

**COWLES COMMISSION  
FOR RESEARCH IN ECONOMICS**

**REPORT FOR PERIOD  
JULY 1, 1949 - JUNE 30, 1950**

**THE UNIVERSITY OF CHICAGO**

The COWLES COMMISSION FOR RESEARCH IN ECONOMICS is a not-for-profit corporation founded in 1932 for the purpose of conducting and encouraging investigations into economic problems. The results of research by members of the COMMISSION's staff are published in two series: COWLES COMMISSION MONOGRAPHS in book form, and shorter papers, usually reprints of articles from journals, as COWLES COMMISSION PAPERS, NEW SERIES. The research activities of the COMMISSION are integrated with other research and teaching activities of the University of Chicago through an Executive Committee which includes the Dean of the Division of the Social Sciences and the Chairman of the Department of Economics. The COMMISSION is affiliated with the ECONOMETRIC SOCIETY, an international society for the advancement of economic theory in its relation to statistics and mathematics.

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## THE REPORT IN BRIEF\*

The research of the Cowles Commission is devoted to the application of mathematics and mathematical statistics toward the solution of economic problems, a field of research which has become known under the name "econometrics." In particular, the efforts of the Commission over a period of years have been and continue to be directed toward a better understanding of business cycles, of fluctuations in employment and prices, of the conditions for sustained economic prosperity. The approach of the Commission is to construct and assemble pieces of analysis that are building blocks for such an understanding. These building blocks are studies of the economic behavior of consumers, of investors, of dealers, etc., and studies of the methods necessary to make such studies. Members of the research staff of the Commission participated in and contributed their work to a conference on business cycles research held in November, 1949, sponsored by the National Bureau of Economic Research through the Universities-National Bureau Committee.

In addition, increasingly in recent years, the Commission has approached the study of economic behavior from the point of view of best utilization of resources. Here the question is not "how do consumers, investors, dealers, governments actually behave?" but "what behavior rules or patterns would best serve the purposes of economic activity?" In regard to this type of investigation, the Commission's work has so far been directed particularly to theoretical problems of productive efficiency, in a plant, in an industry, in a government agency, or in the economy as a whole. Problems of organization and of decentralization of decision-making are now being taken up for analysis.

The Cowles Commission is particularly well equipped to cope with the manifold aspects of these problems. Its research activities require the cooperation of research workers with a variety of backgrounds and training: economists who specialize either in theory, the analysis of policies, or empirical work; statisticians; mathematicians; and (among research consultants) a political scientist and a physicist. This group numbered thirty individuals, working full- or part-time, during the period of this report. Teamwork is promoted by frequent staff meetings (thirty-five during the current year) at which the resident staff is joined by research workers from other institutions. Also participating in these discussions are advanced students

\*The remarks in the present section of this report are addressed to the general public. The following section, "Report on Research Activities," has been written for those interested in a more detailed account of the research activities of the Commission.

and research fellows from other American and foreign academic centers. The effectiveness of these research efforts is enhanced by an office staff of eleven which provides library, computational, editorial, and secretarial services.

The Commission conducts a seminar (meeting two or three times monthly) devoted to varying topics related to the measurement and analysis of social phenomena. It cooperates in research projects with the Agricultural Economics Research Unit and the National Opinion Research Center of the University of Chicago, the Bureau of Business Research of the University of Illinois, the Agricultural Economics Research Group at Iowa State College, and the Department of Farm Economics of the University of Kentucky. It also maintains contact with a research project at the University of Michigan sponsored jointly by the Survey Research Center and the National Bureau of Economic Research. In addition, members of the Commission have rendered consultative services to The RAND Corporation, a nonprofit research organization under contract with the United States Air Force.

The Commission is affiliated with the Econometric Society, an international society for the advancement of economic theory in its relation to statistics and mathematics, and assists in the publication of its journal, *Econometrica*. The Society experienced a considerable increase in membership during the period covered by this report and now has approximately 2,000 members and nonmember subscribers, chiefly libraries, representing 65 different countries. Meetings of the Econometric Society were held in Boulder, Colorado; New York, New York; and Colmar, France, in 1949, and meetings are currently scheduled for Tokyo, Japan; Berkeley, California; Cambridge, Massachusetts; Varese, Italy; Chicago, Illinois; and India, for 1950.

The research output of the Commission is made available through publication of books and through reprints of papers from various journals. Interested research workers and students have access to the work of the Commission through these means, as well as through invitations to staff meetings, attendance at the seminar, use of the library of the Cowles Commission, and through the courses offered in various universities by members of the staff.

