Guy Orcutt

Use of Natural Experiments in Microanalytic Modeling

Im folgenden Aufsatz werden Forschungsstrategien für den Aufbau mikroanalytischer Modelle erörtert. Durch solche Modelle können die Konsequenzen geplanter Maßnahmen aufgezeigt und somit wichtige Informationen zur Vorbereitung politischer Entscheidungen gewonnen werden.

1. Microanalytic Modeling

The designing of governmental policies affecting employment, output, inflation, health and social services would be facilitated, if it were possible to predict results of hypothetical policies by means of policy explorations using realistic models. Clearly, however, the policy relevance of any model depends on the adequacy of the theories which have been built into it. Unfortunately, social system modelers have found the achievement of a policy-useful level of understanding extremely difficult.

At present there are three major frameworks, or paradigms, used in developing models that appear to be useful in economic policymaking. They are: the macro time series or macroeconometric approach - the most widely used of the three, the interindustry approach and the microanalytic simulation approach.

Attempts to quantitatively implement the macro time series approach date back to the pathbreaking work of Tinbergen (1937,1939). Major sectors, such as the household and business sectors, are basic components. Macroeconometric relationships for these components are specified, estimated and tested on the basis of annual or quarterly time series data of such variables as aggregate consumption and income of the household sector and are represented by finite difference equations of a stochastic nature. Both recursive and simultaneous equation systems have been developed.

The second most widely utilized approach to the construction of models of the United States stems from Leontief's highly important work (1951). Industries are used as basic components in these models. Emphasis is placed on the cross-sectional structure of the economy rather than on its dynamic features. Physical outputs of industries are assumed to be strictly proportional to physical inputs.

The main features of microanalytic simulation modeling were conceived by me (1957) and first implemented by Orcutt, Greenberger, Korbel and Rivlin (1961). While being of the same general statistical type as other models of national economies, microanalytic models are the most general in terms of their statistical structure. Each major type of model of a national economy may include stochastic or random elements, use previous values of variables as part of what is treated as given and be expressed as a system of equations. Microanalytic simulation models are more general than macroeconometric and interindustry models in that they contain one or more populations of microunits, such as individuals, families, enterprises and metropolitan areas, instead of but a single case of each kind of unit, as is true with both the Tinbergen and Leontief type models. Consequently, microanalytic simulation models open up important possibilities for substantially improving the simulation of economies and other large-scale socioeconomic systems in support of social and economic policy. By offering an excellent framework for applying past and future research work of many individuals and by effectively utilizing developments in computers and statistics, microanalytic simulation models provide a fruitful way of mobilizing the understanding and data which are, or could be, available for policy analysis. Descriptions of a number of policy oriented, microanalytic simulation modeling efforts may be found in Bergmann, Eliasson and Orcutt, eds. (1980); Haveman and Hollenbeck, editors, 2 volumes (1980); Orcutt, et al. (1976); and in Orcutt, Merz and Quinke, eds., (1985).

2. Two Major Research Approaches

Since time immemorial, a major source of interest in, and support of, scientific research endeavors has been the promise that such efforts will enable humans to extend their control over events and developments. If one examines, in detail, research endeavors actually undertaken, one will be impressed by the enormous variety of efforts aimed at finding ways of extending influence and control over events and developments. But, looking at the efforts made from a more distant perspective, two broadly conceived, but fairly distinct, streams of research endeavors emerge with surprising clarity.

The main stream, by far the oldest, I will refer to as the *treatment-response* focussed stream. It is frequently referred to as the experimental approach. However, while it does encompass the experimental approach, it is significantly broader. The second stream, which has been followed by non-experimental social scientists and has reached its highest state of development in efforts to build policy useful models of socio-economic systems, I will refer to as the *macro-econometric approach.*

Although the treatment-response approach has been the mainline approach to achievement of control in the natural sciences, it has seldom been followed in social system modeling done in the social sciences. No doubt this is mainly because planned experimentation has proved to be too costly and difficult in these areas. However, it may be partly due to the lack of recognition of possibilities for effective use of natural experiments in learning consequences of treatments which could be delivered in such a way as to extend some control over undesired aspects of national economies.

