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ON ESTIMATING THE PARAMETERS

OF ECONOMIC RELATIONS: A REVIEW*

George G. Judge

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College of Commerce and Business Administration

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This essay is focused on attempts over the last three decades to cope with the problem of measurement in economics. In particular, it is directed to a review of analytical methods developed and employed in analyzing and learning from economic data. To some extent, it is a report of an experiment -- an experiment in non-experimental model building. The achievements realized through a systematic use of economic and statistical models, methods and data, give empirical content to economic theory and practice, bring out clearly the complementarity between theory and measurement, and have made economics a leader of the non-experimental sciences.

It is with great pleasure that I take this intellectual trek through time, although the virtual explosion of knowledge over the last few decades points to the impossibility of such a task. Perhaps during the first half of this century it would have been possible to summarize, as many tried to do, the theory and method of economics. I doubt if any economist in his right

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To appear as a chapter in a literature review volume on quantitative economics.

*D. Aigner, G. E. Brandow, J. P. Doll, R. J. Foote, W. A. Fuller, G. W. Ladd, L. R. Martin, E. R. Swanson, T. Takayama, G. Tintner, T. D. Wallace, F. V. Waugh, and A. Zellner read an earlier draft of this paper and made many helpful comments, which in one way or another found their way into this paper.

mind would attempt to do so today. My task is only to review a subset of quantitative economic knowledge, but in this area the pace of development is so rapid I have a feeling that if I do not hurry and finish this paper, I shall be rightly accused of not being in my right mind.

This literature review is a brief, personal, partially documented statement of one man's view of the development of econometric theory and applications and cannot and should not be considered exhaustive or all-inclusive. Rather, it is only a subjective sampling of some of the creative analytical and empirical work over the last thirty years. Others who have looked back over the field and have viewed with alarm and pointed with pride, as they emphasized various aspects of the evolution of econometrics, include Tintner [1966], Wold [1969], Lesser [1968], and Klein [1971]. Since the econometric methods and applications I will discuss cut across subject matter areas, I have chosen time as a frame on which to hang and contrast the developments. Other subject matter survey papers have been commissioned that will include detailed reviews of applied econometric results, and for this reason I have been very selective in the application references noted.

The Pre-1940 Period

As the 1930's closed, economists had available to them the following ingredients in their search for knowledge: An economic theory developed over the decennia which included, among other things, the general equilibrium theory of Walras, the partial equilibrium theories of Marshall and the aggregative economic theory of Keynes; a steady flow of economic data from the developed countries; the elements of classical statistical theory and scientific method developed under the influence of such men as K. Pearson [1938] and R. A. Fisher [1935]; and the wonderful statistical tool known as multiple correlation or

regression. Armed with these tools, economists and statisticians in the twentieth century, after the casual empiricism of the nineteenth century, made a systematic and scientific use of statistical data (i) to give empirical content to economic theory by refuting, refining or modifying the conclusions reached from abstract reasoning, and (ii) to estimate the parameters of demand, supply, production, cost, consumption and investment relations so they could be used as a basis for decision making.

The statistical study of demand, which started with H. L. Moore [1914], culminated with Henry Schultz's [1938] classic work title The Theory and Measurement of Demand. This work was concerned with making use of economic theory, mathematical economics and the regression statistical model in specifying and estimating the parameters of the demand relations for agricultural commodities. Ezekiel, Bean, Warren, Pearson and H. Working were important contributors to the development of demand analysis in the 1920's and 1930's. E. J. Working [1926], in his paper, "What Do Statistical 'Demand Curves' Show?", looked at this activity which made use of data passively generated by society and questioned the possibility of deducing statistically the Cournot-Marshall demand curve when only the coordinates of intersection of the demand and supply relations were given for a series of points in time. In addition, the least squares approach to estimation was a method in which different estimates were obtained for a given parameter, depending on which variable was chosen to play the dependent role. Demand theory was stated in functional terms, and hence, treated all variables symmetrically. Investigators faced the multiple-parameter-dilemma and reacted to the problem by reporting two relations for each commodity analyzed -- one for price and one for quantity.

On the supply side, the focus was on agricultural commodities and much of the work concerned single equation economic and statistical models, in-

volving the variables acreage and lagged price. This work was summarized by J.D. Black [1924] in an article in the Journal of Farm Economics, and several years later Bean [1929] published his famous article, "The Farmers' Response to Price".

Also during this period, Black, Jensen, Spillman and others were attempting to estimate production functions for the technical units and processes in agriculture and Cobb and Douglas [1928] worked on industry relations. Dean [1936] specified and estimated statistical cost functions and Bressler [1942] and his associates were generating the data for and estimating cost-output functions. Stone and Stone [1938-39] made a statistical study of the macro consumption function and S. Kuznets [1935] and Tinbergen [1938] used statistical evidence to reject Clark's accelerator model of investment.

As the first forty years of this century came to a close, attempts were being made to deal with the endogenous generation of economic data, and multi-relation models came to the foreground in econometric research. S. Wright [1934] put forth the method of path analysis to reflect interdependencies in social processes. Frish [1934] extended his work to complete regression systems and Tinbergen [1938] developed his macro-economic model for the Netherlands and the United States [1938]. About the same time, Leontief [1937] completed the work started by the physiocrats in the eighteenth century and developed input-output analysis to make it possible to take into account the interdependence between the sectors of an economy and permit structural analysis. Although they could not satisfactorily solve the puzzle, many investigators during this period were aware of the conceptual problems of using single equation regression models, and in order to patch up the regression method, they proposed and applied a variety of procedures such as canonical

correlation (Hotelling[1933]), the variate difference method (Tintner [1940]), confluence analysis (Frisch [1934]), principal components (Hotelling [1933] and Girschick [1936]), and weighted regression (Koopmans [1937]).

The Decade of the 1940's

The early 1940's marks the beginning of the era of modern econometrics. The conceptual problems raised by E. J. Working [1926], Frisch [1934], Tinbergen [1938] and others, emphasized among other things that economic data are generated by systems of economic relations that are stochastic, dynamic and simultaneous, and pointed to the many unsolved problems of statistical inference, from the observed data to the relations. It was fully realized that if the results of econometric ventures were to reflect desired properties in estimation and inference, there must be consistency between the statistical model employed and the sampling model by which the data were generated.

In formulating statistical models consistent with the way economic data are supposed to be generated, a milestone was reached in 1943 when two articles were published in Econometrica by Haavelmo [1943] and Mann and Wald [1943], and Haavelmo wrote his monograph entitled The Probability Approach to Econometrics [1944]. Haavelmo converted the economist's simultaneous equation model to a statistical model by assuming a random disturbance for each equation and specifying the distribution of these random variables. Mann and Wald suggested a large sample solution to the estimation problem arising from the new formulation. Marschak and Andrews [1944] pointed out the simultaneous nature of production decisions leading to the determination of input levels in the production function. Anderson and Rubin [1949] developed the "limited in-

formation" maximum likelihood estimators for estimating the parameters of an equation in a system of equations, and derived corresponding large sample properties and statistical tests. Koopmans [1949] faced up to the problem first raised by Working [1926] and developed, with the aid of zero linear restrictions, necessary and sufficient conditions for identifying each mathematical equation as a definite economic relation and discriminating between alternative competing structures. Vining and Koopmans (1949] debated the question of measurement without theory as one goes about searching for knowledge. Marschak [1947,1953] made clear the need for structural estimation if the results were to be useful for policy purposes and suggested decision models for making use of empirical results. In two important articles which appeared in the Journal of Farm Economics, Cooper [1948] made clear the role of the econometric model in inference and Gale Johnson [1948] discussed the use of econometric models in the study of agricultural policy. The work of the 1940's which was based squarely on economic and statistical theory was to a large extent centered in the Cowles Foundation at the University of Chicago. A monograph edited by Koopmans [1950] summarized the state of the tools of quantitative knowledge after the developments of the 1940's.

On the applied side, Girshick and Haavelmo [1947] completed their classic article on the demand for food. Haavelmo [1947] made use of a system of equations in estimating the parameters of the consumption function. Klein [1950] completed his work on a sophisticated macro-econometric model of the U.S. economy. Working with Hurwicz and Thompson, Judge [1949] completed a systems of equations analysis of the feeder cattle sector; Ogg [1949], with the help of Hildreth, completed a simultaneous equation analysis of the production relation for a sample of firms and French [1950] completed a structural analysis of the demand for meat. Computational burdens with the new techniques were

significant since the desk calculator was still the main work horse of the "estimators". Anyone who has inverted a 10 x 10 matrix on a hand calculator can attest to the reality of this computing restriction.

At the end of the 1940's, Samuelson published his book on the Foundations of Economic Analysis [1948], Von Neumann and Morgenstern [1947] introduced the profession to game theory, Wald [1950] alerted us to statistical decision theory, Dantzig [1951a,1951b] developed the simplex algorithm for use with linear optimizing models and Koopmans [1949] and his cohorts were putting together the conceptual basis for the activity analysis approach to price and allocation problems in economics. Each of these creative efforts had a significant impact on the demand for and structure of econometric efforts in the 50's and 60's. Economists interested in agriculture were leaders in applying the new statistical procedures for estimation and prediction and at the end of this period, there was great optimism that we were on the road to making mathematical economics and econometrics into tools that would serve the needs and aspirations of the discipline and society.

The Decade of the 1950's

As the decade opened, Haavelmo's [1947] view of endogenous data generation was questioned by Wold [1956], and he proposed the recursive or casual chain economic and statistical models which were characterized by a triangular matrix of coefficients for the endogenous variables and diagonal covariance matrix. The term "single equation or least squares bias" became firmly implanted in the literature (Bronfenbrenner [1953]). The argument of single versus system of equations estimators was launched and reasons were advanced why single equation techniques were or were not satisfactory for a wide variety of agricultural commodities or sectors (Fox [1953], Foote [1955a], G. Kuznets [1955]). Hood and

and Koopmans [1953] published their book on studies in econometrics, and Tintner [1952] and Klein [1953] published textbooks which gathered together the theory and practice of those techniques that today we call econometrics. Most economics and agricultural econom.cs departments with an emphasis on graduate work introduced a course or courses in econometrics. "How to" handbooks appeared (Foote [1958], Friedman and Foote [1955]), and there was hardly an agricultural commodity that was not statistically analyzed as Hildreth and Jarrett [1955], Judge [1954], Nordin, Judge and Wahby [1954], Fox [1951], Foote [1953a, 1953b, 1952, 1955b], E.J. Working [1954], Rojko [1953, 1957a, 1957b], Cromarty [1959a, 1959b, 1962], Meinken [1953,1955], Harlow [1960], G.King [1958], Gerra [1958,1959], Shuffet [1954] and many others (Buchholz, et.al. [1962]) specified and estimated systems of equations. These econometric ventures, which involved systems of behavioral, technical, definitional, and institutional equations, did much to increase our understanding of the economic process and institutions underlying each of the agricultural sectors, the interactions between the agricultural sectors, and between the agricultural sector and the other sectors of the economy. In addition, the econometric results sometimes generated numbers that were useful for choice purposes at one or more of the structural decision making levels. At the macro or economy level, almost every major country had one or more simultaneous equation models constructed, estimated, and used, with perhaps the Dutch being the most conscientious in using econometric results for economic policy and planning purposes.

Chernoff and Divinsky [1953] specified the "full maximum likelihood method", which in contrast to the limited information system, used information concerning the structure and data from all of the variables in the system. Unfortunately, with this procedure, since the estimating equations involved were non-linear, numerical methods had to be used for solution purposes

and in the 1950's and for large systems perhaps today, the method was (is) impractical. As an alternative estimator for the parameters of an equation in a system of equations, Theil [1954] and Basmann [1957] proposed the generalized classical or two-stage least squares estimator and Theil [1954] the k-class estimators. The addition of these estimators to the econometrician's tool chest meant that we had reached the stage of multiple parameter estimates for any given economic model, and just as early econometricians had asked the question which regression, we now had to ask which estimator. The choice of estimator question was a difficult one: for the system of equations estimators only the asymptotic properties were available, and many estimators were asymptotically equivalent. For economists who usually have to work with small samples of data, however, finite sample results are essential. In order to get some idea of the performance of the alternative estimators in finite samples, simulation or sampling experiments were proposed and carried through by Ladd [1957], Wagner [1958], Neiswanger and Yancey [1959], Summers [1965] and others for certain specialized models, some of which involved measurement and specification errors. The progress via this route was slow and at the 1958 winter meetings, the Econometric Society sponsored a panel discussion under the pleading title: "Simultaneous Equation Estimators -- Any Verdict Yet?". To a large extent at that time (and to some extent now), the final verdict was (is) not in. In the 1950's, the electronic computer became a reality and put system of equations estimators within the reach of the individual researcher.

