Neoclassical Econometrics

The Agenda*

by

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Economics and Research Staff
World Bank

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The views presented here are those of the author, and they should not be interpreted as reflecting those of the World Bank.
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* The substance of this paper was originally intended to be part of a presentation, at the invitation of the American Statistical Association (ASA) Annual Meetings in August 1982, in a memorial session in honor of my father, H.O. Yartley (HOY), a Past President of the ASA. The influence of his work on this paper is implicit. I would like to thank the ASA for organizing this session, "Approaches for Modelling the 'Real World' ala HOY," and Dr. Paul Riemer, session chairman and a former student of HOY, for the invitation to participate. Unfortunately, to avoid premature dissemination, I was obliged to withdraw Parts One and Two and the substance of this paper.

** The views expressed in this paper represent those of the author and in no way should he be associated with those of the World Bank. The author does however, wish to acknowledge many extremely useful discussions with Professor Richard Bellman, Lawrence Klein and Richard Quandt, who will sketched in this paper. I would also like to express my gratitude to the World Bank for creating the environment and resources to permit pursuit of these issues.
Abstract

The paper proposes a new approach to econometric modeling and parameter estimation which permits the construction of Macro-econometric models from general Microeconomic foundations. It provides, inter-alia, Full Information Maximum Likelihood estimation methods which permit the following:

(a) a statistical solution to the (Exact or Consistent) Aggregation Problem,
(b) a new approach to the problem of Parameter Identification,
(c) a systematic approach to the problem of Model Selection,
(d) obviates the need for the use of the Duality Theory of Cost and Profit Functions by working solely on Primal problems,
(e) treats the spectrum of perfectly competitive to monopolistic/monopsonistic market structures,
(f) applies, in principle, to both partial and general equilibrium models, and
(g) obtains the structural form of "limited dependent variable" econometric estimation methods directly from neoclassical (constrained optimization) behavioral models.

—all in the context of well-behaved, but essentially unrestricted, functional forms, subject to a general set of "rationality postulates" regarding the behavior of individual economic units. These are all developed in the course of Parts One to Four of the paper.
Neoclassical Econometrics

Part One: General Considerations

Part Two: Motivation and Synthesis

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Neoclassical Econometrics:

The Agenda 1

by

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I. Introduction:

Richard Bellman has pointed out to me that these papers are part of "...a book which could have been written 30 years ago" (personal communication, December 3, 1982). In this section I shall attempt to indicate why this is the case and, also, why this did not occur. In addition, since present circumstances beyond my control require the release of these "as is" (rather than waiting for completion a "real world" example -- originally intended as the development of econometric models of the supply of perennial crops: a case study of the Sri Lankan rubber industry), I shall indicate now the topics I propose to treat in subsequent parts. Here, "economies of shale" and the magnitude of the tasks suggest that collaborative efforts will serve a larger purpose. Accordingly, the remaining papers will be jointly authored to

1/ This paper is the result of extensive discussions with Professor Richard Bellman, Lawrence Klein and Richard Quandt and was written on January 16, 1983.
reflect the inputs of my various collaborators -- at this juncture involving, inter alia, Professors Richard Rellman, Lawrence Klein, Richard Quandt and certain of my colleagues in the World Bank.

II. Research Agenda:

The long run target is to construct an operationally useful econometric model of the world economy as soon as possible, subject to the constraints of available resources. The research strategy involves taking the best existing "macro-time-series" econometric models of the world economy (Ylein's Project Link, Fair's global model, etc.) and constructing hybrid versions using the better features of each. This will provide an immediately feasible tool with which to analyze the coordination of the separate national interests required to improve global welfare. Subject to the limitations of all macro-time-series econometric models (see Hartley [1980]), and given the specific structure of these hybrids (i.e., any "convex combination" of the available choice set), the important question of the setting of national economic policies in the interest of all peoples may be addressed -- in particular, see the recent policy statement, Promoting World Recovery, A Statement on Global Economic Strategy by Twenty-six Economists from Fourteen Countries, developed as a consensus of the participants in a conference organized by the Institute for International Economics, C. Fred Bergsten (Director), and written by John Williamson.

The feasibility of this approach requires reaching a consensus among the various national governments as to what are the relevant (endogenous) variables within each country's "national welfare function", and what are appropriate "weights" to be associated with each country in defining a "global welfare function." The latter is then to be maximized over some suitable "planning horizon", subject to the constraints of the estimated structure of the global economy and making judicious use of the available "policy instruments" -- e.g., fiscal and monetary policies, as sketched in Promoting World Recovery. It will be noted that this is, itself, a dynamic programming problem -- see Rellman [1957] and Bellman and Dreyfus [1962] -- but not an easy one!
The next step is to develop, in parallel, the computer technology, neoclassical econometric tools, numerical methods (algorithms), mathematical specifications and data bases necessary to produce a new generation of econometric models of the various types of national economies -- including the range from mixed capitalist to mixed socialist forms. We shall address each of these in turn.