The year covered by this report has been one of consolidation, following the almost twofold increase in scale of operations which took place in the preceding period. Major staffing and reorganization problems have been successfully met, and a publication program is going forward which will overcome the delays encountered earlier in making the research of the Commission available.

Monographs published in the summer of 1950 include a volume developing new statistical methods in the measurement of economic relationships, a

volume applying some of these methods to construct a model of the U. S. economy in the interwar period, and a volume studying the economic aspects of atomic energy. On the way to publication in the near future are a volume studying the logical problem of reducing diverse individual preferences to a common denominator of social choice, a volume devoted to the theory of efficient allocation of resources in production, and a volume reporting on new developments in statistical methods in econometrics in an expository style.

The Commission has continued to benefit from the support and recognition given by the University of Chicago and the Rockefeller Foundation to its general research program, and has carried further its study of the best allocation of resources under its subcontract with The RAND Corporation. The above arrangements have contributed much to the research productivity of the group. They only partially meet the need for the long-term support essential to the continuity of the Commission's research effort. The Commission must turn its attention in the years ahead to the seeking of such recognition of its potentialities over a long period and to reexamination of the proper balance of basic and applied research in its program.

#### REPORT ON RESEARCH ACTIVITIES

##### *The Study of Economic Behavior*

In the report for the period ending June 30, 1949, the area of research of the Commission was set out in relation to various aspects of economic behavior, described as actual behavior, rational behavior, and optimal behavior.

The study of *actual behavior*, that is, of actual decisions as to spending by consumers, as to investment in plant and equipment by business men, as to inventories by dealers and others, etc., leans most heavily on empirical information. This information may be obtained by economic soul-searching (introspection), or from interviews with individuals or executives, or from statistical data of a cross-section or time-series type. The purpose of this type of study is to formulate and measure mathematical relationships describing the typical behavior of various groups (consumers, investors, etc.) in a certain environment (period, country). Such study cannot rest solely on the empirical information it analyzes. The choice of the introspective or interviewing questions, as well as the choice of variables in the relationships fitted to data, depends on further hypotheses. These hypotheses may be derived from the analysis of rational behavior, or they may express nonrational types of behavior suggested by other observations.

The study of *rational behavior*, that is, behavior best calculated to serve the economic interest of the individual or firm, has two motivations. One is to supply hypotheses to be used, or tested against data, in the study of actual behavior, as mentioned above. The other is to provide a basis for advice to individuals or firms as to what decisions are in their economic interest. The second motivation gains in importance where the external conditions are more complicated and hence where the analytical difficulties of the decision problem are greater. In either case the study of rational behavior requires that one specify the individual's anticipations with respect to future external conditions, and the degree and type of uncertainty to which these anticipations are subject.

The study of *optimal behavior*, known also as welfare economics, is based on the choice of some economic purpose (goal) regarded as desirable for society, and deals deductively with that behavior of all individuals or other decision-making units which best serves the purpose adopted for study. An intermediate form of analysis, the study of government *economic policy*, takes individual behavior as actually observed, and asks what government policy will best serve a stated objective. Such analysis may therefore be regarded as the study of rational behavior by government toward a given purpose.

While the foregoing brief summary may serve as a frame of reference in arranging the discussion of research problems, the present report will place most emphasis on those problems and areas on which research effort has been concentrated during the year.

In the report we shall reverse the order of the topics of study, dealing first with work on optimal behavior, then with work on rational and actual behavior combined. This arrangement will bring out the role of deductive elements in the analysis, which is strongest in regard to the study of optimal behavior but is present even in the study of actual behavior, as has already been indicated. Three further sections, one on testing econometric models, one on the development of statistical methods, and one on mathematical tools, complete the report on research activities.

The various papers that have resulted from the research activities described below are listed at relevant places in the text. While many of these were prepared only for staff meetings and limited circulation in order to stimulate further discussion, others were published or presented publicly during this report period. An asterisk denotes those papers published or presented by staff members. The date and place of publication or presentation of such items will be found in the section "Staff Notes and Publications," which also includes discussion topics and papers mentioned in the previous report but published in 1949-50.



### *Best Use of Resources in a Given Technology*

Even though the study of optimal behavior is deductive in character (once the economic purpose has been formulated), it depends on empirical elements which underlie all study of economic decisions. These elements are the technological conditions that determine the alternatives between which choice is to be made.

