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The Care and Feeding of Econometric Models

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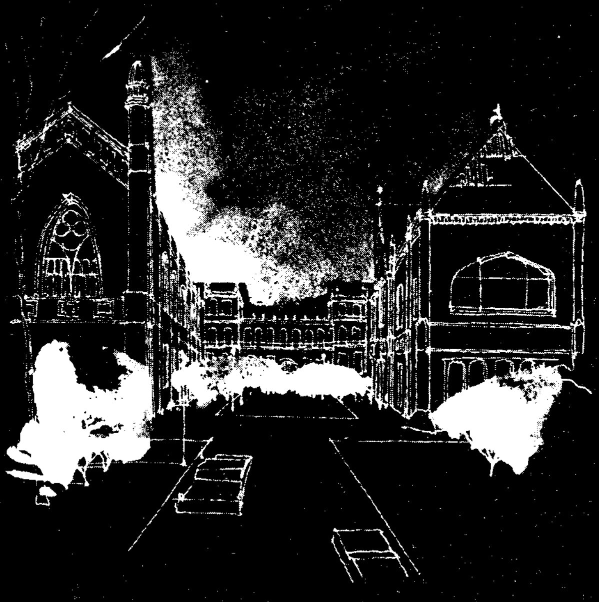

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The Care and Feeding of Econometric Models

IT IS ACCURATE to state that we are witnessing the emergence of an econometric model building industry. Models of internal firm activities, firms, banks, households, markets, regional economies, national economies, and even the world economy have been or are being constructed.[1] In part, the growth in modeling activities is due to the fact that mathematical modeling involves the capability of representing the interaction of many factors or variables in an explicit, logically consistent, mathematical manner.[2] Such a mathematical representation often helps in achieving an understanding of the system being modeled whether it be a firm, a market, or a national economy. In addition, models may be useful in forecasting future values of variables such as a firm's sales or GNP for an economy,[3] and in appraising the probable effects of alternative policies. That statistical and computer methods are available for "checking out" models using empirical data is also of prime importance since otherwise models might be mere mathematical flights of fantasy. By confronting models with actual data, we are in a position to appraise their performance.

AS IN OTHER areas, it is important to distinguish between theoretical and applied work in the modeling area. For example, in the automobile industry we have engineers who design and help build automobiles. While they utilize the principles of physics, they are not primarily concerned with discovering new physical laws or theories. Rather they are concerned with applying and adapting known laws of physics,

Footnotes are presented at the end of the paper.

etc., to enable them to build good automobiles. Similarly, in the econometric modeling area there are theoreticians who are concerned with producing better economic theories, statistical methods, and computer techniques. While this work is of fundamental importance, it should not be confused with the work of applied econometric modelers who are in the main attempting to apply and adapt existing theory and methods to produce useful models. Often this applied work is very much an art and involves approximations and ad hoc procedures to bridge gaps in our economic knowledge and inadequacies of current statistical and econometric methods.

Frustrating and irritating as these approximations and ad hoc procedures may be to theoreticians, it is accurate to say that they are needed in many instances because theorists have not as yet produced solutions to quite a few problems faced by applied workers building econometric models. And in fact, it may be that approximations and ad hoc procedures which work in practice will be rationalized in future theoretical work.

In this paper we shall be in the main concerned with the activities of applied econometric model builders who are striving to produce good models on the basis of currently available theoretical results, statistical and computer methods, and data.

Given that we are concerned with the activities of applied econometric model builders, it is pertinent to note that such activities can and do take place in different institutional settings. Some model builders operate in consulting firms, some in governmental agencies, some in academic institutions, and others in private firms. While the institutional setting and arrangements can have an important influence on modeling activities, in this paper we shall merely mention this fact without going into these considerations in detail. Rather, we shall review aspects of model building activities abstracting from many institutional constraints which can be important in particular instances. In order to catalogue the various specific activities needed in econometric modeling, it is important to have a good perspective of the general characteristics of a modeling operation, including its initiation and subsequent development.