A. The State of Computer Technology

To implement the general goal of constructing a model of the world economy from the micro-foundations, based upon the economic or rational behavior of individual decision-making units, it will clearly be necessary to expand the frontiers represented by the current state of computer technology. As noted in a recent (January 13, 1983) article in the Wall Street Journal (WSJ), "..... personal computers and other microcomputers are well on their way to becoming the biggest part of the computer industry." The rate of technological change in the industry has reached such a level that The Computer was Time Magazine's "Man of the Year." As the WSJ adds,

"The change is profound, because the predominance of mainframes, the giant computers, often costing millions of dollars, has long been taken for granted. Through the 1970's, minicomputers -- which are smaller and more accessible than mainframes and often bear prices in the $20,000 to $100,000 range -- were the fastest-growing as capable, and almost as expensive as the smallest mainframes.

Now, however, most industry observers think microcomputers will squeeze all but the most powerful minicomputers out of the market place. Microcomputers are built around microprocessors -- computers on a single chip of silicon the size of a fingernail. They include: personal computers for home use and costing from $80 to $1,000; personal computers for individual use in offices and costing as much as $5,000; and the most sophisticated small-business and engineering computers.
which may cost as much as $30,000 -- far more than the cheapest minicomputers.

Howard Anderson, president of Yankee Group, a Boston - based consulting firm, estimates that 150 computer makers are selling microcomputers. They range from International Business Machines, which joined the rush in 1981, to brand-new "start-up companies."

With this background in mind, it should be evident that the prediction:

Microcomputers will soon possess the requisite memory sizes, speed, software (numerical algorithms), etc. to construct and manage a global econometric mode of both the Klein-type and the "micro-macro general equilibrium" national and global models previously sketched in Hartley [1983].

is not far from realization. My guess is that it is only a matter of years before this technological development occurs. In the meantime, much can be accomplished, since the existing mainframe computes already permit the construction of micro-macro country models and Klein-type global models. 

We next turn to the nature of the neoclassical econometric problems (and associated mathematical tools) to be worked out. This should proceed according to the following sequence:

B. Partial Equilibrium Yodels (Microanalysis):

We must first work out the partial equilibrium models associated with the various types of individual decision-making units -- households (or individuals within households), firms within a given taxonomy of industrial

The technology for mainframes, which are more powerful than micro- computers, is also improving. If we had a model of the world economy, each terminal can get the data from a particular country or region. The original mainframe can then coordinate this data. Finally, there are many mathematical methods which prevent the overall optimization problem from being too large.
classifications (say at the 2-digit level), governments (local, regional and national), banks (both private and central), labor unions, and any other institutional cross-classifications of interest. In this step, careful attention must be paid to the spectrum of market structures from perfect competition to pure monopoly. Also, it is of critical importance, here, to introduce the role of risk and uncertainty on decision-making. See, e.g., Hartley [1982a], for an illustration of the econometric methods applicable to the case of deciding, inter alia, on the "optimal" use of fertilizer in the context of uncertainty with respect to weather factors (which occur between the planting decision and harvest-time) and the price which the farmer will confront at the time of marketing. Such risks vary with respect to time and place. Further, different types of farmers -- e.g., smallholders versus

1/ A suitable general taxonomic framework for classification of households into "types" for purposes of estimation of their (presumably) common interests -- i.e., the same objective function is assumed to hold across members of a particular subclass -- must be developed. The structure of national censuses should provide the basis for such a useful taxonomy. The system of industrial classification is already available for firms. Governments are obvious. Finally, the Social Accounting Matrix (SAM) of Pyatt, et al. [1976, 1977] is a "natural" framework from which to develop a taxonomy appropriate the subsequent closure of models and the requisite "feedback effects", required for determination of prices in the goods and factor markets, interest rates in the various financial markets (spot and future), etc. See also King [1981] for a general discussion of SAMs.

2/ We are already at a fairly advanced stage for most of these problems -- in terms of developing the appropriate neoclassical econometric methods and computation with. These issues will have to be dealt with due to the constraints of other obligations and the finite time available. We shall report on these subsequently in Part Three.