Information concerning the technological possibilities of production comes to us in a vast mass of engineering literature and experience relating to specific processes and commodities. It is necessary to condense, formalize, and generalize this information before it can be used in a systematic analysis of best utilization of resources. To perform this condensation it is necessary to bring out what formal aspects are common to all productive processes and to provide for the description of individual processes by a limited number of numerical characteristics.

Following the conference on linear programming in June, 1949, described in our previous report, a good deal of work has been devoted to the further development and application of a simple theoretical model of technology. In this model each of a finite number of *activities* (processes) is characterized by the rates of input and output (technological coefficients) of each good or service involved in it when that activity is carried out at a unit level. The assumption of *divisibility* states that, if other levels of the same activity are chosen, the rates of input and output vary in proportion. The assumption of *additivity* states that the net outputs resulting from several activities at given levels are the sums of the rates of net output associated with the individual activities at those levels. Taken together, these assumptions imply what the economist calls constant returns to scale of production.

Clifford Hildreth and Stanley Reiter applied this model in a discussion of a rational production policy of the individual farmer under given price anticipations. Tjalling C. Koopmans and Reiter applied the same model to the problem of most efficient routing of transportation equipment and to the construction of freight rates conducive to an optimal geographical distribution of industry. Herbert A. Simon used the model for estimating the effects of a given technological change on the level of national real income from data available before the new process in question is introduced. This research topic originated in the project on economic aspects of atomic power, described on p. 19. George H. Borts studied the application of models of production to the railroad industry, considering separately the activities related to line-haul, switching, and maintenance and repair. Reiter explored the limitations of the additivity assumption and the need for combination of activities that involve commodities whose transfer in space or time is subject

to economic loss. This work throws light on the question of the optimal size of the firm and the optimal combination of functions in one firm. Hildreth, in a discussion of substitution possibilities in agricultural production, explored a continuous generalization of the model which retains the assumption of constant returns to scale.

Efficient use of resources in production can be defined as a situation where further increase in the output of any one good can be attained only at the cost of a decrease in the output of some other good. Mathematical criteria for efficiency in a linear model of technology were developed by Koopmans. These criteria bring out the role of prices as guides to efficient allocation, emphasized by many writers in welfare economics.

The following discussion papers or publications deal with productive efficiency in a given technology.

On the Choice of a Crop Rotation Plan:† *Hildreth and Reiter*

A Model of Transportation:† *Koopmans and Reiter*

Invention and Cost Reduction in Technological Change:† *Simon*

Production Relations in the Railroad Industry: *Borts*

A Note on Additivity in Linear Programming Models: *Reiter*

Combining Technical and Survey Data on Crop Production:\* *Hildreth*

Production as an Efficient Combination of Activities:† *Koopmans*

Efficient Allocation of Resources:\* *Koopmans*

The studies listed above are concerned with static models, or comparisons between static models, and thus leave out of account planned or anticipated changes in activity levels as well as possible uncertainty about the outcome of productive activities. The introduction of change and uncertainty in the technology gives further importance to a problem area that already exists without it. This area might be called the technology of decision making, as distinct from the principles or rules guiding the decisions. This technology involves the capacities and other limitations of communication channels in which information is transmitted regarding the outcome of productive activities and regarding decisions with respect to the levels of such activities. It further involves the capacities of absorbing and acting on such information at various decision-making centers. Problems involving such data are usually regarded as part of the study of administration. They have the same relationship to the study of economic decision making that technology has. In both cases the information in question relates to the physical and human environment in which and with regard to which economic decisions are made.

Discussions of dynamic allocation problems in terms of flows of informa-

\*Presented. For additional information see "Staff Notes and Publications."

†To be included in Monograph 13 (see p. 30).

tion between decision-making centers, and in terms of other administrative circumstances, were contributed by Leonid Hurwicz, Carl N. Klahr, Reiter, and Simon. Even if we assume identity of interests among decision-making centers, limitations on communication may reduce the efficiency of resource utilization and may set up unintended waves and fluctuations in the levels of activities. Further inefficiencies may arise from diversity of interests between centers of decision making. While study of such models of decision making is obviously related to business cycle theory, it is also relevant to the internal organization of a large enterprise or agency.

The Stochastic Element in Models of Production: *Hurwicz*  
Production Under Incomplete Information: *Hurwicz*  
Economic Controls Based on Technological Data and Information Theory: *Klahr*  
Administrative Aspects of Allocative Efficiency: *Simon*

All the studies referred to so far emphasize the efficiency of allocation of resources in production. Another aspect of efficiency is involved in the direction of productive effort toward those goods most wanted by consumers. Both aspects of the efficiency problem are considered in Gerard Debreu's work on the construction of a measure of allocative inefficiency. The intent of this study is to give a measurable expression to such concepts as the loss of welfare arising from taxes or monopolies and the gain in welfare due to technological change. The role of government economic policy in attaining allocative efficiency in production and distribution was discussed by Trygve Haavelmo.