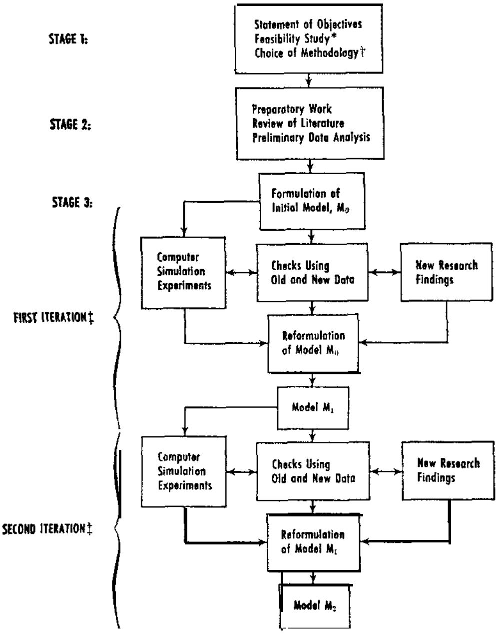
Overview of *Modeling Activities*

Often specific problems arise which potentially can be dealt with by a modeling approach. For example, a firm may be having personnel problems, and perhaps a personnel model incorporating its personnel policies (e.g., hiring, firing, retirement, and salary policies) would be helpful in reducing costs and in finding ways to get better performance in other respects. Or a government may wish to know how proposed changes in a transport system may affect economic growth; perhaps a modeling approach would be useful in solving this problem. In these two examples, and in others, it is important to develop as clear-cut a statement of the problem as possible. Then the question to be asked is: what are the relative costs and advantages of alternative approaches available for solving the problem? Obviously, for some problems a modeling approach may not be feasible, perhaps because it is too expensive relative to the estimated benefits, or because the requisite knowledge and/or data needed for a modeling approach are unavailable. If, however, a modeling approach is considered appropriate, then an issue which must be faced is: should the modeling work be done "in-house" or by contract with (say) a consulting firm? In making this decision, it is of course important to assess relative costs and probabilities of successful problem solution. This specific problem deserves serious study. For present purposes, we shall not consider it further but shall turn to a description of modeling activities in general.*

THE SCHEMATIC diagram in Fig. 1 is a useful representation of some key elements involved in modeling activities. As shown at the top of the diagram, in Stage 1 it is important, as mentioned above, to set forth the problem and objectives as clearly, simply and specifically as possible. Then a feasibility study should be undertaken to determine whether or not the project is feasible and to appraise alternative methodological approaches. If a modeling approach is decided upon, then in Stage 2 a good

FIGURE 1

SCHEMATIC OF RESEARCH STRATEGY



* It is assumed that this study shows the project to be feasible.

† It is assumed that a "modeling" approach is selected.

‡ The iterative procedure may disclose problems in the original formulation of goals, feasibility, and methodology so that refining and reformulation of the effort may not be confined solely to the model itself.

deal of preparatory work must be undertaken. This will involve a review of the literature bearing on similar modeling projects, etc., and preliminary data analysis. This preparatory work's object is the formulation of an initial model, denoted M0. It is understood that the initial model will be checked for mathematical consistency and consistency with economic principles. Then, just as an airplane model is subjected to wind-tunnel experiments, the initial model is put on the computer and subjected to simulation testing. In addition, checks using old and new data are made and relevant research findings are brought to bear on the initial model. All of this activity is aimed at producing an improved version of the model, say M1. Then the whole process is repeated to obtain a better version, M2, and so on. In this way we attempt to "iterate in" on a model which is capable of achieving the objectives of the model building project. If the objectives involve operation of the model over long periods of time, then of course the iterative procedure can be pursued as long as the model is in use. In addition, as the model evolves it may be found that it is possible to broaden the objectives of the project, or it may be necessary to narrow them.

In the approach to modeling set forth above, it is clearly the case that many specific activities are involved which require knowledge from a variety of disciplines, for example, economics, econometrics, statistics, mathematics, computer sciences, and other disciplines relating to the problem being analyzed. There will be a definite need for coordinating and administering a broad range of activities and a staff of several specialists and technicians.6 It appears useful to have a model manager to administer model building activities. To do this effectively and to have the whole set of modeling activities proceed smoothly and in an orderly fashion require most importantly that the model manager be a good administrator with respect to planning operations, budgeting, and personnel relations. In addition, modeling activities require well-organized systems of documentation. Some observations on the specific nature of these latter requirements are made in the next section.