The decade of the 1940's made us acutely aware of the necessity for consistency between the assumptions underlying economic and statistical models. When models are correctly specified statistical theory provides procedures for obtaining point and interval estimates and evaluating the performance of

various linear estimators. Unfortunately, we seldom work with true models and a method was not available for drawing inferences based on "false" models. Because of the dichotomy that statistical theory provided inferential statements conditioned on true models and investigators in the main were working with false models, a large amount of effort was devoted to asking if-then type questions such as: If relevant variables are omitted from an equation, what is the impact on the properties of the estimates and how will the inferences be distorted (Griliches [1957], Theil [1957,1958])? If the disturbances are autocorrelated, how will the efficiency of the estimator be affected and how can we mitigate the impact of this specification error (Hildreth and Liu [1960], Cochrane and Orcutt [1949], Durbin and Watson [1950,1951])? What is the inferential impact of not fulfilling the assumption of the disturbances being identically (homoscedasticity) as well as independently distributed? What are the implications of stochastic rather than fixed regressors? What are the statistical implications of using variables that contain a measurement error (Durbin [1954])?

Since some progress was being made in formulating statistical models to cope with the simultaneous and stochastic nature of economic data, attention was directed to the dynamic aspects of economic models and data. Asking the question of how to specify models consistent with the dynamic characteristics of economic data led to the consideration of the autoregressive case and the specification of distributed lag economic models and their attendant problems of estimation. The work of Koyck [1954], Cagan [1956], and Nerlove [1958a,1958b,1958c] stand out in this development and their formulations led to the application of the distributed lag model (Nerlove and Addison [1958]) with emphasis on estimating the short and long run parameters of behavior patterns. The practical difficulties of distinguishing between different lag schemes when using non-experimental data was early recognized and to a large extent, the problem still exists today.

In the demand area, in addition to the commodity analyses already alluded to, Stone [1954] estimated a system of expenditure functions which satisfies various theoretical conditions, Frisch [1959] developed a scheme for computing cross elasticities of substitution and Brandown [1961] completed his work concerned with the interrelations among demands for farm products. There was a feeling during this decade, perhaps largely due to T.W. Schultz, that we had made more progress in capturing the parameters of demand relations than had been made with those for supply relations. This realization generated a flurry of activity led by Cochrane [1955], Heady, et.al. [1961], Nerlove [1958] and others, and the debate of positive versus normative supply response functions began.

Questions relating to the economic and statistical impact of using aggregate economic data and relations have an early origin and intuitively most analysts feel that aggregation involves a loss of information. An important work in this area was the book by Theil [1954], Linear Aggregation of Economic Relations, in which he dealt with the problem of interpreting the parameters of macro relations estimated from aggregate data, when the observed data are generated from a set of micro relations. One of his major results, assuming the micro coefficients are constant, was that when macro variables are obtained by simple aggregation (aggregate result postulated to hold independently of the micro relations), the expectation of the macro coefficient estimator will depend on a complicated combination of corresponding and non-corresponding micro coefficients. As a result, Theil [1954] raised the question of whether we should abolish the macro models and estimates. Alternatively, Klein [1953] showed that when the macro and micro relations are derived so that they are consistent, then the macro variables are weighted averages of the micro coefficients. If the weights are stable over time

then no aggregation bias results. The usual case, however, is for the weights to change over time. Grunfeld and Griliches [1960] gave a "no" answer to the question, "Is Aggregation Necessarily Bad?", but the outcome was as many had suspected: the question should have been answered "yes" (Zellner [1962]). It is interesting to note that in spite of the discouraging words of Theil, Klein, and Zellner, during the 1950's macro-econometric model building and estimation continued at full pace.

Given the questionable virtue of the macro data, in the 1950's much effort by persons such as Orcutt [1961] went into specifying a framework for and actually generating more complete micro data over time. Data panels and banks were set up and sample surveys were conducted to capture these data. From an estimation point of view, this expanded data base made it imperative to develop estimating methods which would permit the combining of cross section and time series data. In the 1950's, covariance analysis, usually through the use of dummy (zero-one) variables, provided the major estimating technique, although extraneous estimators were being talked about and actually applied by Tobin [1950] and others.

Much econometric activity in estimating production and cost functions was evident during this decade. Head, and Baker [1954], in their article concerned with resource adjustments to equate productivities in agriculture, exemplify the techniques employed in estimating the parameters of aggregate production and the use to which they were put. Swanson [1956], in his article concerned with optimum size of business, gives a good example of some of the problems of empirical production function analysis. Hoch [1958], Mundlak [1961], and others investigated the sampling properties of conventional parameter estimates of production functions for total farm or non-experimental

situations. Assuming that income shares accruing to each production factor are equal or proportionate to the output elasticities, Solow [1957] estimated and started the debate concerning how to measure the impact of technical progress on output or growth.

Concern over the richness of macro data or relations also raised questions about the necessity of generating data via controlled experiments. Within this context, it was realized by Heady [1961] and others that in estimating production functions, if we were to trace out the parameters of the production surface, in order to estimate the iso-product and production possibility relations data from controlled experiments would be necessary. This generated work on the appropriate experimental design to employ (Heady and Dillon [1961] and the actual applications of these designs to generate the experimental data.

About the same time, many were raising questions concerning the use of passively generated data in estimating the parameters of price-consumption response relations. This led Godwin [1952], Brunk [1958], Franzmann and Judge [1957] and others to design and carry out controlled experiments in retail markets and develop parameter estimates for an array of commodity response relations. Questions as to the generalizability of these results to a wider range of data were raised and by the end of the decade, the generation and use of experimental price-consumption data trended downward.

Friedman [1957] put forth his permanent income hypothesis and separated income and consumption for behavior purposes into the unobservable permanent and transitory components. Houthakker [1958], Eisner [1958], Nerlove [1958], and others investigated the implications of this framework and how to measure these nonobservable variables and actually test the permanent income hypothesis in Friedman's consumption function model.

Given the development in the 1950's of various linear and nonlinear decision and simulation models under certainty and uncertainty (Batchelor [1959-64]) and the formation of operations research and management science, the need for hard quantitative knowledge at all structural decision levels was emphasized and econometrics started serving these new masters.

In spite of the rapid pace of developments in theory and application, econometrics was, as the decade ended, an essay in persuasion. The alternative choices or permutations regarding the model, method and data facing an investigator were many (Booth and Judge [1956]), and in many cases, one had the feeling in reading an article or bulletin that the researcher had searched over a variety of models, methods and data to find a set of numbers satisfying a theory of his own intuition. In some cases in the data dredging process the investigator reported many alternative results and in some sense appealed to the reader to make a choice among the possibilities. In the 1950's, as in the 1940's, economists interested in agriculture took the leadership in applying and sharpening the new and old econometric tools. As a casual observer during this period, the author has the feeling that many of these results were seldom if ever used for decision purposes.

The Decade of the 1960's

If the 40's and 50's were instrumental in emphasizing the role of the economic model (the prototype of the sampling model that generated the data) in determining appropriate statistical models, the 60's made us aware of the necessity of developing statistical models which (i) provide systematic ways of combining sample and a priori information and (ii) are appropriate f economic decision problems-- the fruit of an idea introduced by Wald [1950] i . the forties. As some have implied, in some sense the respectability of prob-

ability as state of mind was reestablished. It was suggested that if econometric models are constructed and estimated as a source of information for decision making or choice, the theory of statistical decision, based on an analysis of losses due to incorrect decisions, can and should be used. In addition, it was argued, that since non-experimental observations are the main data source of the economist, the criterion of using "performance in repeated trials, and thus, unobserved samples" as a basis for rationalizing sampling theory approaches, should be questioned.

For economic data, which are by and large non-experimental in nature, the statistical decision theory problem is that of making the "best" decision on the basis of a given set of data, when θ, the true state of the world (parameter) is unknown. A number of solutions have been proposed and used for this statistical decision problem. Traditionally, the class of decision rules (estimators) is typically restricted to those that are linear and unbiased, and in conventional estimation theory where a quadratic loss function is assumed, this approach leads to minimum variance unbiased estimators. In spite of the near godly stature of unbiasedness that one gets from economic literature, the notion of unbiasedness, although intuitively plausible, is an arbitary restriction and has no connection with the loss due to incorrect decisions and is thus unsatisfactory from a decision theory point of view. In any event, as the decision theorists noted, the conventional sampling theory approach does not always lead to an optimal decision rule (estimator) and as Zellner [1972] has shown, may not in some cases satisfy even certain minimal properties.

As a means of facing up to some of these objections, in the 1960's Bayesian approach to inference and decision problems was revived and developed.

In this approach, the decision maker's prior information about the state of the world or parameter θ is combined with the sample information y to make the "best decision". It is assumed that the investigator's information or uncertainty about some parameter, θ, can be summarized in a prior probability function $p(\theta)$. This information is then combined with the sample density function $p(y|\theta)$ to yield a posterior probability density function $p(\theta|y)$. Then, given a loss function, say $L = L(\theta,\hat{\theta})$, which reflects the losses due to an incorrect estimation, the Bayesian choice of a point estimate $\hat{\theta}$ is the one that minimizes the expected loss, where the posterior distribution of θ is used in the expectation. Thus, the posterior probability density function combines both prior and sample information and it is this distribution which is employed in estimation and to make inferences about the parameters.

Given this framework and building on the work of Jeffreys [1961], Savage [1954], Raiffa and Schlaifer [1961], Dreze [1962], and Zellner [1971] and his associates developed a Bayesian formulation of the regression model with extensions to cover the problems of autocorrelated errors, distributed lags, prediction and decision, and multi-equation systems. One problem of applying Bayesian decision theory is finding a set of prior distributions rich enough to incorporate the investigator's knowledge but simple enough to be algebraically tractable. Modern methods of numerical analysis, however, have done much to change the definition of what is tractable. Much of the theory and practice of Bayesian inference in econometrics, which took place in the sixties, has been summarized in a recent book by Zellner [1971], and some of the elements of the debate still raging between the Bayesians and the non-Bayesians are contained in articles by Zellner [1972] and Rothenberg [1972].

Alternatively, within the spirit of combining prior and sample information, several sampling theory estimators were developed for the regression model, and the following alternative specifications have been analyzed and applied.

(i) When the prior knowledge concerning an individual or group of coefficient(s) is exact in nature, the methods and test statistics proposed by Wilks [1947], Tintner [1940], and Chipman and Rao [1964] may be employed. Either the conventional likelihood ratio test or the Toro-Vizcarrondo and Wallace [1968] or Wallace [1972] tests may be used with this model for deciding when, under a mean square error or squared error loss criterion, the restricted least squares estimator based on possibly incorrect, although exact prior information, is superior to the conventional estimator using only sample data;

(ii) If the prior information on an individual or group of coefficient(s) is of a statistical nature (i.e., stochastic linear hypotheses), with known finite mean and variance, then the methods and test statistics proposed by Durbin [1953], Theil and Goldberger [1961], and Theil [1963], which make use of Aitken's generalized least squares technique may be employed to estimate the parameters and test the compatibility of the prior and sample information. It should be noted that this estimator yields the same results as the mean of the limiting distribution for the Bayesian formulation assuming a locally uniform prior for $\underline{\beta}$ and σ^2;

(iii) When the prior knowledge is less complete and information exists only in the form of inequality restraints, one possibility when placing a prior upper and lower bound on a coefficient is to specify a mean and variance for the parameter which would give a very low probability to values outside this range. Under this specification, the resulting information could be used in the same way as Theil and Goldberger [1961] use prior knowledge of a statistical type and Aitken's generalized least squares estimator could be applied. Alternatively, when the prior information consists of linear inequality restraints on the individual coefficients or combinations thereof, then following Zellner [1963] and Judge and Takayama [1966], the problem may be specified and solved as a quadratic programming problem. The minimum absolute deviations (linear programming) estimator whose properties have been analyzed by Ashar and Wallace [1963], Blattberg and Sargent [1971], and Smith and Hall [1972], is still another alternative specification for handling the linear inequality parameter restriction problem.

