policy, the agent choosing money demand function *d* would learn about the aggregate money demand function *D* and the resulting law of motion *P* for the price level. In equilibrium, the function *D* that the agents take into account when solving their optimization problems coincides with the aggregate of the individual *d*'s.

[6]Discussions of this kind of stability for dynamic competitive models can be found in Kydland and Prescott (1977, Appendix) and in Lucas (1978, Section 6). One might take the point of view that if an abstraction works in the sense of describing the data well, then there is no need to check for stability. Of more interest, perhaps, are cases where stability arguments could help one choose between more than one candidate for an equilibrium. In dynamic noncooperative games there is generally a difference between the policy rule (or sequential in the terminology of Prescott and Townsend, 1980) Nash solution and the path (also called open-loop) solution. Kydland (1975), in effect, argued on stability grounds that only the former makes sense as an equilibrium concept in economics.

The fact that incorporating learning about the structure is difficult should not keep us from trying to make progress in that direction. At the present time, however, while we are still searching for the more basic model elements that are needed for explaining the variability and comovements of output and other key aggregate variables, we are probably better off not attempting to make such learning about the structure an integral part of our models other than perhaps the ones intended for unconditional forecasting.

Finally, I believe several of these comments also have relevance for the paper by Meyer and Webster (1982) appearing in this issue.

References

Barro, R.J.

(1976) Rational Expectations and the Role of Monetary Policy. *Journal of Monetary Economics,* 2: 1-32.

———— (1977) Unanticipated Money Growth and Unemployment in the United States. *American Economic Review,* 67: 101-115.

———— (1978) Unanticipated Money, Output, and the Price Level in the United States. *Journal of Political Economy,* 86: 549-580.

Bomhoff, E.J.

(1982) Predicting the Price Level in a World that Changes All the Time. Carnegie-Rochester Conference Series, this issue, eds. K. Brunner and A.H. Meltzer. Amsterdam: North-Holland.

Brunner, K., Cukierman, A., and Meltzer, A.H.

(1980) Stagflation, Persistent Unemployment and the Permanence of Economic Shocks. *Journal of Monetary Economics,* 6: 467-492.

Crawford, R.G.

(1979) Expectations and Labor Market Adjustments. *Journal of Econometrics,* 11: 207-232.

Hansen, L.P. and Sargent, T.J.

(1980) Formulating and Estimating Dynamic Linear Rational Expectations Models. *Journal of Economic Dynamics and Control,* 2: 7-46.

Hansen, L.P. and Singleton, K.J.

(1982) Generalized Instrumental Variables Estimation of Nonlinear Rational Expectations Models. *Econometrica,* forthcoming.

Jovanovic, B.

(1979) Job Matching and the Theory of Turnover. *Journal of Political Economy,* 87: 972-990.

Kantor, B.
(1979) Rational Expectations and Economic Thought. *Journal of Economic Literature*, **17**: 1422-1441.

Kydland, F.E.
(1975) Noncooperative and Dominant Player Solutions in Discrete Dynamic Games. *International Economic Review*, **16**: 321-335.

Kydland, F.E. and Prescott, E.C.
(1977) Rules Rather Than Discretion: the Inconsistency of Optimal Plans. *Journal of Political Economy*, **85**: 473-491.

――――――
(1982) Time to Build and Aggregate Fluctuations. *Econometrica*, forthcoming.

Lucas, R.E., Jr.
(1972) Expectations and the Neutrality of Money. *Journal of Economic Theory*, **4**: 102-124.

――――――
(1975) An Equilibrium Model of the Business Cycle. *Journal of Political Economy*, **83**: 1113-1144.

――――――
(1977) Understanding Business Cycles. *Stabilization of the Domestic and International Economy*. Carnegie-Rochester Conference Series, **5**, eds. K. Brunner and A.H. Meltzer. Amsterdam: North-Holland.

――――――
(1978) Asset Prices in an Exchange Economy. *Econometrica*, **46**: 1429-1445.

Meyer, L.H. and Webster, C., Jr.
(1982) Monetary Policy and Rational Expectations: a Comparison of Least Squares and Bayesian Learning. Carnegie-Rochester Conference Series, this issue, eds. K. Brunner and A.H. Meltzer. Amsterdam North-Holland.

Prescott, E.C. and Mehra, R.

(1980) Recursive Competitive Equilibrium: the Case of Homogeneous Households. *Econometrica,* **48**: 1365-1379.

Prescott, E.C. and Townsend, R.M.

(1980) Equilibrium Under Uncertainty: Multiagent Statistical Decision Theory. *Bayesian Analysis in Econometrics and Statistics,* ed. A. Zellner. Amsterdam: North-Holland.

Sargent, T.J.

(1981) Interpreting Economic Time Series. *Journal of Political Economy*, **89**: 213-248.

Townsend, R.M.

(1981) Forecasting the Forecasts of Others. (Working Paper, Carnegie-Mellon University).

Zellner, A.

(1971) *An Introduction to Bayesian Inference in Econometrics.* New York: John Wiley & Sons.