The Economic Loss Associated with a Nonoptimal Situation: *Debreu*  
The Coefficient of Resource Utilization: *Debreu*  
Economic Equilibrium and Welfare: *Haavelmo*

### *Rational Behavior and Actual Behavior*

We are combining in our report the studies of rational and of actual behavior because of the strong support lent to the latter by the former. It must be admitted, however, that studies of rational and actual behavior embrace a very wide range of subjects, from the logic or psychology of planning by men facing an uncertain future to the testing of empirical forecasts of business cycles. If we confined ourselves to the theory of rational behavior, we would lose touch with reality; if we approached reality without theory, we would not be able to choose among the infinite number of explanations of economic fluctuations, all equally compatible with recorded statistical time series, but not all equally "making sense."

William C. Hood provided a critical appraisal of some recent literature on the economics of expectations, including in particular the ideas of G. L.

S. Shackle. Are expectations best described by assigning to each alternative possible event a numerical probability, as in life insurance and the games of chance? Or can we define and use, instead, some less rigid concepts such as "degrees of belief" or "psychological probabilities"? Herman Rubin studied the latter question by postulating behavior axioms under uncertainty and showing how degrees of belief associated with alternative possible events are implied in such behavior. Quite often, however, the individual knows only what alternative "states of nature" are possible but is not able to assign to each of them a "degree of belief." He might then (following L. J. Savage's suggestion) compare in advance the "regrets" that would result from each of the possible decisions when the true state of nature is revealed, and choose that decision which would lead to the smallest regret in the worst case—the "minimax" rule. On the other hand, Herman Chernoff showed that certain general criteria of rational behavior are not consistent with the minimax rule and that these criteria imply the truth of the classical rule that "fifty-fifty" odds be assigned to a pair of alternatives whose probabilities are unknown. These various approaches, or sets of postulates, agree in spirit with recent formal thinking on rational behavior in general and are applicable not only to economics but to other fields of human decision as well, such as games, political and military strategy, administrative decision, and the design of scientific experiments and statistical samples. The whole problem is of obvious practical importance to those who have the responsibility of taking what is loosely called "calculated risks," a vague concept which can and must be replaced by more clear-cut guides to action.

To achieve greater simplicity and realism in the analysis of decisions affecting a distant future, Koopmans suggested, as part of an alternative set of postulates of rational behavior, the preferability of postponement of choice. Another simplification is gained if, on the basis of certain plausible postulates about human preferences, it becomes reasonable for an individual to assign measurable weights ("utilities," "payoffs") to the possible outcomes of alternative actions. Jacob Marschak used this simplification (also advocated by J. von Neumann and O. Morgenstern, and by M. Friedman and L. J. Savage, and going back to Alfred Marshall and, indeed, to Daniel Bernoulli) in studying the rational behavior of a firm, especially the relative advantages of diversified or specialized production programs, and the effect of progressive profit taxation upon the choice between safe and risky investments. Harry Markowitz laid out a plan for empirically measuring the behavior of, for example, an institutional investor in securities who is continually revising his portfolio in such a way as to combine any given degree of estimated "riskiness" (properly defined) with the highest possible estimated long-run average profit. On a similar basis, Hurwicz analyzed the logic of "single-person single-period planning of production under incomplete infor-

mation," a preliminary step to his more complex model of the enterprise in an organization characterized by "multi-person multi-period planning" (see pp. 8-9 above).

Recent Literature on Expectations in Economics: *Hood*

Postulates for the Existence of Measurable Utility and Psychological Probability:\* *Rubin*

Rational Selection of a Decision Function:\* *Chernoff*

Utility Analysis of Decisions Affecting Future Well-Being:\* *Koopmans*

Rational Behavior, Uncertain Prospects, and Measurable Utility:\* *Marschak*

Towards a Theory of Financial Behavior: *Markowitz*

Measuring the Liquidity Preference of Banks: *A. J. Brown*, University of Leeds, England