These Bayesian and non-Bayesian formulations (Judge and Yancey [1969]) permit the investigator to take account of prior information about the unknown parameters that exists via the routes of postulation, experimentation, or "revelation". When a certain minimum amount of information is available concerning the structure of the relation(s), these estimators, either through restrictions or other outside information, may offer one way of coping with the troublesome problem of multicollinearity. The sampling properties of the inequality restricted least squares estimator are yet to be established, but initial Monte Carlo sampling

studies, such as those by Thornber [1967] and Lee, Judge and Zellner [1970], yield encouraging results relative to its performance. Both the Bayesian and sampling theory estimating methods can handle the cases for a multivariate regression system and a simultaneous equation system (Lee and Seaver [1971]). In deriving new estimators during the decades of the 1950's and 1960's the standard practice appears to have been i) change the statistical model, ii) change the prior or way to use prior information, or iii) change the loss or measure of goodness. While not all of the inferential and philosophical problems in this area were solved in the sixties, these procedures appear to offer promise in our search for "optimum" estimators and suggest systematic ways for proceeding as we attempt to learn from experience and data.

In the early 1960's Graybill's book [1961] on linear statistical models was published and provided the theoretical base and format for the econometric texts of this era. Johnston [1963] and Goldberger [1964] were the two outstanding textbooks of the period, and their appearance along with other econometric texts had much impact on the quality of instruction and the level of the econometric sophistication of students.

In the 1960's, systems analysis and control theory provided a framework for combining into one package automatic or adaptive control, estimation, prediction, and some utility functional or optimality criterion and thus the joining of optimization, estimation, and the design of experiments (Pontryagin [1962], Aoki [1967]). These methods, especially in the discrete form, suggested for example ways to deal with the effects of lags and uncertainty on the conduct of stabilization policy and permitted one basis for following up the early contributions of Phillips [1954]. Bayesian methods, as outlined by Fisher [1962], Zellner and Geisel [1968], and Prescott [1967] provide a systematic way of handling control problems since they permit optimal, com-

putable solutions which use both prior and past sample information, take account of uncertainty about parameter values, make use of new information as it becomes available and in an experimental design sense, devise optimum settings for the control variables.

Within the classical sampling theory approach, Zellner and Theil [1962] developed the three stage least squares simultaneous equations estimator and compared its asymptotic sampling properties with its competitors. Nagar [1962] widened the class of system estimators to include the double k class variety. Rothenberg and Leenders [1964] developed the method of linearized maximum likelihood and investigated some properties of the alternative systems estimators. Several Monte Carlo (Cragg [1966,1967,1968], Summers [1965]) and analytical (Basmann [1957,1965], Dhrymes [1965], Kabe [1964], Richardson [1968], Sawa [1969], Madansky [1964]) distribution studies were completed, and we have gradually learned a little more about the finite sample properties of alternative system of equations estimators. Shortly prior to and to some extent in conjunction with his three stage least squares work, Zellner [1962], formulated an Aitken type estimator for handling sets of regression equations when the equations are disturbance related and the regressors vary over equations, and developed a test for aggregation bias and some small sample properties for this model. The debate on the appropriate statistical model and methods for prediction purposes was fed by Waugh's [1961] provocative article on the place of least squares in econometrics.

Work continued on how to detect and mitigate such specification errors as autocorrelation and heteroscedasticity and even the old multicollinearity problem took on new interest. In particular, Lancaster [1968], Goldfeld and Quandt [1965], Glejser [1969], and Rutemiller and Bowers [1968] advanced the topic of

estimation in a heteroscedastic regression model; Theil [1965], Koerts[1967], Theil [1965,1968], Kadiyala [1968], Durbin [1970a,1970b], Zellner and Tiao [1964], and Griliches and Rao [1969] contributed procedures and tests for autocorrelation; Farrar and Glauber [1967], Silvey [1969] and Toro-Vizcarrondo and Wallace [1968] contributed procedures and tests for handling multicollinearity.

Interest in and use of some of the multivariate techniques developed in the 1930's was revised. Discriminant analysis and linear probability functions which permit the measurement of the effect of continuous variables on group membership were reviewed by Ladd [1966], and used for example, by Ladd [1967] to analyze the objectives of fluid milk cooperatives; by Adelman and Morris [1968] to explore the forces affecting a country's prospects for development; and by Fisher [1962] to study the purchase of durable goods. Factor analysis and principal components, inductive procedures that are used among other things to develop hypotheses from data, were reviewed by Scott [1966] and used by Baumer, et.al. [1969] to study psychological and attitudinal differences between milk purchasers; and by Massy, et.al. [1968], to study various measures of consumer purchasing power.

In regard to enriching the data base by using both time series and cross section data, Balestra and Nerlove [1966], Mundlak [1961], Wallace and Hussain [1969], and Maddala [1971] specified a components of error model whereby the regression error is assumed to be composed of three independent components -- one with time, one with the cross section, and one overall component in both the time and cross section dimensions. Nerlove [1971] investigated, by Monte Carlo procedures, the properties of various estimators with-

in this context and proposed a two round estimation procedure. Chetty [1968] reformulated the cross section-time series problem along Bayesian lines. Swamy [1971], in contrast to conventional fixed coefficient models, recognized the heterogeneity of behavior among individuals and over time (i.e., the invariance of parameter systems), by developing the random coefficient statistical model, and analyzed estimation procedures for it. Hildreth and Houch [1968] and Griffiths [1970] extended the results for this statistical model. Zellner [1967] analyzed the statistical implications of the aggregation problem within the context of the random coefficient statistical model.

In the last few years time series analysts have revised or modified the harmonic analysis used by economists many years ago and added the tool which has become known as spectral analysis (Cargill [1971]). This tool of frequency domain analysis which has also been referred to as harmonic, Fourier and periodogram analysis, is based on the idea of decomposing a stochastic process into a number of orthogonal components, each of which is associated with a given frequency (Granger and Hatanaka [1964], Nerlove [1964], Fishman [1969]). These methods are in general possible when the variances and covariances are time independent. Cross spectral methods which deal with relations between variables are of great importance to economists but at this time are the least developed. Since modern computers can easily handle these techniques, a large number of researchers have made use of spectral procedures in the time series modeling of economic phenomena (Dhrymes [1971, pp. 483-484]) and spectral methods have been extended to such areas as estimating time domain distributed lag models (Dhrymes [1971, pp. 263-325], Fishman [1969]) and evaluating the dynamic properties of structural systems of equations (Howrey [1971]).

The distributed lag or autoregressive model with moving average error continued to enjoy considerable use in empirical work. Fuller and Martin

[1961] considered a distributed lag model with autocorrelated errors and suggested a consistent estimator. Griliches [1967] surveyed the work in this area during the fifties and early sixties, concentrating his emphasis on estimating distributed lags in the form of difference equations. Since this time emphasis has shifted to estimation of distributed lags under more general stochastic assumptions about the disturbance (Hannan [1967], Amemiya and Fuller [1967], Dhrymes [1971], Fishman [1969], Hall [1971], Jorgenson [1966]), constraining the lag function to belong to a family controlled by a few parameters (parameterization) and/or treating the least squares estimates so that adjacent lag coefficients lie close to one another (smoothing). In the linear parameterization area, the idea of fitting polynomials to a series of coefficients which can be dated back to Fisher was identified as the Almon [1965] approach and became the dominant method of modern empirical work in distributed lags. The work of Ladd and Tedford [1959] reflects one pre Almon application of this procedure in the agricultural economic literature. An alternative to making exact parametric restrictions is a probabilistic (Bayesian) characterization of the lag distribution which has been proposed by Leamer [1970] and Schiller [1970]. In closing this discussion, let me note the work of Box and Jenkins [1970] on time series models from the class of discrete linear stochastic processes of integrated autoregressive moving average form and the work of Aigner [1971] in integrating this work with that of econometrics.

The econometric dimensions of the consumer's problem of how to allocate income to N commodities, given prices and income, was pushed forward on the theoretical, estimation and testing fronts. Some of the major econometric contributors to the problem of estimation of demand parameters under consumer budgeting that give empirical content to the ideas of Frisch [1959], Gorman [1959], and Strotz [1959], include the work of Barten [1968], Theil [1967,1971]

De Janvry, et.al. [1972], Goldberger [1970], Powell [1966], and Boutwell and Simmons [1968].

One important activity of the sixties was the econometric study of investment behavior which developed fr m empirical comparisons of alternative determinants of producer behavior. This work is important here since it has provided an important basis for the development of new econometric techniques for representing the time structure of economic behavior. Some of the contributors in this area include Meyer and Kuh [1957], Eisner and Strotz [1963], Griliches, Modigliani, Grunfield, and especially Jorgenson [1971].

The dynamic and stochastic nature of economic data led several to suggest that our economic observations may be viewed as being generated by a stochastic process -- that is, a process that develops in time or space according to probabilistic laws. This proposition led to the use of a first order stationary Markov process as the appropriate probability model when the observation at any time is the category in which an observation falls. The object of this type of analysis is to use the time-ordered movements of micro data as a basis for estimating the transition probability system. The parameters of the probability system are then used as a basis for summarizing the dynamic characteristics of the data, predicting future outcomes and the long run equilibrium of the system. This type of model has found many applications ranging from the work of Goodman [1965] gauging social mobility to that of Adelman [1958], Judge and Swanson [1962], Preston and Bell [1961], Steindl [1965], and Hallberg [1969] on the size distribution of firms. One problem in making use of this model is that in many cases the data for the micro units are not available and only their aggregate counterparts (proportions in each state) exist. In order to use the aggregate data as a basis

for estimating the behavior system for the micro data (transition probabilities), Miller [1952] and later Telser [1963] formulated the problem within the least squares framework. Building on this work, Lee, Judge, and Zellner [1970] developed restricted least squares, maximum likelihood and Bayesian estimators of the transition probabilities. Simulated sampling studies with these estimators have shown that each of the estimators perform well when the aggregate data are generated by a first order Markov process, although the Bayesian estimator, using a multivariate beta prior, appears to yield the best performance.

Growth theory received much emphasis during the decade of the sixties and since the aggregate production function, which expresses the basis relationship among output, employment and capital stock, is the engine for most of the models searching for the golden rule of accumulation, this relation provided the basis for a large number of studies on technical change and growth. As a replacement for the Cobb-Douglas specification which implies a unitary elasticity of substitution between the factors, Arrow, Chenery, Minhas and Solow [1961] proposed the constant elasticity of substitution (CES) production function which permitted the elasticity of substitution to lie between zero and one, Dhrymes [1965] developed statistical tests for the CES production function; Revankar [1966] proposed the variable elasticity of substitution production function; Zellner and Revankar [1969] proposed a generalized production function which permits variable returns to scale and Newman and Read [1961] and Ferguson and Pfouts [1962] proposed a production function that would permit variable factor shares. These specifications result in relations which are nonlinear functions of the parameters, and conventional estimation methods fail because alternative estimators lead to the

problem of solving a system of nonlinear equations. Because of this result, various attempts have been made to circumvent the problem of nonlinear estimation methods (Kmenta [1967], Bodkin and Klein [1967], and Tsang [1971]). Aigner and Chu [1968] questioned the conventional rationale used in estimating the parameters of production functions and developed and applied procedures for estimating the frontier of a production function. Meanwhile, back at the ranch, the old problems of multicollinearity, aggregation bias, specification error, how to isolate the management inputs and technical progress, and the question of the meaning to be attached to the parameters of macro production functions were still alive, and to some extent, unsolved problems.