3/ Risk is usually defined as the conditional variance of profits, given the values of the decision variables selected by the particular economic unit and given the values of all "state variables" -- see e.g., Hartley [1982a]. Bellman has suggested an alternative definition applicable to the present problem, viz., the (conditional) probability that yield will exceed some preassigned level. To the extent that agricultural extension services and planter's manuals often stress the importance of maximizing yields (regardless of relative prices), this suggestion may be a more useful positive characterization of risk. In any event, our methods permit experimentation with a range of possible definitions of uncertainty, risk and higher-order moments of the distribution of profits and/or yield. The "correct" choice will vary with cultures, time and place and, hence, is an empirical matter. Dynamic programming can handle the generalized risk criterion as easily as expectations.
large estates — may exhibit different "attitudes toward risk", a problem which can also be treated systematically by an interface between neoclassical econometrics and numerical integration (both numerical quadrature and Monte Carlo methods) — see Haber [1970] for an early reference. Finally, these models must also incorporate, to the extent possible, a careful treatment and definition of the types of decision variables at the disposal of individual economic units and the state variables to which they are subject — some of which will represent policy instruments set by various levels of government (e.g., a local sales tax, a state income tax, a national income "social security" tax or a ceiling on certain types of interest rates1).

1/ In this connection it is important to account for the domain of definition of the decision variables within a neoclassical econometric framework. Sensitivity to these issues has recently surfaced in the econometric literature under the general heading of "limited dependent variable" problems. These issues, and their connection with the construction of macro models from micro foundations have been discussed elsewhere (see Yartley [1980, 1981a, 1981b, 1982a]). For the present, it suffices to note that the existing state of the econometric literature is largely correct for the case of a single decision variable — see, e.g., Hartley [1958], Hartley [1976, 1977a, 1978], Dempstet, Laird and Rubin [1977], Hartley and Swanson [1980], and Quandt and Ramsey [1980]. In the case of multiple decisions with restrictions on the domain — e.g., in a household budget survey, certain households are observed to spend no money on one or more categories of goods and services (including savings or, more generally, asset portfolios), subject to the constraint of various sources of income and the ability to borrow or liquidate certain assets. It is interesting that James Tobin has made seminal (univariate) so-called "Tobit models" — see Tobin [1958, 1965] and Hartley [1976] — both of which must be generalized to address the present problem. Thus, the essence of the standard approach to the problem is how to define the mechanism by which infeasible regions of the decision space in an unconstrained optimization problem map into the feasible region — in the present example, the non-negative orthant of the feasible goods space (with an accumulation of probability mass at the intersection of the (positive) budget-constraint hyperplane and the boundary of this subspace). Our approach to this problem will, in general, require the use of dynamic programming ala Bellman and Dreyfus [1962] and is more direct. Details will appear in Part Three.
C. General Equilibrium Models (Macro-analysis):

1. Country Models:

This task involves working out the various interactions between the sets of individual agents and their aggregation into suitable macroeconomic concepts, according to the variety of taxonomies or cross-classification schemes adopted in B above. E.g., a household will be called upon to make a variety of decisions, conditioned by the age composition, sex composition, and other socio-economic-demographic state variables -- such as how much labor each member will offer to the various segments of the labor market; how to select or restructure its asset portfolio (if any); how much of various types of goods and services to buy; how much of various goods to produce (e.g., an agricultural household is both a consuming and a producing unit; children may be viewed as the result of a decision by two members of the opposite sex to produce a (human) investment or capital good; etc.). As for households and firms, it is important to incorporate a treatment of the organizational structure of the economic unit and its relation to how decisions actually get made. 1/ Here, we are concerned with positive issues. However, at a normative level, it seems obvious that the interest of the decision-making unit, as a whole, is best served when the interests of the individuals associated with such a unit are at one with those of the "corporate entity".

1/ A useful and insightful survey of these issues is given by Simon [1966], who explores firms' decision-making. Issues of particular importance to the Third World countries which should be treated within the household joint decision-making model include labor force participation, occupational-choice, educational enrollment; length of education and resulting literacy/illiteracy outcomes, inter-regional migration, family size, income determination, allocation of income and housing quality decisions -- see Hartley [1980].
The role of profit-sharing and other similar incentive schemes is a useful way of addressing "supply-side" issues in such an organizational context.