Optimal Investment of a Firm:\* *Marschak*

Production Under Incomplete Information: *Hurwicz*

Our previous report mentioned the Project on Expectations and Business Fluctuations that is being directed at the University of Illinois by Franco Modigliani, a research consultant of the Cowles Commission. (See also p. 21 for our cooperation with this project.) In studying the motivation determining the investment in plant and equipment, he found it necessary to distinguish three types of reactions: (1) the formation of expectations on the basis of previous information; (2) the formulation of forward plans on the basis of expectations; (3) the taking of immediate action in carrying out a plan, possibly adjusting it to new information. With respect to the first problem (expectations), a body of data of both the cross-section and the time-series type is being analyzed. The main sources of cross-section data are surveys by *Fortune* magazine and by Dun and Bradstreet. Valuable time series are provided by quarterly forecasts of carload requirements based on anticipations submitted by a sizable number of firms. In addition, content analysis of the business press is used to clarify press influences on the expectations of the business community. With respect to the second and third problems (planning and action), Modigliani drew on the work of Avram Kisselgoff, of the National Bureau of Economic Research, who is analyzing investments in selected firms and industries in selected years, and Jean Bronfenbrenner, who is analyzing, in cooperation with the staff of the Department of Commerce, quarterly and annual survey data on investment plans and their realization.

While the credit for the work described in the preceding paragraph belongs to the sponsoring institutions, we have mentioned this work at some length here because of its interest to our research program and because of

\*Published or presented. For additional information see "Staff Notes and Publications."

the mutual stimulation it has engendered. A similar informal relationship exists with respect to the work of Lawrence R. Klein and others at the Survey Research Center of the University of Michigan (cosponsored by the National Bureau of Economic Research) on the evaluation of survey data of household assets, incomes, savings, and expenditures. The success of future econometric work will, to no small degree, depend on results of such empirical inquiries into the behavior of individual firms or consumers, thus reinforcing or supplementing the information obtained from time series of economic aggregates.

Expectations and Business Fluctuations—A Progress Report: *Modigliani*  
Empirical Studies of Expectations and Investment Decisions: \* *Modigliani*  
The Use of Sample Surveys in Econometrics: *L. R. Klein*, University of Michigan  
Sample Surveys and Household Behavior: *Klein*

As is pointed out on p. 6, the policy of a government toward a stated economic purpose depends on knowledge of actual behavior of individuals in the economy. This is clearly illustrated in Arnold C. Harberger's study of the effectiveness of currency depreciation as a possible device for lessening a country's unfavorable balance of trade. He demonstrated how the effect of currency depreciation depends on the elasticities of demand for imports by the country in question and by the rest of the world.

As a case study of the firm's behavior with respect to inventories, Stephen G. Allen investigated fluctuations in inventories of flaxseed and linseed oil in the United States. He constructed a model of the markets in question and computed preliminary estimates of the coefficients of inventory equations from quarterly data. Interesting aspects of these markets are the apparent inelasticity of demand for linseed oil and the typically small annual carry-overs of flaxseed in two of the major producing countries.

Hildreth continued to work on the problem of estimating production functions for Midwest agriculture and completed computations on a study using cross-section data obtained in a 1947 survey in Iowa.

Currency Depreciation, Income, and the Balance of Trade: \* *Harberger*  
Empirical Determination of the Elasticity of Demand for Imports: *Harberger*  
Inventory Fluctuations in Flaxseed and Linseed Oil: *Allen*

It is ultimately necessary to fit together the behavior equations of groups of various individuals in explaining the determination of prices, of national employment and product, and of other important aggregates. The natural starting point for this purpose is the traditional static theory of markets. This theory neglects, even in its more articulate and general expression as

\*Presented. For additional information see "Staff Notes and Publications."

the so-called general equilibrium theory, not only uncertain expectations but even certain ones. It does not offer a satisfactory logical treatment of debts or securities or even of the simpler phenomenon of paper money (including bank deposits), which is demanded and held in stock yet used neither for consumption nor for production. Earlier studies by Don Patinkin devoted to a criticism of traditional monetary theory (Cowles Commission Papers, New Series, No. 28) provoked a lively discussion among economists, some of it published during 1949–50 (see articles by W. Braddock Hickman, Wassily W. Leontief, and Cecil G. Phipps, in *Econometrica*, January, 1950). Karl Brunner undertook the necessary task of systematizing the assumptions and checking the conclusions advanced by various authors. Brunner and Marschak pointed out that the demand for goods and for holdings of money must be determined simultaneously by the expectations, tastes, and resources of individuals. Desire for money holdings presupposes the expectation of changing market or production conditions and the existence of transaction costs as a form of market imperfection; the “liquidity” advantage of otherwise “useless” money cannot be defined except in a changing economy. With the *rationale* of demand for money holdings thus explained, it follows that the so-called “money illusion” is itself rational: a proportional change of all prices relative to money must lead to a change in the rationally desired stocks of money, and hence to a revision of the levels of all commodity stocks and flows which, before the change in money prices, were those chosen by each businessman or consumer as the preferred ones. This sensitivity of the economy to prices of goods (including labor) in terms of money, and not only to ratios between these prices, has vast implications for the understanding of fluctuations of employment, neglected in the traditional static theory. By extending similar considerations to the bond market, Brunner analyzed conflicting theories of interest rate.