During the decade of the sixties, interest and work continued in the area of macro-econometric models (Nerlove [1966], Hallberg [1972]), and produced such outcomes as the SSRC-Brookings (Griliches [1968]), FRB-MIT-Penn (Rausch and Shapiro [1968]), and St. Louis (Andersen and Carlson [1970]) specifications. The first two of these models entailed the cooperative efforts of the theorist, applied economist, statistician, mathematician, and computer scientist in the job of model specification, estimation and modeling. These models involved several industrial sectors, of which agriculture was one, and the national income accouting and input-output systems were combined in the specification. Thus, these efforts continued the tendency to increase the size of the macro-econometric models by a finer disaggregation of the major macro variables. Monetary sectors were added as monetary policy became more in vogue. Nonlinear systems were estimated and solved. As a sign of the times in terms of working with these econometric models, Zellner [1970] did a paper on "The Care and Feeding of Econometric Models". The macro-econometric models were used by

Goldberger [1959], Evans and Klein [1967], Fromm and Taubman [1968] and others for _ex ante_ forecasting. As the models got bigger, the debate between the big and the small specifications gathered steam. Within this context, Cooper and Nelson [1971] compared the FRB-MIT Penn 171 equation model, the St. Louis 8 equation model, and the simple Box-Jenkins autoregressive moving average model for _ex post_ and _ex ante_ prediction of six endogenous variables and found that no single model or predictor could be said to dominate the others. Given this result, they suggested a convex combination of the estimates as one superior alternative. However, the debate continues and Klein [1971] and others talk of models in the 1000 equation range. The timid during this period continued to ask where one is to get the data base to support the parameter space for these larger and larger ventures. Unfortunately, they were not swamped with either the data or the answers to the query. At this stage, perhaps the greatest payoff is, as it was in the 1950's, in the building of the models and the identification of conceptual, data, estimation, and non-linear system solution needs.

One break from the past, where it was conventional to toss econometric results to the masses with a plea for their use by somebody, at some place and at some time, was to set up and carry through simulation experiments in order to see if the outcomes of the estimated systems are consistent with observed behavior and expected results. This further testing of our models through modeling did much to improve the usefulness of the results and raise the interesting philosophical question of whether simulation procedures, which iterate on parameter systems, may not be one meaningful way to capture unknown parameters or systems. Much of the macro-econometric estimation and modeling was made possible by advances in computer technology. What formerly seemed out

of reach estimation and analysis-wise in the 40's and 50's became accepted practice in the 60's.

Since the econometric machine runs on data we will close this section by noting that as the 60's ended, we were well on our way to creating large data banks of economic statistics, using remote access computer consoles and starting to talk seriously about and design large scale controlled experiments as a basis for understanding existing or potential economic processes and institutions.

The Here and Now

As the decade of the 1970's began, the rapid pace of econometric developments, started in the 40's and 50's, continued. Methods for estimating economic relations and testing economic hypotheses were refined and extended. The use and place of Bayesian estimation and inference in econometrics was firmly established and no longer had to be justified anew each time it was mentioned or applied. Many schools introduced Bayesian techniques in their econometric courses. Recent contributions to Bayesian inference in econometrics were summarized in a book in honor of Savage that was edited by Zellner and Fienberg [1974]. Several econometric texts were completed (Theil [1971], Kmenta [1971], Dhrymes [1970], Malinvaud [1970], Walters [1970], Johnston [1971], Aigner [1971] and others) and in contrast to the 1950's, the teacher and student have almost unlimited material for texts and references.

Analytical work concerning the finite sample properties of systems of equations estimators took a jump forward. Sawa [1972] evaluated the finite sample moments of the k-class estimators for $0 \leq k \leq 1$ and developed numerical calculations of the mean square error and the bias for specific cases. Mariano [1972, 1973] obtained necessary and sufficient conditions for the existence

of even moments of the two stage least squares estimator and approximated the distribution function of the two stage least squares estimator up to the terms whose order of magnitude are $1/\sqrt{n}$, where n is the sample size. Mariano and Sawa [1972] developed the exact finite sample distribution of the limited information maximum likelihood estimator when the structural equation being estimated contains two endogenous variables and is identifiable in a complete system of linear stochastic equations.

Box and Jenkins [1970] techniques for time series analysis were applied and evaluated, and one of the more interesting and promising developments in the area centered around the analysis of dynamic simultaneous equation models within the context of general linear multiple time series processes. Zellner and Palm [1973], building on the idea that if a set of variables is generated by a multiple time series process it is often possible to solve for the processes generating individual variables, showed that if a multiple time series process is appropriated specified, we can obtain the usual dynamic simultaneous equation model in structural form and then, the associated reduced form and transfer functions can be derived.

One of the problems that characterizes most econometric ventures pertain to measurement and observation errors. In most statistical models it is assumed that errors occur in the equations and that the variables are measured without error. Unfortunately, most data that we generate or that is generated for us do not have this quality. These errors in the variables, as is well known, cause conventional estimators to give both biased and inconsistent reresults. Out of the procedures proposed to cope with the measurement error problem, the method of instrumental variables, which dates back to the 1930's, has probably been the most widely known and used. Excellent survey articles

on the errors in the variables model covering the 1940 to 1970 period may be found in Madansky [1959], Moran [1971], and Malinvaud [1970]. When making use of one of the alternative consistent estimators when measurement errors are suspected, the investigator is usually uncertain whether the virtue of consistency in his finite sample is sufficient to outweigh the increased variance from the use of instrumental variables. As an approach to this problem Feldstein [1973] has suggested and evaluated alternative procedures for balancing the loss of efficiency in instrumental variable estimators against the potential gain or reduced bias. Fuller [1972] in an unpublished paper has investigated the properties of the estimators of errors in the variables model when the covariance matrix is estimated. Unobservable variables, such as permanent and transitory income, are a special case of the errors in the variables model and have been studied by Zellner [1970] and Goldberger [1972]. Zellner considered a regression model containing a single unobservable variable and, for the practical situation where the variances are unknown, developed an operational version of generalized least squares where sample variances replace their unknown population counterparts. He also, in customary Zellner fashion, proposes a Bayesian analysis of the model. Goldberger [1972] building on the work of Zellner develops a maximum likelihood procedure for the unobservable independent variable problem. This revival of econometric interest in the errors in the variables problem and realization of the possibility of identification and efficient estimation in unobservable variable models has contributed to the development of a unified statistical methodology (Goldberger [1971]) for the social sciences.

In regard to sampling theory estimators, the inferential problem of making use of preliminary tests of significance, a problem first emphasized

by Bancroft [1944] received new attention. This problem arises since in much of the work in economic measurement there is uncertainty as to the agreement between the sampling model that generated the data and the statistical model that is employed for estimation and inference purposes. Statistical theory provides estimator properties and inferential statements conditioned on true models, whereas post data model construction, by making use of preliminary tests of significance based on the data in hand, constitutes a rejection of the concept of true models. Two stage procedures which yield an estimate after a preliminary test of significance make the estimation procedure dependent on the outcome of a test of hypothesis and lead to preliminary test or sequential estimators. Although this estimator is widely used by applied workers, little is known of the sampling properties of the estimator and the possible distortion of subsequent inferences when preliminary tests of significance are performed. Bancroft [1964], Sclove, et.al. [1972], Ashar [1970], and Kennedy and Bancroft [1971] in the 60's and early 70's studied, usually for special cases, the properties of the resulting statistics in terms of their mean values and mean square errors and contrasted the forward and backward selection and sequential deletion model building procedures. Bock, Judge and Yancey [1971a], building on the work of Bancroft and Sclove, derived analytically the risk for the preliminary test estimator (PTE) for the general case, showed that there are points in the parameter space where the risk of the PTE exceeds that of the conventional estimator, and developed the conditions necessary for the risk of the PTE to be equal to or less than that of the conventional estimator under squared error loss. Bock, et.al. [1971b] also derived the sampling properties of the PTE and con-

sidered the sampling information of the PTE under a generalized mean square error criterion. Yancey, et.al. [1970] and Judge, et.al. [1973] extended the mean square error test of Toro-Vizcarrondo and Wallace [1968] to include stochastic linear hypotheses and developed the properties of the stochastic PTE (i.e., the sampling properties of Theil's [1963] mixed regression estimator when the compatability statistic is used).

At the same time work on the preliminary test estimator was going on, renewed interest emerged in Stein-like estimators, which lie outside of the class of linear unbiased estimators. Stein [1956] showed the conventional least squares estimator of the multivariate mean (with components greater than two) was inadmissible under the squared error loss measure of goodness, and Stein and James [1961] showed that when certain conditions are satisfied relative to number of parameters and tho appropriate critical value of the test that under the trace criterion the Stein-James estimator dominates the conventional estimator. Baranchik [1964] showed in general that the positive-part version of the Stein-James estimator dominates the original estimator. Strawderman [1971] developed, for the case when the number of parameters involved was greater than five, an estimator that was admissible and minimax. Sclove, et.al. [1972] showed that a modified positive-part version of the Stein-James estimator dominates the PTE over the range of parameter values. Bock [1975] has generalized the results for the above estimators for cases usually found in practice. Zellner and Vandaele [1972] developed Bayesian interpretations of and alternatives to the preliminary test and Stein-like estimators. Hill [1972] has investigated the problem of the inadmissibility of the usual multivariate estimator of a multivariate location parameter and presents a unified approach to estimation and hypothesis

testing which is based directly on the concept of subjective probability. Lindley [1968] has considered the analysis of data under the regression model, and argues that the form of the analysis should depend on the use to be made of the results; in his approach to the variable choice problem, he makes uses of ideas from decision theory. While some problems remain (e.g. for the sampling theory estimators the optimal level of the test), we now have a much better feel for the sampling performance of a wide range of new and old estimators, and this should pay off in terms of improved procedures for sequential model building and learning from data.

The work on post data model evaluation or discriminating among alternative admissible economic and statistical models, continues at full pace. Some of the hypothesis and decision rule procedures indicated above have implications for post data model evaluation and choice. Dhrymes, Hymans, Kmenta, et.al. [1972] surveyed the alternative and to some extent ad hoc procedures for the parametric evaluation of econometric models and noted the unsatisfactory nature of econometric practice and the state of the art. Beale [1970] summarized many of the most commonly used regression model building procedures, many of which are based only on intuitive appeal, and lends support to the backward stepwise method of variable elimination. Kennedy and Bancroft [1971] consider the forward selection and sequential deletion model building procedures, and via numerical sampling experiments study the relative efficiency of the two procedures and recommend significance levels to use in confronting the best subset problem. Much work has been done via Bayesian procedures for comparing and choosing among alternative models and some of the productive efforts that stand out in this context are Box and Hill [1967], Geisel [1970], Thornber [1966], and Zellner [1971]. An excellent

survey of these and other procedures for model selection is given in Gaver and Geisel [1973]. In spite of these advances in both the Bayesian and non-Bayesian areas, much remains to be done since we know little of (i) the sensitivity of these procedures to specification errors, (ii), the finite sample behavior of these procedures, and (iii) implications for multiple equation models.

^{t}(1973 - θ)

Having enumerated some of the elements and events in the econometric set which help us to determine where we are and where we have been, let us now turn to the future and engage in a little ex ante prediction as it relates to econometrics.

If what we have achieved is in any way prologue, it seems apparent that we will continue to refine and develop our economic and statistical models to cope with the special problems of our sample data and the decision problems for which the results are to be used. We will continue to improve our knowledge of the finite sample properties of sampling theory estimators and learn more of the implications and possibilities for combining prior and sample information for the purposes of estimation, prediction and control. Nonlinear estimators and their stochastic properties and random coefficient statistical models will be further developed and become standard equipment in the econometrician's tool chest. We will improve by both sampling theory and Bayesian procedures, our ability to handle the distributed lag estimation problem and to transform the distributed lag model into the frequency domain. The progress to date in the area of post data model evaluation warrants an optimistic forecast that the development and extension of useful selection methods will continue. Computer programs for alternative Bayesian estimators will become available and the use of Bayesian inference, estimation and deci-

sion processes will grow rapidly in our search for "optimal" actions (estimators). There will continue to be a significant growth in the average level of sophistication of economists with respect to econometric techniques, and perhaps ten years from now everyone will be at least a residual Bayesian. The gap or lag between theory and analytic l tools and application should continue to narrow.