While making use of the same body of statistical forms, estimation procedures, and tests of significance as in the approach used by macro econometricians, the treatment-response research approach is radically different in several key respects. Most importantly, the treatment-response approach focusses on learning the consequences of one or more *treatments* of particular interest, and this is often achieved long before much of the observed variation of any hypothesized dependent variable is accounted for. This contrasts with the macroeconometric approach which usually focusses on picking variables, multiple regression forms of relationship, and parameter values so as to account for as much of the variation as possible of pre-selected dependent variables. In fact, by following a treatment-response research strategy, it frequently has happened that with the use of feedback information, control of a serviceable nature over previously uncontrolled events and developments has been accomplished long before anything like reasonably full understanding is achieved.

A related fundamental difference between the treatment-response and the macroeconometric approach to causal modeling is as follows. In the macroeconometric approach the focus is on parameter estimation, given numerous assumptions about included and excluded variables, which enable the identification of structural, or what might equally well be called causal, relations. The basis of such critically important assumptions is taken to be prior knowledge, sometimes referred to as »theory« but frequently appearing to the skeptical observer as nothing more than assumptions of convenience. In treatment-response research, on the other hand, the attempt is made to either create or find situations which will assist in choosing between competing causal hypotheses or, at least, between causal hypotheses and seriously proposed null hypotheses.

3. The Macroeconometric Approach

The macroeconometric approach derives considerable support from the fact that it focusses so directly on prediction of macro variables such as Gross National Product, Employment, Unemployment, and the GNP Implicit Price Deflator, variables which frequently behave in distressing ways and over which governments need to exert some control.

The primary building blocks of models of national economies are multiple regression equations, each of which conceptually relates a dependent variable of interest as of time, t, to lagged variables and to current period variables which will be regarded as predetermined. Some of the predetermined variables are measured and thought of as controllable. Other predetermined variables are thought of as unmeasured and stochastic or probabilistic in nature.

Tinbergen developed a series of recursive models of national economies built up out of just such regression equations, and his work attracted the attention of many young econometricians, who during the 1940s and 1950s sought to build upon, and improve, his work. Great impetus was also given to efforts to develop national accounting systems able to yield time series needed for macro-econometric modeling. Wold (1961, 1964) and many others, including myself, sought to develop estimation procedures which took appropriate account of the highly autocorrelated nature of most macro time series, whether included or part of the unmeasured stochastic terms. Havelmo (1943), Koopmans (1945), and many others associated with the Cowles Commission focussed their efforts on developing estimation procedures which would take reasonable account of the fact that some of the stochastic error variables in systems of regression equations, thought of as structural, would be correlated with variables being treated as predetermined in Tinbergen's and Wold's recursive modeling.

By now, every econometric text book devotes a great deal of attention to simultaneous equation estimation and avoidance of autocorrelated error terms. But what seems to be missed by many students is that, while the formal conditions under which various estimating procedures will have desirable properties are explored in great detail, little guidance is given as to how needed assumptions can be justified on the basis of any kind of empirically based evidence. Instead, one seems always to be left in the situation of knowing that, if certain critical assumptions are made, then the resulting estimates will have certain desirable properties. In fact, it is quite obvious that critical assumptions underlying causal interpretations of results are seldom tested. As far as I can see they are either assumed as articles of faith, ignored because there seems to be no way of testing them, or ignored out of sheer ignorance of how dependent the results obtained are on them. The present situation is perhaps worst when it comes to use of existing macroeconometric models for guidance about the control possibilities achievable by use of available macro monetary and fiscal policy tools. If a way can be found of appropriately specifying the application of treatments deliverable by known actions in terms of measured variables and of also specifying systems of micro and macro relations which capture consequences found to follow applications of such treatment, then macro econometric and interindustry models might be correctly specified and simultaneous equations estimating procedures could be fruitfully applied in final estimations of macro parameters using available macro time series data.