Remarks on Patinkin's Indeterminacy Problem: *Brunner*

The Rationale of Money Demand and of “Money Illusion”:\* *Marschak*

Demand for Money in a Riskless Society:\* *Marschak*

### *The Testing of Econometric Models*

The report for the period ending June 30, 1949, outlined the task undertaken by Carl Christ: bringing up to date, revising, and testing (as revised) Klein's Model III which appears in its original form in Klein's “The Use of Econometric Models as a Guide to Economic Policy” in *Econometrica* for April, 1947, and also in Cowles Commission Monograph 11, *Economic Fluctuations in the United States, 1921–1941*. The provisional outcome of Christ's experiment was presented to a conference on business cycles research

\*Presented. For additional information see “Staff Notes and Publications.”

organized by the Universities-National Bureau Committee in November, 1949, in New York. In the present section, appropriately placed between the discussions of actual behavior measurement and statistical methodology, we report on this experiment and on other contributions of members of the Commission staff to the discussions in that conference. We understand that a full report on all papers and discussions at this extremely stimulating and valuable conference is being prepared by the National Bureau of Economic Research.

The starting point for Christ's tentative revision of Klein's hypotheses and estimates is a paper by Andrew Marshall, entitled "A Test of Klein's Model III for Changes of Structure." Klein's model consists of twelve "structural equations." Each of these, assumed valid up to a "random disturbance," is intended to describe the behavior of a particular economic group in a particular market. From data for 1921-41 Klein estimated the coefficients of each equation and the statistical properties (the distribution) of random disturbances. From the same data, Marshall estimated "tolerance intervals" within which, in any given year, the "unexplained residual" of each equation would fall with a specified high probability if that equation continued to hold and were subject to the same kind of random disturbances. If, for 1946 and 1947, the residual of a certain equation falls outside of the tolerance interval, the equation has failed to describe the post-war years as well as it described the interwar years. It is therefore desirable to give it a revised form which will describe both periods; or, if this is not possible, one has to account for the change of economic structure. Accordingly, Christ modified Klein's consumption equation to account for the influence of cash balances; he replaced Klein's supply equation by a production function; and he made a few more such changes. Christ then tested the revised equations against still more recent data (1948). A larger number of equations passed this test, compared with the 1946-47 test for Klein's original equations.

In addition to examining the validity of structural equations, Christ also tested the predictive power of the (revised) model with respect to specified economic variables when the future values of predetermined variables, such as tax yields or bank excess reserves, are known. In fact, this experiment reproduces the practical situation of economic forecasting, which is always conditional upon assumed levels of political variables and must always be made before any economic variables, of the period for which the prediction is made, have become known. Christ's test consisted in comparing the success of such predictions, made for 1948 on the basis of a revised model, with predictions obtained (following a suggestion of M. Friedman) on the basis of "naive" models. The latter models cannot predict the effect of changes in taxation or of other policies because they simply assume either that there was



no change from 1947 to 1948 in the variable in question or that the change from 1947 to 1948 was the same as that from 1946 to 1947. In predicting the values of variables without assuming changes in policy, these "naive" predictions came close to the truth as often as those by the econometric model. Although the test was applied to one year only and although it happened to fall in a period of economic stability, the outcome of the test does show the need for further thorough revisions of the model and/or strengthening of its basis in statistical data. In particular, the data, based mainly on time series of national income and its components, require thorough readjustment in accordance with revisions published by the Department of Commerce since the war before extrapolations from such models can be taken seriously.

Since a mathematical model, accompanied by precise definitions, states explicitly all assumptions and all evidence used, it appears to be more "vulnerable" than most verbal writings on economics and policy. This is indeed an advantage of the mathematical model. It can be tested. It can be rejected if false. It can be improved in clearly stated steps, and each step is again accessible to a test. Conclusions from Christ's experiment were tentatively drawn by Koopmans in the discussions at the conference. He emphasized the desirability of strengthening the statistical basis of econometric models by studies of sectors of the economy using less aggregative variables, possibly using cross-section data as well as time series, the latter preferably quarterly. While we do wish to have models that can predict the effect of change in policies, we also require that their forecasting record in the absence of policy changes compare well with the mechanical application of the "naive" models.