The communalities between problems and methods in the social sciences will become more apparent, and we will move toward a unified set of quantitative techniques which hopefully will preclude a situation whre the tools and techniques of one discipline are rediscovered twenty-five years later in another (Hauser and Goldberger [1971]). We will gradually learn that quantitative tools are less specialized than the people who use them and start to make use of such far afield procedures as linear filter and prediction theory (Kalman [1960] that has been developed by engineers to cope with the problem of estimation in dynamic systems which involve unobservable variables and non time constant parameters.

Dynamic and stochastic decision models will grow in sophistication and usefulness, and econometrics will serve as a foundation stone in the development of operational routines for a formal analysis of decision problem under uncertainty. The use of structural modeling and simulation procedures will continue to grow very rapidly and especially modeling of macro-econometric models will increase in importance as a tool to gauge the relative performance of alternative estimators and models and to understand the meaning of our results. Future methods and models will, as they become more appropriate for economic decision problems under uncertainty, continue to emphasize use of systems or stochastic control theory which combines in one package, automatic or adaptive control, estimation, prediction, and some optimality criterion (Dreze [1972]).

Data will continue to be a problem, but since the model builders and the model users are now getting together, there are many reasons to be optimistic in regard to an improvement in quantity, form, and accuracy. Quantitative economists will realize that Federal collection agencies will not supply many of their data needs and new institutional arrangements will be specified and implemented for acquiring the research data we need. One hopeful sign is that we are finally actually generating data from large social experiments (for example, the experiments in New Jersey, North Carolina regarding the negative income tax proposal). Thus, over the next ten years, we should see a flow of much more usable experimental and survey generated data, where data design is integrated with use, and the situation relative to social statistics, where currently we know more about the population of hogs and cows than that of people, will be improved. Central files of data and prior research results will be stored with ready access to the researcher via remote terminals. When this information is combined with econometric programs and remote terminals, the individual researcher, department or institute will have ready access to large scale systems now only available to a few.

Finally we note, since mathematical economics is one of the foundation stones of econometrics, that much of our modern economic theory is a theory of position and not of movement. This means that in order to have a conceptual base for many of the major concerns facing society, we must develop a more workable theory of change which is more concerned with leads, lags, and expectations, with intertemporal relations among phenomena and the dynamic mechanism of transmitting impulses. As Nerlove [1972] has noted dynamic economics is still in large part a thing of the future. Econometric procedures

now available or on the horizon, along with more and better data and computing possibilities provide the ingredients appropriate for evaluating economic hypotheses and in accumulating a system of uniformities in the form of mathematical economic theory which will permit us to better understand the dynamic characteristics of economic processes and institutions.

Concluding Remarks

We are now at the end of a very inadequate tour. When I finished putting together these remarks, I was impressed by how hard the problems were and how far we have come. The last thirty years have been a very important experiment in non-experimental model building and the current interdisciplinary focus in academia has only helped to emphasize that our achievements in econometric theory and applications have made economics a leader of the social sciences. Economists interested in agriculture have had a significant role over time in testing the new methods of estimation and inference and in many cases modifying, sharpening and extending them. The list of econometricians who cut their teeth on agricultural data, or at least did some work on agricultural problems during their careers, is indeed an impressive one. Agricultural economics will continue to be an important testing ground for econometric work but its uniqueness in this respect will diminish as economists get a better break at the funding table and the general economics departments continue to develop their research programs.

In a post-industrial society, theoretical and empirical knowledge in economics will become a primary source of innovation and policy analysis, and academic economic research, where this knowledge is codified and tested, will be asked to assume a task greater than it has carried through history. In

spite of past performances and the importance of the charge for the future, econometrics will continue to have its social and other critics and to be under suspicion to some. Some will point out that we continue to work or fiddle with the properties of esoteric estimators while the world burns and people suffer. Others will point out that we are out to violate man's sacred beliefs and deal him the final moral insult by developing schemes to manipulate or control human behavior and that we are hard at work on a set of structural equations which will capture the relevant behavioral mechanisms or processes and make the understand, predict and control trichotomy operational. Our response to the charges of irrelevance and impiety and our future performance as a science will ultimately depend on how well we fulfill the prescriptive goal of helping peoples and their governments to satisfy their social, cultural and economic aspirations. This goal is best served by a science that provides an understanding of the regularities of economic life and a framework for using this information as a basis for prediction, control and choice. In the quest for this kind of a science of economics, the continued development and application of tools of econometric analysis is essential.

REFERENCES

Adelman, I.G. (1958): "A Stochastic Analysis of the Size Distribution of Farms," Journ. Am. Stat. Assn., 55:893-904,

Adelman, I.G. and C.T. Morris (1968): "An Econometric Model of Socio-Economic and Political Change in Underdeveloped Countries," Amer. Econ. Rev., 58:1184-1218.

Aigner, D.J. (1971): Basic Econometrics, Englewood Cliffs, New Jersey, Prentice-Hall.

Aigner, D.J. (1971): "A Compendium on Estimation of the Autoregressive-Moving Average Model from Time Series Data," Intl. Econ. Rev., 12:348-371,

Aigner, D.J. and S.F. Chu (1968): "On Estimating the Industry Production Function," Amer. Econ. Rev., 48:826-39.

Almon, S. (1965): "The Distributed Lag between Capital Appropriations and Expenditures," Econometrica, 33:178-196,

Ameniya, T. and W. Fuller (1967): "A Comparative Study of Alternative Estimators in a Distributed Lag Model," Econometrica, 35:509-529.

Anderson, L.C. and K.M. Carlson (1970): "A Monetarist Model for Economic Stabilization," Federal Reserve Bank of St. Louis Review, 52:7-25,

Anderson, T.W. and H. Rubin (1949): "Estimation of the Parameters of a Single Equation in a Complete System of Stochastic Equations," Annals of Math. Stat., 20:46-63,

Aoki, M. (1967): Optimization of Stochastic Systems, New York, Academic.

Arrow, K.J., H.B. Chenery, B.S. Minhas, and R.M. Solow (1961): "Capital Labor Substitution and Economic Efficiency," Rev. of Econ. and Stat., 43:225-250.

Ashar, V.G. (1970): "On the Use of Preliminary Tests in Regression," unpublished thesis, North Carolina State University, Raleigh.

Ashar, V.G. and T.D. Wallace (1963): "A Sampling Study of Minimum Absolute Deviations Estimators," Operations Research, 11:747-758.

Balestra, P. and M. Nerlove (1966): "Pooling Cross Section and Time Series Data in the Estimation of a Dynamic Model: The Demand for Natural Gas," Econometrica, 34:585-612.

Bancroft, T.A. (1944): "On Biases in Estimation Due to the Use of Preliminary Tests of Significance," Annals of Math. Stat. 15:190-204.

Bancroft, T.A. (1964): "Analysis and Inference for Incompletely Specified Models Involving the Use of Preliminary Test(s) of Significance," Biometrics, 20:427-442.

Baranchik, A.J. (1964): Multiple Regression and Estimation of the Mean of a Multivariate Normal Distribution, Stanford University Technical Report No. 51.

Barten, A.P. (1968): "Estimating Demand Equations," Econometrica, 36:213-251,

Basmann, R.L. (1957): "A Generalized Classical Method of Linear Estimation of Coefficients in a Structural Equation," Econometrica, 25:77-83,

Bassman, R.L. (1965): "A Tchebychev Inequality for the Convergence of a Generalized Classical Linear Estimator, Sample Size Being Fixed," Econometrica, 33:608-618,

Batchelor, J. (1959-64): Operations Research: An Annotated Bibiliography, 4 Volumes, St. Louis, St. Louis University Press.

Baumer, E.F., W.K. Brandt, R.E. Jacobson, and F.E. Walker (1969): "Dimensions of Consumer Attitudes in Fluid Milk Purchases," Ohio Agricultural Research Bulletin 1028.

Beale, E.M.L. (1970): "Note on Procedures for Variable Selection in Multiple Regression," Technometrics, 12:909-914.

Bean, L.H. (1929): "The Farmers' Response to Price," J. Farm Econ., 11:368-385.

Black, J.D. (1924): "Elasticity of Supply of Farm Products," J. Farm Econ., 6:145-155.

Blattberg, R. and T. Sargent (1971): "Regression with Non-Gaussian Stable Disturbances: Some Sampling Results," Econometrica, 39:501-511.

Bock, M.E. (1973): "Minimax Estimators of the Mean of a Multivariate Normal Distribution," Forthcoming in the Annals of Statistics.

Bock, M.E., G.G. Judge, and T.A. Yancey (1973): "Estimation in Regression After Preliminary Tests of Significance," forthcoming in The Journal of Econometrics.

Bock, M.E., T.A. Yancey, and G.G. Judge (1973): "Properties of Some Preliminary Test Estimators in Regression Using a Quadratic Loss Criterion," J. of Am. Stat. Assn., 68: 109-116.

Bodkin, R.G. and L.R. Klein (1967): "Nonlinear Estimation of Aggregate Production Functions," Rev. Econ. and Stat., 49:28-44,

Booth, E.J.R. and G.G. Judge (1956): "The Impact of the Choice of Model on Measurements of Economic Behavior," J. Farm Econ., 38:570-583.

Boutwell, W.K.,Jr. and R.L. Simmons (1968): "Estimation of Demand for Food and Other Products Assuming Ordinally Separable Utility," Am. J. Agric. Econ., 50:366-378,

Box, G.E.P. and W.J. Hill (1967): "Discriminating among Mechanistic Models," Technometrics, 9:57-71.

Box, G.E.P. and G.M. Jenkins (1970): Time Series Analysis, Forecasting and Control, San Francisco, Holden-Day.

Brandow, G.E. (1961): Interrelations among Demands for Farm Products and Implications for Control of Market Supply, Pennsylvania State University Bulletin 680.

Bressler, R.G. (1942): Economies of Scale in the Operation of Country Milk Plants, New England Research Council Technical Bulletin, Boston.

Bronfenbrenner, J. (1953): "Sources and Sizes of Least Squares Bias in a Two Equation Model," in Studies in Econometric Method, ed. W.C. Hood and T.C. Koopmans, New York, John Wiley & Sons, pp. 221-235.

Brunk, M.E. (1958): "Use of Experimental Design in Marketing Research," J.Farm Econ., 40(Proceedings):1237-1246.

Buchholz, H.E., G.G.Judge and V.I. West (1962): A Summary of Selected Estimated Behavioral Relations for Agricultural Products, University of Illinois Research Report 57.

Cagan, P. (1956): "The Monetary Dynamics of Hyperinflation," in Studies in the Quantity Theory of Money, ed. M. Friedman, Chicago, University of Chicago Press, pp. 25-117.

Cargill, T.F. (1971): "Early Applications of Spectral Methods to Economic Time Series," paper presented at Western Economic Assn. Meeting, Vancouver, British Columbia.

Chernoff, H. and N. Divinsky (1953): "The Computation of Maximum-Likelihood Estimates of Linear Structural Equations," in Studies in Econometric Method, ed. W.C. Hood and T.C. Koopmans, New York, John Wiley & Sons, pp. 236-269.

Chetty, V.K. (1968): "Pooling of Time Series and Cross Section Data," Econometrica, 36:279-290.

Chipman, J.S. and M.M. Rao (1964): "The Treatment of Linear Restrictions in Regression Analysis," Econometrica, 32:198-209.

Cobb, C.W. and P.H. Douglas (1928): "A Theory of Production," Am. Econ. Rev., 18(Proceedings Supplement): 139-165.

Cochrane, D. and G.H. Orcutt (1949): "Application of Least Squares Regression to Relationships Containing Auto-Correlated Error Terms," J. Am. Stat. Assn., 44:32-61.

Cochrane, W.W. (1955): "Conceptualizing the Supply Relation in Agriculture," J. Farm. Econ., 37(Proceedings):1161-1176.

Cooper, G. (1948): "The Role of Econometric Models in Econometric Research," J. Farm Econ., 30:101-116.

Cooper, J.R. and C.R. Nelson (1971): "The Exante Prediction Performance of the St. Louis and FRB-MIT-Penn Econometric Models," unpublished paper, University of Chicago.