The interactions between the aggregate consequences of individual decision-making units will, in a market economy, jointly determine all relevant domestic relative prices -- treating the "rest of the world" as given. This is in the spirit of the Walrasian model of general equilibrium -- developed by Arrow, Debreu and others -- largely in the context of the limiting case of perfect competition. In this model, the feedback effects of price determination are explicit. Under the assumption of full-information on the part of all participants in all relevant goods, factor and asset markets, prices, wages and interest rates are determined via aggregation of the demand/supply functions of individual decision-making units. These, in turn, feed back to jointly determine those decisions. In short, the prices, wages, interest rates, etc., that were taken as state variables in the partial equilibrium setting, are now jointly determined by the institution of the "market system". Thus, they are endogenous variables in a general equilibrium system, but in general, are not decision variables -- except in the case of a monopoly/monopsony or other imperfectly competitive market situations, in the case of interdependent objectives (such as the OPEC cartel), or in the case of implicit or explicit joint decision-making across units -- such as "collusive" price-fixing agreements.

The basic outlines of the structure of these types of micro/macro general equilibrium models have been worked out and a general approach to solve the econometric estimation problems has been considered by Bellman.
Klein, Quandt and myself. Some details, however, remain to be decided — particularly the knotty issue of appropriate "closure rules". 1/

In terms of model structure, it is, again, important to attempt to capture the effect of changing institutional arrangements over time — see, e.g., the discussion of this problem in Hartley [1981b, 1982b]. In this connection, a realistic model should incorporate government policy instruments and legal restrictions — local, regional and national — within models of the various classes of individual decision-making units, since these are precisely the instruments by which public officials utilize to influence the course of the national economy in pursuit of "the national interest" — however defined. 2/

It is important to stress that Micro-Macro-General Equilibrium (MMGE) models of a particular country should pay due attention to (1) all types of feedback effects between micro-units and the macro-aggregates — both within and across time-periods, as well as other types of cross-sectional disaggregations — and (2) to the process of expectation formation. On this latter issue, in Hartley [1981a, 1981b, 1982a] I have discussed the present controversy regarding how to model such processes — see Merlove, Grether and ...

1/ See also Klein [1981] for a discussion of the role of money, and its relation to the determination of nominal (as opposed to relative) prices.

2/ In the case of Less-Developed Countries (LDCs), national econometric models should place particular emphasis upon the development of systematic submodels of both the agricultural and manufacturing sectors. In the former case, see Hartley [1982a, 1982b] for methods which treat both annuals and tree crops (perennials) in the context of uncertainty and risk. In the latter, particular attention should be devoted to the twin issues of small-scale industry and the international transfer of technology.
Carvalho [1979, Chapter XIII] and Lucas and Sargent [1981], the latter being advocates of the so-called "rational expectations theory", which originated with Muth [1961]. I would regard the latter as an approach which attempts to represent how individuals ought to behave, but not how they do behave. In short, it is

1. a normative theory with, apparently, little positive value, and
2. even if a positive theory, it offers an incomplete treatment of the problem -- since it fails to take account, inter alia, of the twin problems of risk and uncertainty.

2. Global Models:

In terms of its mathematical structure, the problem of developing the links between national economies via trade, capital and migration flows, etc., and the determination of world prices in the various global markets of interest, is largely analogous to the types of problems encountered in building micro-macro general equilibrium models of a national economy.

With respect to the modelling of Eastern Bloc economies, Professors Quandt, Portes, Winter and others have developed many useful ideas which will be employed in studying the types of non-market or "command" economies. Mixed cases, such as the "Yugoslavia case", can also be treated in principle, though a considerable number of details remain to be worked out. In each of these, much use will be made of the emerging literature -- both theoretical and econometric -- on the problem of modelling so-called "markets in disequilibrium." A comprehensive bibliography on these matters is available from Professor Quandt. See also Hartley and Mallela [1977b].
D. Mathematical Methods and Data Constraints:

Professor Bellman has indicated to me (personal communication, December 3, 1982) that in order to do justice to the general research program sketched above, it will be necessary to employ more modern mathematical tools. These include:

(1) time lags,
(2) deterministic processes and dynamic programming,
(3) stochastic processes and dynamic programming,
(4) simulation (both deterministic and stochastic) and
(5) fuzzy systems and economics.

To these I would add:

(6) numerical integration.

Key references in connection with the suggestions above are Bellman, Glicksberg and Gross [1956], Bellman [1957], Bellman, Clarke, Craft, Malcolm and Ricciardi [1957], Bellman and Dreyfus [1962], Bellman and Cooke [1963], Bellman, Kakaba and Lockett [1966], Bellman and Zadeh [1970], Uellman [1978] and Bellman and Roth [1982], etc. A good introductory account is provided in the book, Mathematics in the Social Sciences (Bellman [1982]) -- particularly the discussion of so-called "fuzzy systems.""