In another contribution to the conference on business cycles research, Marschak attempted to state explicitly some hypotheses that justify the late Wesley Mitchell's statistical procedures and to compare them with hypotheses using more extensively the available knowledge of human behavior and of social institutions. Hurwicz outlined a formal analysis of economic forecasts and their use in government policies; he applied the general concept of optimal strategy as developed in the theory of rational behavior, including games and statistical inference.

A Revised Klein Econometric Model for the United States, 1921-1947:\* *Christ*  
Construction and Testing of Econometric Models:\* *Christ*

The Accuracy of Naive Models: *Markowitz*

A Note on the Use of Tolerance Intervals: *Andrew Marshall*, The RAND Corporation

A Note on Limited-Information Estimates and Methods for Their Appraisal:  
*Christ*

\*Presented. For additional information see "Staff Notes and Publications."

- Discussion of "The Reformulation of Current Business Cycle Theories as Refutable Hypotheses" by Jan Tinbergen:\* *Koopmans*  
 Comments on "What Happens During Business Cycles—A Progress Report" by Wesley Mitchell:\* *Marschak*  
 Discussion of "Business Cycle Analysis and Public Policy" by Arthur Smithies:\* *Hurwicz*

### *The Study and Development of Statistical Methods*

The methodological problems of model construction were investigated both in a general way, with a view to applications in the social sciences and beyond, and with specific reference to models useful in econometric work.

The problem of identification continued to occupy the minds working in this area. If a model is loosely described as a set of postulated relationships between variables, some of which are observable, the identification problem is concerned with the question to what extent these relationships are accessible to statistical measurement. Some examples may now be mentioned.

The term "factor analysis" has come to be associated with the tracing of mental abilities from observed numerical performance scores in psychometric tests. Olav Reiersøl completed his study of identification problems in the factor analysis models developed by L. L. Thurstone. Paul Lazarsfeld, of the Bureau of Applied Social Research, Columbia University, gave a presentation of his models for "latent attribute analysis" which were developed to trace basic attitudes underlying the responses to public opinion tests. The difference between this and factor analysis lies in the fact that the data for the former are classifications of individuals (by "yes" or "no" answers) rather than numerical scores. Reiersøl also studied identification problems in the measurement of a linear relationship between variables subject to errors of measurement. Koopmans and Reiersøl gave a systematic discussion, drawing on earlier work of other members of the staff, of the identification problem, choosing illustrations from the studies just mentioned and from econometric work. T. W. Anderson and Hurwicz continued their work on identification in econometric models that combine disturbances in behavior with errors of measurement in the variables.

- On the Identifiability of Parameters in Thurstone's Factor Analysis:\* *Reiersøl*  
 The Analysis of Latent Structures: *Paul Lazarsfeld*, Columbia University.  
 Identifiability of a Linear Relation Between Variables Which are Subject to Error: *Reiersøl*  
 The Identification of Structural Characteristics:\* *Koopmans and Reiersøl*  
 A Note on Models and Identification: *Christ*

While these studies continued and in some sense concluded the elaboration

\*Published or presented. For additional information see "Staff Notes and Publications."

of ideas developed over a period of years, two new directions of methodological study were initiated. Erling Sverdrup emphasized that a model should specify not only the postulated relationships between the variables, but also the type of predictions for which these relationships are to be used. The study of identifiability and of methods of estimation can then be directed toward the parameters directly entering in that prediction process. Hurwicz discussed model construction as a problem of strategy on the part of the investigator. In a given state of ignorance or partial information with respect to the phenomena to be described by a model, the choice of the model must balance the consequences of biases and other errors arising from possible oversimplification against the disadvantages, in terms of loss of information or cost of computation, of making the model more general than is perhaps necessary.

Links Between Prediction Problems and Problems of Statistical Estimation: *Sverdrup*

Prediction Problems and the Theory of Statistical Decision Functions: *Sverdrup*  
On Specification Bias: *Hurwicz*

We turn now to problems of statistical method more specific to econometric model construction. Harberger encountered two interesting methodological problems in his investigation of elasticities of demand for imports (see p. 12). One was concerned with the aggregation of various imported goods into a single commodity, "imports." Harberger found reasons for believing that the use of ordinary price and quantity index numbers for imports would lead to an understatement of the elasticity of demand for imports, and was able to derive theoretically correct procedures from explicit disaggregation models. He also made an attempt to evaluate from a priori knowledge the probable order of magnitude of the bias in least-squares estimates of the coefficients in the demand for imports equations, using the work by Jean Bronfenbrenner mentioned below. His tentative conclusion was that in this particular case the various contributions to least-squares bias were probably not in the same direction and that the net bias was probably not sufficient to destroy the usefulness of least-squares estimates in this problem.