Documentation and Modeling Activities

Good documentation of modeling activities is of the utmost importance in providing for orderly and cumulative progress. In an important sense, this is similar to the requirement that a laboratory scientist record his experiments and work in his lab notebook, or that a business have an accountant maintain a good set of books. While it is difficult to generalize about what records should be kept, it is thought that a model manager will find it useful to maintain at least the following files:

1. Literature File
2. Model File
3. Data File
4. Statistical Inference File
5. Forecasting File
6. Simulation Experiment File
7. Computer Program File
8. Budgeting and Planning File

We shall now discuss the nature of these files.

1. *Literature File:* As its name implies, this file includes items from the literature which are particularly relevant for modeling activities. Generally speaking, it will be necessary to include works from the areas of economic theory, empirical economics, statistical methods, computer methods, mathematics, etc., in the Literature File. In addition, the specific nature of a modeling effort will usually imply the need for coverage of other areas of the literature. For example, if the modeling project is a regional one dealing with water problems, it will be necessary to have the Literature File

include relevant works from the areas of regional economics, economics of water, hydrology, etc.

To be useful to modelers, the Literature File should be kept in an orderly and careful manner. In some cases, a special library can be formed; in others, existing library facilities can be employed. In either case, it will be useful to develop a good classification scheme for works in the Literature File and to have information relating to items in the file keypunched on computer cards. Given that this is done in an intelligent manner, it is possible to develop bibliographies relating to specific topics merely by sorting cards. Also, with the Literature File on computer cards, it is possible to have copies of the file made easily.

2. ***Model File:*** This file contains specific information regarding the model and model changes. This file is of great importance since it incorporates information relating to the iterative steps taken to improve the initial and subsequent versions of a model. When the initial model, M0, has been formulated, its equations and variables, along with their definitions, should be incorporated in the Model File, perhaps in the form of a dated computer listing. As work with the initial model proceeds, as described above, equations of the initial model may be changed. Altered versions should be entered in the Model File, appropriately dated and identified with references to other files wherein explanations and justifications for changes are provided. For example, an equation's coefficients' values may be changed as a result of reestimation based on new data. Reference would then be made to an entry in the Statistical Inference File (to be described below) which provides the details of the reestimation.

As changes in the initial model accumulate, a new version, M1, will emerge. Its equations and variables, with definitions, should then be entered in the Model File along with future changes and modifications. As the model begins to "stabilize," it will become useful to institute systematic review procedures. For example, an annual review of the model can be scheduled and changes instituted on an annual basis. Having a basic model available throughout the year to which continuing work can be related is important. Also, since it is often the case that revised national accounts data become available once each year, reestimation and further testing can be scheduled so as to utilize this new information when it appears.

The Model File at any point in time will contain a complete description of the initial model, subsequent variants, and a detailed description of various model changes along with references to other files describing the rationale and reasons for such changes. Having all this information available in a computer listing is very useful to workers working with the current variant of a model.

3. *Data File:* As the name implies, this file contains the data employed in a modeling project. Naturally, it is important that the Data File be kept carefully. Sources of data, variables' definitions (including units of measurement), variables' symbols, etc., should all be incorporated in the Data File. In addition, since data are often first available in the form of preliminary estimates and then revised, it is important that entries in the Data File reflect revisions of the data. Then too, the Data File should be broad enough to include the results of studies bearing on data accuracy, relations between provisional and revised estimates, etc.

4. *Statistical Inference File:* This file is maintained to provide detailed information regarding statistical operations with variants of a model, for example descriptions of statistical tests and estimation of parameters. It is important that such operations be fully described. Among other things, it is relevant to indicate

and explain the objectives and results of a statistical operation and the methods, data, and computer programs utilized. In addition, the variant of a model under study should be specified (a reference to the Model File may suffice). With such information entered in the Statistical Inference File for each statistical operation, it is possible for current workers to appreciate what work has been done on statistical problems in the past and to plan future work more effectively.

5. *Forecasting File:* If a model is used for forecasting, it is extremely useful to maintain a file containing information about past forecasts, forecast errors, and analyses of forecast errors. Naturally in describing forecasts, it is necessary to indicate the variant of the model employed, how and with what data it was estimated, any assumptions utilized in obtaining forecasts, the way in which forecasts were obtained, the forecast period, etc. Also relevant here are comparisons of the model's forecasts with those provided by other models or by other methods if they are available. By having the information systematically entered in the Forecast File, a model's forecasting performance can be appraised on a continuing basis.