4. The Treatment-Response Approach to Exploring Consequences of Actions

Treatment-response research is focussed, by choice, on learning consequences of treatments which can be delivered by feasible actions. The preferred method of obtaining data and carrying out explorations focussed on testing is that of planned experimentation, as is true generally in the strategy of scientific research. Treatment-response research is distinguished from other scientific research largely by its emphasis on the achievement of control.

In planned experimentation an attempt is made to apply a treatment of interest at three or more widely separated levels of application. If the implications of two or more actions are being explored, then, an attempt is made to avoid or minimize the covariation between assigned treatment levels. In an effort to avoid mistakenly attributing outcomes to treatments, experimentalists make use of observations on carefully selected control groups. These groups of entities are selected so as to be as similar and as similarly situated as possible, except that they either do not receive the treatments or receive different levels of the treatments. Central concepts in planned experimentation are associated with such keywords as treatments, controls, replication, randomization of treatment assignment, and replication by others of experiments.

In studying naturally occurring applications of treatments it is helpful to mimic the planned experimentalist, in-so-far as possible, in making effective use of both parallel and before-after controls. Replication of essentially the same treatments on similar entities is also needed in order to assist in recognizing treatment effects in the presence of a great deal of variation from unknown sources. The experimentalist is extremely selective with respect to sample points. He or she selects, not on the basis of outcomes, but in such a way as to ease the problem of interpreting and learning from observed outcomes of selected treatments. The researcher who wishes to learn from naturally occurring applications of treatments has every reason to be equally selective of sample points. If we knew enough about a social system, all data points might be of some value. But when very little is known, great selectivity is required in order to focus on situations and comparisons simple enough to assist learning. To make such selectivity feasible there must be observations on entities of which there are many-of-a-kind. The social scientist can invent hypotheses relating to any desired level of aggregation, just as the physicist may promulgate hypotheses about the behavior of gases, as well as about the behavior of molecules or components of molecules. However, not all hypotheses are equally testable and useful. Moreover, the social scientist does have a peculiar advantage in producing hypotheses about the behavior of individuals, families and firms that he or she does not have at other levels of aggregation.

5. Causal Modeling and Feedback Control

The notion of identifiable types of actions of which humans are capable and which they individually and collectively can carry out, if they so desire, is a firm notion probably acquired by individuals even before the acquisition of the ability to communicate by use of words. By using controllable actions and feedback information, individuals and groups of individuals learn to control delivery or execution of a variety of events or conditions which may then be used as treatments aimed at influencing still other events and developments. Such learning from experience, involving much trial and error, seems to be a normal part of everyone's experience. It is similar in nature to learning from systematic research efforts, but is too commonplace to be referred to as scientific research. Control is frequently thus extended from control of treatments to control of things found to co-vary with treatments long before much is known about other factors influencing that which is controlled. By use of feedback information their influence is simply overridden.

The treatment-response research strategy may well be the result of attempts to enhance ordinary learning about control possibilities on the basis of experience. Development of working hypotheses about relation of outcomes to treatments is pursued more systematically. Testing of resulting hypotheses, by stacking up their implications against experience, is pursued more vigorously, with needed data being sought by the conduct of numerous experiments and by the search for treatments occurring naturally in situations which are numerous enough and simple enough to be learned from despite unavoidable initial ignorance.

6. Covariation and Inference of Causality

The assertion that one cannot infer causality from correlation is frequently and, I think, thoughtlessly made. Undoubtedly if all that is meant by such an assertion is that, given the existence of one or many highly significant correlations, one cannot prove anything about causality beyond any shadow of doubt, then the assertion must be accepted as true but not very profound. After all nothing about relations in nature, outside of our invented systems of logic and mathematics, seems to be deductively provable and nothing we seem to have learned about relations in nature seems to have been established for all time beyond any shadow of doubt.