Cragg, J.G. (1968): "Some Effects of Incorrect Specification on the Small-sample Properties of Several Simultaneous-equation Estimators," Intl. Econ. Rev.,9:63-86.

Cragg, J.G. (1967): "On the Relative Small-sample Properties of Several Structural-equation Estimators," Econometrica, 35:89-110.

Cragg, J.G. (1966): "On the Sensitivity of Simultaneous-Equations Estimators to the Stochastic Assumptions of the Models," J. Am. Stat. Assn., 61:136-151.

Cromarty, W.A. (1959a): "An Econometric Model for United States Agriculture," J. Am. Stat. Assn., 54:556-574.

Cromarty, W.A. (1959b): "The Farm Demand for Tractors, Machinery and Trucks," J. Farm Econ., 41:323-331.

Cromarty, W.A. (1962): Prediciting the Impact of Alternative Government Programs on the Wheat and Feed-Livestock Economies, Michigan State University Agricultural Experiment Station Technical Bulletin 286.

Dantzig, G.B. (1951a): "Maximization of a Linear Function of Variables Subject to Linear Inequalities," in Activity Analysis of Production and Allocation, ed. T.C. Koopmans, New York, John Wiley & Sons, pp. 339-347.

Dantzig, G.B. (1951b): "The Programming of Interdependent Activities: Mathematical Model," in Activity Analysis of Production and Allocation, ed. T.C. Koopmans, New York, John Wiley & Sons, pp. 19-32.

De Janvry, J. Bieri, and A. Nañez (1972): "Estimators of Demand Parameters under Consumer Budgeting," Am. J. of Agric. Econ., 54:422-430.

De Leeuw, F. and E.M. Gramlich (1968): "The Federal Reserve-MIT Econometric Model," Federal Reserve Bulletin, pp. 11-40.

Dean, J. (1936): "Statistical Determination of Costs with Special Reference to Marginal Costs," Studies in Bus. Adm., Volume 7.

Dhrymes, P.J. (1971): Distributed Lags: Problems of Estimation and Formulation, San Francisco, Holden-Day.

Dhrymes, P.J. (1970): Econometrics, New York, Harper & Row, pp. 272-277.

Dhrymes, P.J. (1965): "Some Extensions and Tests for the CES Class of Production Functions," Rev. of Econ. and Stat., 47:357-366.

Dhrymes, P.J., E. Howrey, S. Hymans, J. Kmenta, E. Leamer, R. Quandt, J. Ramsey, H. Shapiro, and V. Zarnowitz (1972): "Criteria for Evaluation of Econometric Models," Annals of Econ. and Social Measurement, 1:291-324.

Dreze, J. (1972): "Econometrics and Decision Theory," Econometrics, 40:1-18.

Dreze, J. (1962): The Bayesian Approach to Simultaneous Equations Estimation, Northwestern University Technological Institute Research Memorandum No. 67.

Duesenberry, J.S., G. Fromm, L.R. Klein and E. Kuh (1965): The Brookings Quarterly Econometric Model of the United States, Chicago, Rand McNally & Co.

Durbin, J. (1970a): "An Alternative to the Bounds Test for Testing for Serial Correlation in Least Squares Regression," Econometrica, 38:422-429.

Durbin, J. (1954): "Errors in Variables," Rev. of Intl. Stat. Institute, 22:23-32.

Durbin, J. (1953): "A Note on Regression When There is Extraneous Information About One of the Coefficients," J. Am. Stat. Assn., 48:799-808.

Durbin, J. (1970b): "Testing for Serial Correlation in Least-Squares Regression When Some of the Regressors are Lagged Dependent Variables," Econometrica, 38:410-421.

Durbin, J. and G.S. Watson (1950): "Testing for Serial Correlation in Least Squares Regression, I," Biometrika, 37:409-428.

Durbin, J. and G.S. Watson (1951): "Testing for Serial Correlation in Least Squares Regression, II," Biometrika, 38:159-178.

Eisner, R. (1958): "The Permanent Income Hypothesis: Comment," Am. Econ. Rev., 48:972-990.

Eisner, R. and R.H. Strotz (1963): "Determinants of Business Investment," in Impacts of Monetary Policy, Englewood Cliffs, New Jersey, Prentice-Hall.

Evans, M.K. and L.R. Klein (1967): The Wharton Econometric Forecasting Model, Philadelphia University of Pennsylvania Press.

Farrar, D.E. and R.R. Glauber (1967): "Multicollinearity in Regression Analysis: The Problem Re-visited," Rev. of Econ. and Stat., 49:92-107.

Feldstein, M. (1973): "Errors in the Variables: A Consistent Estimator with Smaller MSE in Finite Samples," Harvard Institute of Economics Research Paper 275.

Ferguson, C.E. and R.W. Pfouts (1962): "Aggregate Production Functions and Relative Factor Shares," Intl. Econ. Rev., 3:328-337.

Fisher, J. (1962): "An Analysis of Consumer Goods Expenditures," Rev. of Econ. and Stat., 44:64-71.

Fisher, R.A. (1935): Design of Experiments, Oliver and Boyd, London.

Fisher, W.D. (1962): "Estimation in Linear Decision Models," Intl. Econ. Rev., 3:1-29.

Fishman, G.S. (1969): Spectral Methods in Econometrics, Cambridge, Harvard University Press.

Foote, R.J. (1958): Analytical Tools for Studying Demand and Price Structures, USDA Agr Handbook 146.

Foote, R.J. (1955a): "A Comparison of Single and Simultaneous Equation Techniques," J. Farm Econ., 37(Proceedings):975-990.

Foote, R.J. (1953a): "A Four-Equation Model of the Feed-Livestock Economy and Its Endogenous Mechanisms," J. Farm Econ., [illegible]:44-6[illegible].

Foote, R.J. (1953b): Statistical Analyses Relating to the Feed-Livestock Economy, USDA Technical Bulletin No. 1070.

Foote, R.J. (1955b): "Surveys of Econometric Results in Agriculture--Demand and Price," J. Farm Econ., 37:197-205.

Foote, R.J., J.W. Klein and M. Clough (1952): The Demand and Price Structure for Corn and Total Feed Concentrates, USDA Technical Bulletin No. 1061.

Fox, K.A. (1953): The Analysis of Demand for Farm Products, USDA Tech. Bulletin No. 1081.

Fox, K.A. (1951): "Relations Between Prices, Consumption, and Production," J. Am. Stat. Assn., 46:323-333.

Franzmann, J.R. and G.G. Judge (1957): "Estimation of Response Relationships for Eggs," J. Farm Econ., 39:927-935.

French, B.L. (1950): "The Statistical Determination of the Demand for Meat," unpublished M.S. thesis, Iowa State College.

Friedman, J. and R.J. Foote (1955): Computational Methods for Handling Systems of Simultaneous Equations, USDA Agr. Handbook 94.

Friedman, M. (1957): A Theory of the Consumption Function, Princeton, Princeton Univ. Press.

Frisch, R. (1934): Statistical Confluence Analyses by Means of Complete Regression Systems, Oslo, Universitats Økononiske Institutet.

Frisch, R. (1959): "A Complete Scheme for Computing All Direct and Indirect Cross Demand Elasticities in a Model with Many Sectors," Econometrica, 27:177-196.

Fromm, G. and P.T. Taubman (1968): Policy Simulations with an Econometric Model, Washington, The Brookings Institution.

Fuller, W.A. (1972): "Some Properties of Estimators for the Errors in Variables Model," unpublished paper, Iowa State University.

Fuller, W.A. and J.E. Martin (1961): "The Effects of Autocorrelated Errors on the Statistical Estimation of Distributed Lag Models," J. Farm Econ., 43:71-82.

Gaver, K.M. and M.S. Geisel (1973): "Discriminating Among Alternative Models: Bayesian and Non-Bayesian Methods," to appear in Frontiers of Econometrics, ed. Paul Zorembka, Academic Press.

Geisel M.S. (1970): "Comparing and Choosing Among Parametric Statistical Models: A Bayesian Analysis with Macroeconomic Applications," unpublished doctoral dissertation, University of Chicago.

Gerra, M.J. (1959): The Demand, Supply, and Price Structure for Eggs, USDA Agr. Handbook 1204.

Gerra, M.J. (1959): "An Econometric Model of the Egg Industry," J. Farm Econ., 41:284-301.

Girschick, M.A. (1963): "Principal Components," J. Am. Stat. Assn., 31:519-36.

Girschick, M.A. and T. Haavelmo (1947): "Statistical Analysis of the Demand for Food: Examples of Simultaneous Estimation of Structural Equations,"Econometrica, 15:79-110.

Glejser, H. (1969): "A New Test for Heteroscedasticity," J. Am. Stat. Assn., 64:316-323.

Godwin, M.R. (1952): Consumer Response to Varying Prices for Florida Oranges, Florida Experimental Station Bulletin 508.

Goldberger, A.S. (1971): "Econometrics and Psychometrics. A Survey of Communalities," Psychometrica, 36:83-107.

Goldberger, A.S. (1964): Econometric Theory, New York, John Wiley & Sons.

Goldberger, A.S. (1959): Impact Multipliers and Dynamic Properties of the Klein-Goldberger Model, Amsterdam, North-Holland.

Goldberger, A.S. (1972): "Maximum Likelihood Estimation of Regression Containing Unobservable Variables," Intl. Econ. Rev., 13:1-15.

Goldberger, A.S. and T. Gameletsos (1970): "A Cross-Country Comparison of Consumer Expenditure Patterns," European Econ. Rev., 1:357-400.

Goldfeld, S.M. and R.E. Quandt (1965): "Some Tests for Homoscedasticity," J. Am. Stat. Assn., 60:539-547.

Goodman, L.A. (1965): "On the Statistical Analysis of Mobility Tables," Am. J. of Sociology, 70:564-585.

Gorman, W.M. (1959): "Separable Utility and Aggregation," Econometrica, 27:469-481.

Granger, C.W.J. and M. Hatanaka (1964): Spectral Analysis of Economic Time Series, Princeton, Princeton University Press.

Graybill, F.A. (1961): An Introduction to Linear Statistical Models, New York, McGraw-Hill.

Griffiths, W.E. (1970): "Estimation of Regression Coefficients which Change Over Time," unpublished Ph.D. thesis, University of Illinois at Urbana-Champaign.

Griliches, Z. (1968): "The Brookings Model Volume: A Review Article," Rev. of Econ. and Stat., 50:215-234.

Griliches, Z. (1967): "Distributed Lags: A Survey," Econometrica, 35:16-49.

Griliches, Z. (1957): "Specification Bias in Estimates of Production Functions," J. Farm Economics, 39:8-20.

Grunfeld, Y. and Z. Griliches (1960): "Is Aggregation Necessarily Bad?," Rev. of Econ. and Stat., 42:1-13.

Haavelmo, T. (1947): "Methods of Measuring the Marginal Propensity to Consume," J. Amer. Stat. Assn., 42:105-122.

Haavelmo, T. (1944): "The Probability Approach in Econometrics," Econometrica, 12(Supplement): 118 pp.

Haavelmo, T. (1943): "The Statistical Implications of a System of Simultaneous Equations," Econometrica, 11:1-12.

Hall, R.E. (1971): "A Survey of Recent Work on the Estimation of Distributed Lags," paper prepared for NBER-NSF Seminar on time series and distributed lags.

Hallberg, M.C. (1972): "Macroeconometric Models: A Survey of Applications," unpublished paper, Pennsylvania State University.

Hallberg, M.C. (1969): "Projecting the Size Distribution of Agricultural Firms, Am. J. of Agric. Econ., 51:289-302.

Hannan, E.J. (1967): Time Series Analysis, London, Methuen & Co., Ltd.

Harlow, A.A. (1960): "The Hog Cycle and the Cobweb Theorem," J. Farm Econ., 42:842-853.

Hauser, R.M. and A.S. Goldberger (1971): "The Treatment of Unobservable Variables in Path Analysis," Sociological Methodology, ed. H.L. Costner, San Francisco, Jassey-Boss.

Heady, E.O. and C.B. Baker (1954): "Resource Adjustments to Equate Productivities in Agriculture," The Southern Economic Journal, 21:36-52.