6. *Simulation Experiment File:* As indicated in the previous section, simulation experiments are usually performed to provide information about the operating characteristics of a model. They are also performed to appraise the effects of alternative policies on a model's outputs. Since simulation experiments constitute such an important role in modeling activities, it is critical that they be well-described and documented. It appears useful to write a "lab" report for each simulation experiment and to incorporate such reports in the Simulation Experiment File. These dated reports should include at least a description of the simulation experiment's purposes and objectives, the variant of the model employed, the

simulation program, the conditions of the experiment, and the results and an interpretation of them. If a simulation experiment suggests changes in the formulation of a model, this should of course be noted. The Simulation Experiment File, properly maintained, can be of great value to workers attempting to improve a model and using a model for appraising the possible effects of alternative policies.

Modeling activities usually involve use of several computer programs. For example, computer programs for statistical estimation, for statistical testing, for accessing data files, for transforming variables, for performing simulation experiments, etc., are generally required in modeling work. It is thus useful to have a Computer Program File in which programs being employed are completely described. Then too, changes in computer programs and studies to evaluate the numerical accuracy of computer programs should be well-documented and included in the Computer Program File. By following such procedures, the work of those engaged in modeling activities will be made more effective and efficient.

8. Budgeting and Planning File: This file is one that a model manager will want to maintain so as to insure that modeling activities proceed effectively and remain within budget constraints. At any point in time, there will be a number of sub-projects which must be completed. The scheduling of such projects and the assignment of personnel to complete these projects is a major responsibility of the model manager. It may be possible for him to develop a flow diagram of the work in progress with estimates of completion dates for specific sub-projects. Regular meetings with the modeling staff, say at monthly intervals, to review progress and to assess job priorities and scheduling will probably be useful. The Budgeting and Planning File should include reports of these meetings as well as proposed work plans with budget allocations. By monitoring modeling activities in this way, the probability of realizing the objectives of a modeling effort within budgetary constraints should be raised.

With these remarks made about aspects of documentation, we shall now turn to a discussion of available procedures for appraising model performance.

Procedures for Appraising Model Performance

The best procedure for appraising a model's performance, whether it be forecasting performance or policy analysis performance, is a serious study of the results of its actual performance in use.6 Does the model forecast accurately enough? That is, are its forecast errors small enough to be tolerable? Does it catch turning points? As regards policy uses of a model, has the past use of the model been helpful in understanding the effects of policy changes (for example changes in fiscal and monetary policies at the national level)? For a model of a firm it is relevant to ask: has the model been of value in forecasting? Has it been useful in furthering understanding of firm operations and producing and evaluating changes in firm policies and practices?

Answers to the above questions are relevant for assessing the possible benefits derived from use of a model. To complete the picture the cost side must be considered. What are the costs associated with developing and operating a model? In this connection, the salary component of costs will undoubtedly be a major one. Competent and resourceful individuals are needed to develop and operate a model effectively. Thus in appraising the record of a particular model, which has seen actual use, it is important to assess salary costs realistically, as well as other items of cost. In an important sense, a modeling project should be viewed and evaluated as an investment. While certain costs and benefits may be difficult to estimate, it is still worthwhile to carry through calculations to arrive at a rough rate of return for a modeling project, particularly at the firm level.

IT IS UNFORTUNATE that detailed, long records of the performance of a number of models are not available at present. This is due to the fact that many models have been developed only recently, and also because records of performance are often not made public. More fundamentally, "laboratory and field' experimentation is usually not possible. While airplane designers can employ test flights to evaluate design performance under preassigned conditions, this important procedure is not generally available in the case of econometric models. Procedures for checking out the latter models are somewhat indirect, and hence there is considerable uncertainty about the actual performance characteristics of an econometric model which has not as yet been used extensively in practice.

Some model checks which are currently in use will now be reviewed. First, and of fundamental importance, an econometric model should be checked for logical consistency. Are the equations of the model consistent? Does the model have a unique solution? Are the units of measurement for variables appropriate? These are basic mathematical considerations which may appear obvious; however, they are of such vital importance that it is deemed worthwhile to mention them explicitly.