From earliest childhood on we do learn about consequences of our own actions and about actions of others, and we certainly seem to do so by observing covariations of events and developments with our own actions and with what we take to be analogous actions of others. Notable features of this Teaming may well be that we are able, or at least learn to be able, to exert significant control over our own actions, and we do learn to exert significant control over many events and developments found to co-vary with our actions. The repeatable successful extension of control over things which normally seem to vary in association with many unknown factors or even with known things which we do not control or seem unable to control is the proof in the pudding for most of us.

Experimentalists, upon observing systematic covariation between developments and experimental treatments seldom have difficulty in inferring causation as running from application of the treatments to observed covariation of what will now be referred to as responses. They do of course need to guard against the possibility that outcomes have more to do with the selection involved in assignment of treatments to experimental subjects than with the application or non application of the treatment itself. In this connection randomization in assignment of treatments to subjects can be of help, but much highly productive experimentation has been achieved without using this procedure, introduced about half a century ago by RA. Fisher.

Experimentalists also are faced with the difficulty of trying to sort out what aspects of their »treatments« really account for observed consequences. This is because actions and resulting treatments, while measured in terms of one or more variables seem always to be much richer in nature than the measures used to describe their level of application. As long as what is called a treatment always includes the same ensemble of significant and insignificant features, failure to sort out the significant features may not matter very much and may not interfere with effective extention of control. But if one delivers a somewhat different version of the treatment on other occasions, or if others do so, then the claimed experimental results may not be forthcoming. Presumably this is the reason why, in most experimental areas, replication of experiments by others in other laboratories is always demanded before experimental results are granted much credibility.

There is no sharp line between learning about control possibilities from »natural« experiments and such learning from planned experimentation. Clearly it is not critical that those learning from experiments actually preform the experiments from which they learn. And if those treatments and controls, which an experimenter would have liked to control, occur naturally, then learning from such situations may be as easy and done with almost as much confidence as if the same situations had been made to occur in planned experimentations. Problems, of course, occur in fmding and suitably observing natural experiments that present situations simple enough to learn from, in the absence of understanding which has not yet been achieved. The guarding against misinterpretation due to selectivity in the assignment of treatments to subjects also becomes somewhat more formidable.

7. On the Role of Mathematics

Nearly everyone will agree that mathematics should play an important role in scientific research. But, in what ways is mathematics helpful? There are some who appear to regard mathematics and logic as a source of certain knowledge about nature. Others, including myself and many mathematicians, regard such beliefs as mystical in nature and without foundation in experience. Some appear to take the position that an axiomatic approach to modeling of economic behavior is the only acceptable approach to such modeling. Others, including myself, find such an approach acceptable but think of it as awkward, stifling of needed exploration, stifling of creative invention of working hypotheses, and dangerous in the way in which it leads some to treat deductions flowing from assumed axioms as knowledge about behavior of real world economic entities and systems.

One way in which mathematics can be extremely helpful is in providing an extraordinarily rich storehouse of relations and models with otherwise undefined variables. It is this role which finds an explicit place in Figure 1, which gives an overview of the scientific research strategy as an ongoing process. Mathematics thus provides the natural scientists with a large number of convenient ways of expressing any number of substantive working hypotheses. And if working hypotheses, so expressed, are assembled into models involving systems of such relationships, then the joint implications of such systems may well be available in the form of known theorems. In any case the mechanics of obtaining numerical solutions are likely to be well known.

A second way in which a use of mathematically expressed relationships plays a central, and frequently helpful, role is in providing an almost automatic way of interpolating and extrapolating from observations at a finite and sometimes small number of points. Thus, any continuous line contains an infinite number of points and may extend infinitely far. If such a line is taken to express a relationship between observable variables, then it already provides a way of generalizing from observed results. Of course, such generalizations may not hold, and they become particularly risky when applied in areas far removed from observed points used in fitting the line. Extensive experimental checking is always in order. While complete checking is obviously impossible, realizable checking frequently does serve to make such mathematical expressed relationships extremely useful.