Heady, E.O., C.B. Baker, H.G. Diesslin, E. Kehrberg, S. Staniforth(eds.) (1961): Agricultural Supply Functions--Estimating Techniques and Interpretation, Ames, Iowa State Univ. Press.

Heady, E.O. and J.L. Dillon (1961): Agricultural Production Functions, Ames, Iowa State University Press.

Hill, B.M. (1972): "On Coherence, Inadmissibility, and Inference about Many Parameters in the Theory of Least Squares," Technical Report No.25, University of Michigan.

Hildreth, C. and J.P. Houck (1968): "Some Estimators for a Linear Model with Random Coefficients," J. Am. Stat. Assn., 63:584-595.

Hildreth,C. and F.G. Jarrett (1955): A Statistical Study of Livestock Production and Marketing, New York, John Wiley & Sons.

Hildreth,C. and J.Y. Liu (1960): Demand Relations with Autocorrelated Disturbances, Michigan State University Agr. Exp. Stat. Technical Bulletin No. 276.

Hoch, I. (1958): "Simultaneous Equation Bias in the Context of the Cobb-Douglas Production Function," Econometrica, 26:566-578.

Hood, W.C. and T.C. Koopmans (1953): Studies in Econometric Method, N.York, John Wiley & Sons.

Hotelling, H. (1933): "Analysis of Complex Statistical Variables into Principal Components," J. Educational Psychology, 24:417-29.

Hotelling, H. (1936): "Relations between Two Sets of Variables, Biometrika, 28:321-35.

Houthakker, H.S. (1958): "The Permanent Income Hypothesis," Am. Econ. Rev., 48:396-404 and 48:991-993.

Howrey, E. (1971): "Stochastic Properties of the Klein-Goldberger Model," Econometrica, 39:73-87.

James, W. and C. Stein (1961): "Estimation with Quadratic Loss," Proceedings of Fourth Berkeley Symposium on Mathematical Statistic Problems, Berkeley, Univ. of Calif. Press.

Jeffreys, H. (1961): Theory of Probability, 3rd Ed., Oxford University, Clarendon Press.

Johnson, D.G. (1948): "The Use of Econometric Models in the Study of Agricultural Policy," J. Farm Econ., 30:117-130.

Johnston, J. (1963, 1971): Econometric Methods, New York, McGraw-Hill.

Jorgenson, D.W. (1971): "Econometric Studies of Investment Behavior: A Review," Harvard Institute of Economic Research Discussion Paper 204.

Jorgenson, D.W. (1966): "Rational Distributed Lag Functions," Econometrica, 34:135-149.

Judge, G.G. (1949): "Determinants of the Extent and Type of Cattle Feeding in Iowa," unpublished M.S. Thesis, Iowa State University.

Judge, G.G. (1954): Econometric Analysis of the Demand and Supply Relationships for Eggs, Storrs Agricultural Experiment Station Bulletin 307.

Judge, G.G. and E.R. Swanson (1962): "Markov Chains: Basic Concepts and Suggested Uses in Agricultural Economics," Australian J. of Agr. Econ., 6:49-61.

Judge, G.G. and T. Takayama (1966): "Inequality Restrictions in Regression Analysis," J. Am. Stat. Assoc., 61:166-181.

Judge, G.G. and T.A. Yancey (1969): "The Use of Prior Information in Estimating the Parameters of Economic Relationships," Metroeconomica, 21:97-140.

Judge, G.G., T.A. Yancey, and M.E. Bock (1973): "Properties of Estimators after Preliminary Test of Significance when Stochastic Restrictions are used in Regression," J. of Econometrics, 1:29-47.

Kabe, D.G. (1964): "On the Exact Distribution of the GCL Estimators in a Leading Three Equation Case," J. Am. Stat. Assn., 59:881-894.

Kadiyala, K.R. (1968): "A Transformation Used to Circumvent the Problem of Autocorrelation," Econometrica, 36:93-96.

Kalman, R.E. (1960): "A New Approach to Linear Filtering and Prediction Problems," J. of Basic Engineering, 82:34-45.

Kennedy, W.J. and T.A. Bancroft (1971): "Model Building for Prediction in Regression Based Upon Repeated Significance Tests," Annals of Math. Stat., 42:1273-1284,

King, G.A. (1958): The Demand and Price Structure for Byproduct Feeds, USDA Tech. Bulletin No. 1183.

Klein, L.R. (1950): Economic Fluctuations in the United States, New York, John Wiley & Sons.

Klein, L.R. (1953): A Textbook of Econometrics, Evanston, Illinois, Row, Peterson & Company.

Klein, L.R. (1971): "Whither Econometrics?," J. Am. Stat. Assn., 66:415-421.

Kmenta, J. (1967): "On Estimation of the CES Production Function," Intl. Econ. Rev., 8:180-189.

Koerts, J. (1967): "Some Further Notes on Disturbance Estimates in Regression Analysis," J. Am. Stat. Assn., 62:169-186.

Koopmans, T.C. (1937): Linear Regression Analysis in Economic Time Series, Haarlem, Haarlem Press.

Koopmans, T.C., ed. (1950): Statistical Inference in Dynamic Economic Models, New York, John Wiley & Sons.

Koopmans, T.C. (1949): "Identification Problems in Economic Model Construction," Econometrica, 17:125-144.

Koyck, L.M. (1954): Distributed Lags and Investment Analysis, Amsterdam, North-Holland.

Kuznets, G. (1955): "Survey of Econometric Results in Agriculture: Discussion," J. Farm Econ., 37:235-236.

Kuznets, S. (1935): "Relations Between Capital Goods and Finished Products in the Business Cycle," in Essays in Honor of Wesley Clair Mitchell, New York, Columbia Univ. Press, pp. 211-267.

Ladd, G.W. (1967): An Analysis of Ranking Dairy Bargaining Cooperative Objectives, Iowa State Experiment Station Bulletin 550.

Ladd, G.W. (1957): "Effects of Shocks and Errors in Estimation," J. Farm. Econ., 38:485-495.

Ladd, G.W. (1966): "Linear Probability Functions and Discriminant Functions," Econometrica, 34:873-85.

Ladd, J.W. and J. Tedford (1959): "A Generalization of the Working Method for Estimating Long-Run Elasticities," J. Farm Econ., 40:221-33.

Lancaster, T. (1968): "Grouping Estimators on Heteroscedastic Data," J. Am. Stat. Assn., 63:182-191.

Leamer, E.E. (1970): "Distributed Lag Analysis with Informative Prior Distributions," Harvard Institute of Economic Research, Discussion Paper No. 147.

Lee, T.C., G.G. Judge, and A. Zellner (1970): Estimating the Parameters of the Markov Probability Model from Aggregate Time Series Data, Amsterdam, North-Holland.

Lee, T.C. and S.K. Seaver (1971): "A Simultaneous-Equation Model of Spatial Equilibrium," Am. J. Ag. Econ., 53:63-70.

Leontief, W.W. (1937): "Interrelations of Prices, Outputs, Savings and Investment," Rev. of Econ. and Stat., 19:109-44.

Leser, C.E.V. (1968): "A Survey of Econometrics," J. of Royal Stat. Soc., Series A, pp. 530-566.

Lindley, D.V. (1968): "The Choice of Variables in Multiple Regression," J.of Royal Stat. Soc., Volume 30, pp. 31-66.

Madansky, A. (1964): "On the Efficiency of Three-Stage Least-Squares Estimation, Econometrica, 32:51-56.

Madansky, A. (1959): "The Fitting of Straight Lines when Both Variables are Subject to Error," J. of Am. Stat. Assn., 54:173-205.

Maddala, G.S. (1971): "The Use of Variance Components Models in Pooling Cross Section and Time Series Data," Econometrica, 39:341-358.

Malinvaud, E. (1970): Statistical Methods in Econometrics, Amsterdam, North-Holland.

Mann, H.B. and A. Wald (1943). "On the Statistical Treatment of Linear Stochastic Difference Equations," Econometrica, 11:173-220.

Mariano, R.S. (1973): "Approximations to the Distribution Function of the Two Stage Least Squares Estimator," Econometrica, forthcoming.

Mariano, R.S. (1972): "The Existence of Moments of the Ordinary Least Squares and Two Stage Least Squares Estimator," Econometrica, 40:643-53.

Mariano, R.S. and T. Sawa (1972): "The Exact Finite Sample Distribution of the Limited Information Maximum Likelihood Estimators," J. Am. Stat. Assn., 67:59-63.

Marschak, J. (1953): "Economic Measurements for Policy and Prediction," in Studies in Econometric Method, ed. W.C. Hood and T.C. Koopmans, New York, John Wiley & Sons, pp. 1-26.

Marschak, J. (1947): "Economic Structure, Path, Policy, and Prediction," Am. Econ. Rev., 37 (Proceedings Supplement):81-84.

Marschak, J. and W.H. Andrews (1944): "Random Simultaneous Equations and the Theory of Production," Econometrica, 12:143-205.

Masey, W.F., R.E. Frank, and T. Lodahl, (1968): Purchasing Behavior and Personal Attributes, Philadelphia, University of Pennsylvania Press.

Meinken, K.W. (1953): The Demand and Price Structure for Oats, Barley, and Sorghum Grains, USDA Techn. Bul. No. 1080.

Meinken, K.W. (1955): The Demand and Price Structure for Wheat, USDA Techn. Bul. No. 1136.

Meyer, J. and E. Kuh (1957): The Investment Decision, Cambridge, Harvard Univ. Press, pp. 6-35.

Miller, G.A. (1952): "Finite Markov Processes in Psychology," Psychometrika, 17:149-167.

Moran, P.A.P. (1971): "Estimating Structural and Functional Relations," J. of Multivariate Analysis, 1:232-55.

Moore, H.L. (1914): Economic Cycles: Their Law and Cause,

Mundlak, Y. (1961): "Empirical Production Function Free of Management Bias," J. Farm. Econ. 43:45-56.

Nagar, A.L. (1962): "Double k-Class Estimators of Parameters in Simultaneous Equations and Their Small Sample Properties," Intl. Econ. Rev., 3:168-188.

Neiswanger, W.A. and T.A. Yancey (1959): "Parameter Estimates and Autonomous Growth," J. Am. Stat. Assn., 54:389-402.

Nerlove, M. (1958a): The Dynamics of Supply: Estimation of Farmers' Response to Price, Baltimore, The John Hopkins Press

Nerlove, M. (1958b): Distributed Lags and Demand Analysis for Agricultural and Other Commodities, USDA Agr. Handbook No. 141.

Nerlove, M. (1958c): "Distributed Lags and Estimation of Long-Run Supply and Demand Elasticities: Theoretical Considerations," J. Farm Econ., 40:301-311.

Nerlove, M. (1971): "Further Evidence on the Estimation of Dynamic Economic Relations from a Time Series of Cross Sections," Econometrica, 39:359-382.

Nerlove, M. (1958d): "The Implications of Friedman's Permanent Income Hypothesis for Demand Analysis," Agr. Econ. Res., 10:1-14.

Nerlove, M. (1972): "Lags in Economic Behavior," Econometrica, 40:221-52.

Nerlove, M. (1964): "Spectral Analysis of Seasonal Adjustment Procedures, Econometrica, 32:241-286.

Nerlove, M. (1966): "A Tabular Survey of Macro-Econometric Models," Intl. Econ. Rev., 7:127-175.

Nerlove, M. and W. Addison (1958): "Statistical Estimation of Long-Run Elasticities of Supply and Demand," J. Farm Econ., 40:861-880.

Newman, P.K. and R.C. Read (1961): "Production Functions with Restricted Input Shares," Intl. Econ. Rev., 2:127-133.

Nordin, J.A., G.G. Judge, and O. Wahby (1954): Application of Econometric Procedures to the Demands for Agricultural Products, Iowa State College Research Bulletin 410.

Ogg, W.E. (1949): "A Study of Maladjustment of Resources in Southern Iowa," unpublished Ph.D. thesis, University of Chicago.

Orcutt, G.H., M. Greenberger, J. Korbel, and A.M. Rivlin (1961). Microanalysis of Socio-economic Systems: A Simulation Study, New York, Harper & Brothers.

Pearson, K. (1938): The Grammar of Science, Everyman Edition.