Second, a model should be analyzed carefully to obtain an understanding of how it works. Then the workings of the model should be compared with what is known in theory about the entity being modeled. For example, a model of a national economy should incorporate and not be in conflict with established principles of macroeconomic theory. In addition, the judgment and knowledge of those who are familiar with the entity being modeled should be utilized to evaluate the basic model mechanisms.

Third, as mentioned above, simulation experiments can be employed to aid in the understanding and evaluation of a model.[8] For example, changes in exogenous variables such as federal government spending, tax rates, etc., can be fed into a model to determine its responses. Are they of reasonable magnitude? Is the timing of such responses reasonable? Do any variables assume unusual values? For example, if the functional forms of certain relations are in error, it is possible that an interest rate variable may assume a negative value. In addition, simulation experiments designed to approximate certain historical episodes can be performed. Does the model yield outcomes that approximate well the actual outcomes? Further, it is important to study a model's performance under extreme conditions (large changes in exogenous variables, for example). When the conditions of a simulation experiment are such as to strain a model, some of its weaknesses become apparent. Also, it is the case that extreme conditions may be encountered in using the model in practice. Since periods of extreme conditions are often vitally important, establishing a model's operating characteristics under such conditions is vital.

Fourth, some statistical procedures are available for checking a model using actual data.[9] Of course, it is often the case that data available for statistical checks are not as extensive as desired and do not have the properties that they would have if we could actually design and carry through experiments. Be that as it may, the actual "non-experimental" data that we do have can often be used fruitfully to check for possible inadequate or erroneous formulations. For example, it is good practice to study the properties of residuals from statistically fitted relationships of a model.[10] Intensive residual analysis can often result in the discovery that a functional form of a relationship is in error, an important variable may have been omitted, or a lag structure may have been misrepresented. When such discoveries are made, equations of the model will have to be reformulated and reestimated.

For models that are not too complicated, formal statistical tests of hypotheses can be carried through. For example, it is often of interest to determine whether or not the coefficients of a model are constant in value through time. By splitting the sample in half, with one half relating to an earlier period and the other to a more recent period, it becomes possible to test the hypothesis that corresponding coefficients have the same value in two periods. Large sample tests of identifying restrictions are also available. Unfortunately, the small sample properties, power, etc., for many test procedures applied to relatively complex time series models are not known at present. Also, it is the case that for moderate to large-sized models, limited data must be used to investigate a rather broad range of hypotheses, to find good relations, and to estimate them. When the information in the data is used for a variety of tests, etc., results are often not very sharp and the information in the data will often have to be supplemented by judgment, theoretical principles, and other “outside” information. For example, given the objectives of a modeling project, many use a simplicity criterion in formulating a model-that is, an attempt is made to formulate the simplest model which is consistent with accomplishing the objectives of the project.

Formal statistical methods for comparing non-nested models are being developed but have not as yet been perfected[11] to the point where they are operational for models with (say) 20 or more equations. For such large models, the comparison of alternative versions is still pretty much an art.

Fifth, intensive examination of the forecasting experience and policy uses of models is without doubt the most crucial criterion for assessing the performance of models. On the forecasting side, comparisons can be made with the forecasts yielded by alternative models and by informal techniques. Where poor forecasting is encountered, it is imperative that the source or sources of difficulty be located and the model be improved. On the policy side, a model should be helpful in appraising the effects of alternative proposed policies. A model's performance in this dimension can be checked against outcomes actually observed in particular historical episodes and in current episodes as they unfold in time. For example, with a model of a national economy, it is relevant to set up conditions resembling those actually encountered in a major depression-for example, the 1929 downturn. Given that the outside factors or exogenous variables behave as they did in that downturn, does the model yield paths for endogenous variables, say GNP, the price level, interest rates, unemployment, etc., which resemble those actually encountered historically? This sort of testing should be extended to "credit crunch" periods and other exceptional historical periods. If there are failures in approximating the behavior of the economy in such episodes, this is important information for evaluating a particular model.

Summary and Conclusions

In the present paper, we have attempted to provide an overview of modeling activities. To have these activities proceed as smoothly and effectively as possible requires not only a good and well-trained group of modelers but also managerial talents of a high order.

The manager of modeling activities is often a key person in a modeling effort. His activities, as well as those of the modeling group, will be facilitated by maintaining good documentation. Various documentation files have been described above which will probably be of considerable value in modeling projects. Then too, emphasis has been placed on spelling out as precisely as possible the objectives of a modeling project, since the objectives are important in providing orientation and guidance for the model builders. Further, considerable planning of sub-tasks in a modeling activity is needed in order to insure smooth progress and dovetailing of sub-projects within inevitable budget, personnel, and time restrictions.