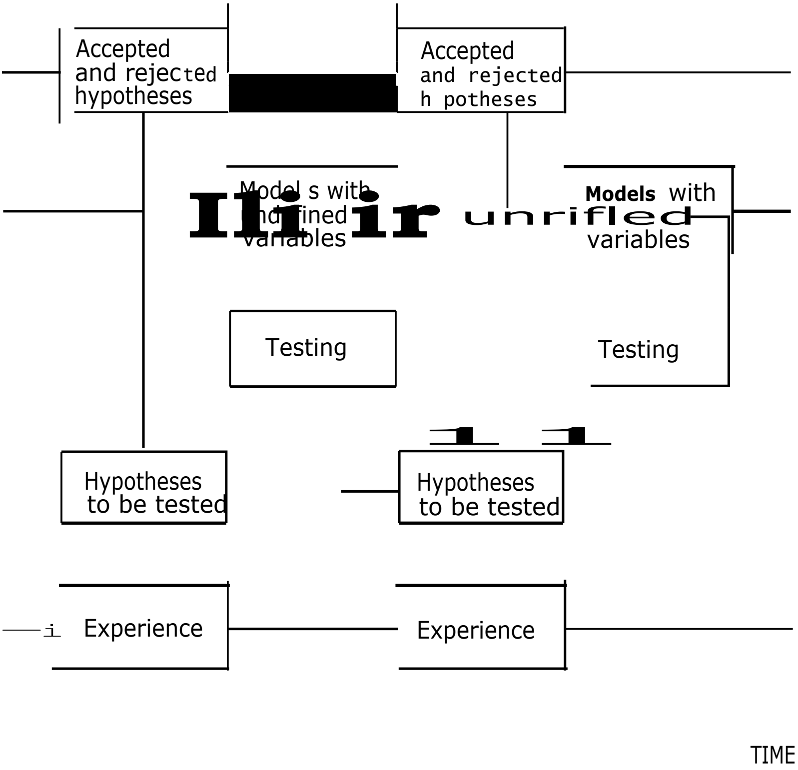

Figure 1, A View of the Scientific Research Strategy

8. Conclusions

8.1. Building from the Ground Up is Essential

We want economic system models which include macrovariables of central interest to macroeconomic policy. But, trying to arrive at a complete system model by following an approach which requires extensive untested assumptions about the form of many equations and the inclusion and exclusion in each equation of many variables with assumed properties, is surely less promising than hunting for a needle in a haystack. In hunting for a needle we could at least know when it has been found.

8.2. A Treatment Response Approach to Modeling Causality is Needed

As pointed out, treatment-response research focusses on creating situations or finding situations simple enough to assist in learning about responses to treatments which could be delivered by controllable actions. Such an approach is needed as a precursor and as a continuing complement to macroeconometric modeling and estimation which proceeds on the basis that needed knowledge about causal structure is already available.

8.3. Panel Data Linking Persons, Households and Firms would be of Great Help

Since enterprises play a key-role in pricing, production and employment decisions, panel data from and about them are clearly needed for all the reasons that panel data about persons and households are needed. It is clearly evident that obtaining data about household and enterprises linked at the microentity level would be useful in following a treatment-response research strategy. Such data, about employment and wage rate outcomes, which are clearly joint products of both households and firms, should go a long way towards making labor market research useful to macroeconomic causal modeling.

8.4. Area and Industry Specific Data are Essential for Measuring Treatments of Interest

A central problem in research directed towards micro to macro modeling of national economies is finding enough naturally occurring situations in which treatments, closely analogous to those deliverable by macro economic policies, actually vary sufficiently and independently enough to permit effective learning. The most promising solution to this problem, that I can think of, is to obtain time series information on key variables, such as price, employment and production indexes by geographical area and by industry within area. Then, such variables as these could be used as measures of

»treatments« of interest in conjunction with area and industry-linked microunit panel data. The panel data would be used to provide the information needed to explore and test behavioral response hypotheses.

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