Phillips, A.W. (1954): "Stabilization Policy in a Closed Economy," Econ. J., 64:290-323.

Pontryagin, L.S., et.al.(1962): The Mathematical Theory of Optimal Processes, New York, . Interscience.

Powell, A. (1966): "A Complete System of Consumer Demand Equations for the Australian Economy Fitted by a Model of Additive Preferences," Econometrica, 34:661-675.

Prescott, E.C. (1967): "Adaptive Decision Rules for Macro Economic Planning," unpublished Ph.D. thesis, Carnegie-Mellon University.

Preston, L.E. and E.J. Bell (1961): "The Statistical Analysis of Industry Structure: An Application to Food Industries," J. Am. Stat. Assn., 56:925-932.

Raiffa, H.A. and R.S. Schlaifer (1961): Applied Statistical Decision Theory, Boston, Harvard University.

Rao, P. and Z. Griliches (1969): "Small-sample Properties of Several Two-stage Regression Methods in the Context of Auto-correlated Errors," J. Am. Stat. Assn., 64:253-272.

Rasche, R.H. and H.T. Shapiro (1968): "The FRB-MIT Econometric Model: Its Special Features," Am. Econ. Rev., 58(Papers and Proceedings):123-149.

Revankar, N.S. (1966): "The Constant and Variable Elasticity of Substitution Production Functions: A Comparative Study in United States Manufacturing Industries, Part I," paper presented at the Annual Meetings of the Econometric Society, Univ. of Wis. Social Sys. Res. Inst.

Richardson, D.H. (1968): "The Exact Distribution of a Structural Coefficient Estimator," J. Am. Stat. Assn., 63:1214-1226.

Rojko, A.S. (1953): "An Application of the Use of Economic Models to the Dairy Industry," J. Farm Econ., 35:83 -849.

Rojko, A.S. (1957a): The Demand and Price Structure for Dairy Products, USDA Techn. Bul. No. 1168.

Rojko, A.S. (1957b): "Econometric Models for the Dairy Industry," J.Farm Econ., 39:323-338.

Rothenberg, T.J. (1972): "The Bayesian Approach and Alternatives in Econometrics," in Frontiers of Quantitative Knowledge, ed. M.D. Intriligator, Amsterdam, North-Holland, pp. 194-210.

Rothenberg, T.J. and C.T. Leenders (1964): "Efficient Estimation of Simultaneous Equations Systems," Econometrica, 32:57-76.

Rutemiller, H.C. and D.A. Bowers (1968): "Estimation in a Heteroscedastic Regression Model," J. Am. Stat. Assn., 63:552-557.

Samuelson, P.A. (1948): Foundations of Economic Analysis, Cambridge, Harvard University Press.

Savage, L.J., et.al. (1954): The Foundations of Statistics, New York, John Wiley & Sons.

Sawa, T. (1969): "The Exact Sampling Distribution of Ordinary Least Squares and Two-Stage Least Squares Estimators," J. Am. Stat. Assn., 64:923-937.

Sawa, T. (1972): "Finite Sample Properties of the K-class Estimators, Econometrica, 40: 653-80.

Schipper, L. (1964): Consumer Discretion ry Behavior, A Comparative Study in Alternative Methods of Empirical Resear h, Amsterda , North-Holland Publishing Co.

Schultz, H. (1938): The Theory and Measurement of Demand, Chicago, Univ. of Chicago Press.

Sclove, S.L., C. Morris, and R. Radhakrishnan (1972): "Non Optimality of Preliminary-Test Estimators for the Multinormal Mean," Annals of Math. Stat.

Scott, J.T. (1966): "Factor Analysis and Regression," Econometrica, 34:552-62.

Shiller, R. (1970): The Use of Prior Distributions in Distributed Lag Estimation, Massachusetts Institute of Technology.

Shuffett, D.M. (1954): The Demand and Price Structure for Selected Vegetables, USDA Tech. Bul. No. 1105.

Silvey, S.D. (1969): "Multicollinearity and Imprecise Estimation," J. Royal Stat. Soc., Series B, 31:539-552.

Smith, R. and T. Hall:(1972): "A Comparison of Maximum Likelihood Versus Blue Estimates," Rev. of Econ. and Stat., 54:186-190.

Solow, R.M. (1957): "Technical Change and the Aggregate Production Function," Rev. of Econ. and Stat., 39:312-320.

Stein, C. (1956): "Inadmissibility of the Usual Estimator for the Mean of a Multivariate Normal Distribution," Third Berkeley Symposium on Math. Stat. and Probability, Vol. I, Berkeley, University of California Press.

Steindl, J. (1965): Random Processes and the Growth of Firms, New York, Hafner Pub. Co.

Stone, J.R.N. (1954): "Linear Expenditure Systems and Demand Analysis," Econ.J., 64:511-27.

Stone, J.R.N. and M.W. Stone (1938-39): "The Marginal Propensity to Consume: A Statistical Investigation," Rev. of Econ. Studies, 6:1-24.

Strawderman, W.E. (1971): "Proper Bayes Minimax Estimators of the Multivariate Normal Mean," Annals of Math. Stat., 42:385-388.

Strotz, R.H. (1959): "The Utility Tree- A Correction and Further Appraisal," Econometrica, 27:482-488.

Summers, R. (1965): "A Capital Intensive Approach to the Small-Sample Properties of Various Simultaneous Equation Estimators," Econometrica, 33:1-41.

Swamy, P.A.V.B. (1971): "Statistical Inference in Random Coefficient Regression Models," Lecture Notes in Operations Research and Mathematical Systems, Springer-Verlag, Heidelberg, Volume 55.

Swanson, E.R. (1956): "Determining Optimum Size of Business from Production Functions," in Research Productivity, Returns to Scale and Farm Size, ed. E.O. Heady, et.al., Amers, Iowa State College Press.

Telser, L.G. (1963): "Least Squares Estimates of Transition Probabilities," in Measurement of Economics, Stanford, Stanford University Press.

Theil, H. (1958): Economic Forecasts and Policy, Amsterdam, North-Holland Publishing Co.

Theil, H. (1967): Economics and Information Theory, Amsterdam, North-Holland Publishing Co.

Theil, H. (1971): Principles of Econometrics, New York, John Wiley & Sons.

Theil, H. (1954): Linear Aggregation of Economic Relations, Amsterdam, North-Holland.

Theil, H. (1965): "The Analysis of Disturbances in Regression Analysis," J. Am. Stat. Assn., 60:1067-1079.

Theil, H. (1968): "A Simplification of the BLUS Procedure for Analyzing Regression Disturbances," J. Am. Stat. Assn., 63:242-251.

Theil, H. (1957): "Specification Errors and the Estimation of Economic Relationships," The Rev. of the Intl. Stat. Instit., 25:41-51

Theil, H. (1963): "On the Use of Incomplete Prior Information in Regression Analysis," J. Am. Stat. Assn., 58:401-414.

Theil, H. and A.S. Goldberger (1961): "On Pure and Mixed Statistical Estimation in Economics," Intl. Econ. Rev., 2:65-78.

Thornber, E.H. (1966): "Applications of Decision Theory of Econometrics," unpublished doctoral dissertation, University of Chicago.

Thornber, E.H. (1967): "Finite Sample Monte Carlo Studies: An Autoregressive Illustration," J. Am. Stat. Assn., 62:801-818.

Tinbergen, J. (1938): "Statistical Evidence on the Accelerator Principle," Economica, 164-176.

Tintner, G. (1952): Econometrics, New York, John Wiley & Sons.

Tintner, G. (1940): The Variance Difference Method, Bloomington, Bloomington Press.

Tintner, G. (1966): "Some Thoughts About the State of Econometrics," in The Structure of Economic Science: Essays on Methodology, ed. Sherman Roy Krupp, Englewood Cliffs, New Jersey, Prentice-Hall, Inc.

Tobin, J. (1950): "A Statistical Demand Function for Food in the U.S.A.," J. Roy. Stat. Soc., Series A (General) 113:Part II:113-141.

Toro-Vizcarrondo, C. and T.D. Wallace (1968): "A Test of the Mean Square Error Criterion for Restrictions in Linear Regression," J. Am. Stat. Assn., 63:558-572.

Tsang, H. (1971): "A Generalized Neoclassical Production Function," unpublished Ph.D. thesis, University of Illinois.

Vining, R. and T.C. Koopmans (1949): "Methodological Issues in Quantitative Economics," Rev. of Econ. and Stat., 32:77-94

Von Neumann, J. and O. Morgenstern (1947): Theory of Games and Economic Behavior, Second edition, Princeton, Princeton University Press.

Wagner, H. (1958): "A Monte Carlo Study of Estimates of Simultaneous Linear Structural Equations," Econometrica, 26:117-133.

Wald, A. (1950): Statistical Decision Functions, New York, John Wiley & Sons.

Wallace, T.D. (1972): "Weaker Criteria for Tests for LInear Restrictions in Regression," Econometrica, 40:689-98.

Wallace, T.D. and A. Hussain (1969): "The Use of Error Components Models in Combining Cross Section with time series Data," Econometrica, 37:55-72.

Walters, A.A. (1970): An Introduction to Econometrics, New York, W.W. Norton & Company.

Waugh, F.V. (1961): "The Place of Least Squares in Econometrics,"Econometrica, 29:386-396.

Wilks, S.S. (1947): Mathematical Statistics, Princeton, Princeton University Press.

Wold, H.O. (1956): "Causal Inference from Observational Data, A Review of Ends and Means," J. Roy. Stat. Soc., Series A(General) 119:Part I:28-61.

Wold, H.O. (1969): "Econometrics as Pioneering in Nonexperimental Model Building," Econometrica, 37:369-381.

Working, E.J. (1954): The Demand for Meat, Chicago, The Institute of Meat Packing.

Working, E.J. (1926): "What Do Statistical 'Demand Curves' Show?" Quart. J. Econ. 41:212-235.

Wright, S. (1934): "The Method of Path Coefficients," Annals of Math Stat., 5:161-215.

Yancey, T.A., G.G. Judge, M.E. Bock (1970): "A Mean Square Error Test when Stochastic Restrictions are Used in Regression," Quantitative Economics Workshop Paper 7001, University of Illinois.

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

Zellner, A. (1967): Aggregation: A New Approach to an Old Problem, University of Chicago Center Workshop Paper.

Zellner, A. (1970): "The Care and Feeding of Econometric Models," Paper prepared for 17th Annual Midwest Conference on Statistics for Decision, University of Chicago Graduate School of Business, Selected Paper No. 35, February 19.

Zellner, A. (1962): "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias," J. Am. Stat. Assoc., 57:348-368.

Zellner, A. (1962): On the Questionable Virtue of Aggregation, Soc. Systems. Res. Instit. Workshop Paper 6202, February 12.

Zellner, A. (1963): "Decision Rules for Economic Forecasting," Econometrica, 31:111-30.

Zellner, A. (1972): "The Bayesian Approach and Alternatives in Econometrics in Frontiers of Quantitative Knowledge, ed. M.D. Intriligator, Amsterdam, North-Holland, pp. 178-193.

Zellner, A. (1970): "Estimation of Regression Relationships Containing Unobservable Variables," Intl. Econ. Rev., 11:441-54.

Zellner, A. and S. Fienberg (1974): Volume on Bayesian Inference in Honor of L.J. Savage, Amsterdam, North-Holland Publishing Co.

Zellner, A. and M.S. Geisel (1968): "Sensitivity of Control to Uncertainty and Form of the Criterion Function," in The Future of Statistics, ed. D.G. Watts, New York, Academic.

Zellner, A. and F. Palm (1973): "Time Series Analysis and Simultaneous Equation Models," H.G.B. Alexander Foundation Paper, University of Chicago.

Zellner, A. and N.S. Revankar (1969). "Generalized Production Functions," Rev. Econ. Studies, 36:241-250.

Zellner, A. and H. Theil (1962): "Three-stage Least Squares: Simultaneous Estimation of Simultaneous Equations," Econometrica, 30:5[illegible]-78.

Zellner, A. and W. Vandaele (1972): "Bayes-Stein Estimators for k Means, Regression and Simultaneous Equation Models," unpublished paper, University of Chicago.