As regards evaluation of the final product, the model, various techniques including simulation experiments, statistical methods, and heuristic and theoretical checks have been mentioned. However, in the last analysis, the ultimate check is actual use and performance of a model in performing the tasks, e.g., forecasting, policy analysis, etc., for which it has been built. Simply put, the proof of the pudding is in the eating.

FOOTNOTES

1 For a review of a collection of early models of national economies, see M. Nerlove, "A Tabular Survey of Macro-Econometric Models," *International Economic Review*, May 1966, 127-175. Chapter 4 of H. R. Hamilton, S. E. Goldstone, J. W. Milliman, A. L. Pugh III, E. R. Roberts, and A. Zellner, *Systems Simulation for Regional Analysis*, MIT Press, 1969, provides a review of a number of regional projection models. The recent economic literature contains papers dealing with the Brookings-SSRC and Federal Reserve-MIT econometric models of the U.S. economy.

2 A discussion of mathematical models in the social sciences, with particular emphasis on economic models, appears in H. R. Hamilton, et. al., op. *cit.*, Chapter 2.

3 See, e.g., D. B. Suits, "Forecasting and Analysis with an Econometric Model," American Economic ***Review,*** March 1962, 104-132, reprinted in A. Zellner (ed.), ***Readings in Economic Statistics and Econometrics,*** Little, Brown and Co., 1968, 583-611. Suits presents a comparison of actual forecasts of annual GNP and other items with actual outcomes for the period, 1953-1960.

4 The description which follows is based on material in Ch. 13 of H. R. Hamilton et. al., op. cit.

5 A discussion of these problems appears in H. R. Hamilton et. al., op. cit., Appendix A, "The Management of a Multidisciplinary Research Project."

6 See, e.g., J. Mincer (ed.), ***Economic Forecasts and Expectations: Analysis of Forecasting Behavior and*** Performance, National Bureau of Economic Research, Columbia University Press, 1969, and the references therein for analyses bearing on the appraisal of the forecasting performance of models.

7 G. Fromm and P. J. Taubman, ***Policy Simulations with an Econometric Model,*** The Brookings Institution, North-Holland Publishing Company, 1968, presents a good discussion of policy simulations with references to the earlier literature.

8 There are many unsolved problems in this area regarding the design and interpretation of simulation experiments. Thus simulation experimentation in connection with econometric models is still pretty much an art. See T. H. Naylor, J. L. Balintfy, D. S. Burdick, and K. Chu, Computer ***Simulation Techniques,*** John Wiley and Sons, Inc., 1968, for a useful discussion and references to the literature.

9 The current econometrics texts provide some results (not as extensive as we would like) on this point. See, e.g., A. S. Goldberger, ***Econometric The***ory, John Wiley and Sons, Inc., 1964; J. Johnston, ***Econometric Methods,*** McGraw-Hill Book Co., 1963, C. R. Christ, ***Econometric Models and Methods,*** John Wiley and Sons, Inc., 1966; E. Malinvaud, ***Statistical Methods*** of ***Econometrics,*** Rand McNally and Co., 1966 and the references cited in these works.

10 Residual analysis for regression models has been studied fairly intensively. See, e.g., J. Putter, "Orthonormal Bases of Error Spaces and Their Use for Investigating the Normality and Variances of Residuals," ***Journal*** of ***the American Statistical Association,*** Sept. 1967, 1022-1036; J. B. Ramsey, "Tests for Specification Errors in Classical Linear Least-Squares Regression Analysis," ***Journal*** of ***the Royal Statistical Society, B, 31, No. 2,*** 1969, 350-371, and

references cited in these works. Procedures for systematic residual analysis in the context of "simultaneous equation" econometric models have not received much attention in the literature.

11 See, e.g., G. E. P. Box and W. R. Hill, "Discrimination Among Mechanistic Models," *Technometrics,* February 1967, 57-71; H. Thornber, "Applications of Decision Theory to Econometrics," unpublished doctoral dissertation, U. of Chicago, 1966; and Ch. 10 in A. Zellner, *Bayesian Inference in Econometrics,* lecture notes to be published.