The important point to be made about the above list of mathematical tools is that they will enable the construction of models of a national and global economy which will produce useful numbers. Indeed, the basic idea of

1/ Stochastic simulation involves the use of Monte Carlo methods -- see, e.g., Hamersley and Handscombe [1964].

2/ Fuzzy systems and their analysis will play an increasingly important role in the development of realistic models of socio-economic systems.
This paper is that we wish to replace the tool of the pencil and paper -- employed by much of the mathematically oriented scientific and economics professions -- by the computer, employing the most modern mathematical methods and computer algorithms in order to produce useful numerical results. Of crucial importance in this endeavour is the interface between the availability of reliable data bases and the associated feasible classes of models which the data bases permit.

The advice of Orcutt [1972, Chapter 3] on this matter should be stressed:

"It is time that the data base was molded and developed to meet the needs of economic research. However, until the economics and statistics professions are able to arrive at clearly stated and widely held views about how the data needs of effective economic research can be and should be met, it is naive to think that politicians, policy-makers and statesman will know enough to greatly improve upon the present situation in which, except for the magnetic tape, we might be buried under a mountain of data long before we acquire the types and kind of data needed for effective testing and estimation."

E. Conclusions

Finally, one should take note of a necessary educational function associated with the present (neoclassical econometric) approach. Given the inherent complexity of many of the decisions which individual economic agents are called upon to make in practice, it is, perhaps, not surprising that in the absence of well-formulated models of the associated process, individual agents make mistakes (human fallibility). Hence, at this juncture, the serious researcher should be interested, first, in the question of modelling
how decisions are actually made. 1/ Once this process is understood — an example of a "fuzzy system" problem — and once the structure of relevant primary behavioral functions — utility functions, production functions, expectations — formation processes, etc. — can be represented by a set of mathematical models, one then may address the question of what such agents ought to do when confronted with such decisions. This may be studied by computer simulation models and the results employed to improve the quality of such decisions — hence, the educational function! Given these two conditions, one might reasonably expect that, with learning over time, there will be a convergence between normative theories of behavior and positive models. Implementation of this "research agenda" will therefore require an interdisciplinary research team, capable of analyzing and explaining rational self-interest (and its generalization to various combinations of personal vested interests — e.g., collectives) on the part of individual economic units in the context of a "fuzzy environment". Once this is done, one may then proceed to consideration of the design of appropriate national economic policies which will lead to an improvement in global welfare, given the existing state of knowledge and technology and given levels of available resources. In short, model building is logically prior to enlightened policy analysis. In our view, this is the challenge that serious investigators must address!

In referring to the current dissatisfaction with existing econometric models, Malinvaud [1981] has aptly remarked:

1/ See, again, Simon [1966].
"Before any self-criticism, a look backward will show the origin of the progress that has been accomplished. If the research program of Tinbergen and Klein has borne fruit, it is notably because many econometricians took it seriously from the very beginning and have constructed the tools necessary for its realization.

First, they played an often important role in stimulating a rapid development of economic statistics and the establishment of national accounting. Then they determined inductive procedures adequate for estimating and testing the equations of the models. Lastly, they studied the computation techniques, which permit the construction of the models and their use, notably in getting numerous projections, constituting as many variants on the external environment as on economic policy.

But the work is obviously not yet finished. One would have to be deaf not to hear the many protests which are being directed against it: those from our fellow citizens and from their governments, those from our colleagues the economists, and even those from certain of us econometricians."

The initial question — why not 30 years ago? — has been answered implicitly. The explicit answer is that the availability of data, the requisite mathematical methods and, most important, the state of computer technology, have precluded, until recently, a frontal assault on these problems. [1]

I shall conclude with a quotation from Hartley [1980]:

"With this vision in mind, it is fair game to argue that, even if one were to commence today on a research program similar to the one I have attempted to sketch, it may take several years before a micro-macro national

Indeed, the types of data bases likely to be generated as part of the computer revolution are truly mind-boggling. Consider, e.g., the result of replacement of the household budget survey by the "smart-card" electronic banking-system; the possibility of "instant referenda" on social issues and policy matters through two-way cable information networks, etc.
econometric model is an operational reality. I concede that it is not a problem that admits to a quick solution. I have attempted to provide the best arguments I can think of to justify the direction that such research should take. If these arguments are **persuasive**, I submit that **it is time to face that reality squarely**. Ye should not he deterred by the length of the path, nor by the size of the undertaking. Rather, we should attempt to assemble as large a group of the "best of the brightest" ... that available resources will permit and plunge boldly ahead. Let us make the "new incentive micro-economics" a macroeconomic reality.
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