Hildreth has considered the possibility of combining information from technical experiments with survey data in agricultural investigations. He has also studied the possibility of combining cross-section data with time series, considering problems of identification as well as estimation. He intends to use models of this kind in the estimation of agricultural production functions.

Preliminary Considerations Regarding Time Series and/or Cross-Section Studies: *Hildreth*

Combining Time Series and Cross-Section Data: *Hildreth*

The study of methods of estimation of the coefficients of economic behavior equations continued during the period of the report. Koopmans and Hood are preparing an expository statement of the application of the maximum-likelihood method of estimation to linear systems with normal disturbances, and to subsystems or single equations contained in such a linear system. Rubin and Chernoff have indicated how these methods retain certain desirable properties if nonlinearity of equations, nonnormality of disturbances, and even nonobservability of some of the variables are introduced. The effect of such nonobservability was also illustrated by Allen in a two-equation system. Jean Bronfenbrenner derived and discussed an expression for the specification bias which may arise if the least-squares method of estimation is applied to the coefficients of a behavior equation which is part of a system of several such equations.

The extension of more and more reliable information from statistical time series for the measurement of economic behavior equations depends particularly on further progress of statistical theory in two directions: good methods of estimation from samples of moderate size, and the admission of serial correlation in the disturbances in behavior (to permit larger samples from the same period by the use of quarterly data). Klein reported on studies using quarterly data, and John Gurland's research is concerned both with serial correlation in disturbances and with medium-size sample distributions. As a preliminary step, Gurland reported on sampling experiments conducted by G. H. Orcutt and D. Cochrane.

The Estimation of Simultaneous Linear Economic Relationships:‡ *Koopmans and Hood*

Asymptotic Properties of Limited-Information Estimates under Generalized Conditions:‡ *Rubin and Chernoff*

Example of Loss of Efficiency in Structural Estimation:‡ *Allen*

Sources and Size of Least-Squares Bias in a Two-Equation Model:‡ *Bronfenbrenner*

Autocorrelated Disturbances in Time Series: *L. R. Klein*

Some Comments on Sampling Experiments by Orcutt and Cochrane: *Gurland*

Estimation of the Regressive and Covariance Parameters in Linear Regression: *Gurland*

Monograph 14 (see p. 30), which will include most of these studies, will report in an expository style on the work of the Commission in statistical methods in econometrics, done over a period of years.

### *Mathematical Tools*

Economics has entered a stage in which some of the mathematical tools it requires are no longer found ready-made in the textbooks or monographs up-

‡To be included in Monograph 14 (see pp. 30-31).

on which the user of mathematics is wont to rely. Reference to original publications and development of new mathematical theory have become necessary in such problems as arise in the study of linear models of production, described on pp. 6-8, and also in the theory of games. While these two topics are quite different in content and application, both involve linear functions of nonnegative variables, and hence both require the theory of convex sets in relation to systems of linear inequalities.

Mathematical work on these topics was stimulated by contacts with a research group at Princeton University led by A. W. Tucker. Contributions from this group are listed in the Table of Contents of Monograph 13 on p. 30. Murray Gerstenhaber extended and systematized the theory of convex polyhedral cones in finite dimensional spaces for use in the study of production models. He studied further extensions to infinite dimensional spaces permitting the study of inequalities involving integrals. Morton L. Slater and Koopmans have provided stimulation for this work.

Slater's research is further directed toward the computational problem of maximizing a linear function of variables subject to linear inequalities. Merton Stoltz, of Brown University, presented a paper dealing with properties of stochastic processes useful in economic analysis.

Nathan J. Divinsky succeeded Chernoff and Bronfenbrenner in giving direction to the work of the computing staff of the Commission toward the estimation of economic relationships, and progress was made in reporting on the computation methods developed. Divinsky also gave mathematical advice on a variety of problems to other members of the research staff.

Theory of Convex Polyhedral Cones: † *Gerstenhaber*

Stochastic Processes in Economics: *Merton P. Stoltz*, Brown University

Gradient Methods of Maximization: *Chernoff and Bronfenbrenner*

The Computation of Maximum-Likelihood Estimates of Linear Structural Equations: ‡ *Chernoff and Divinsky*

## SPECIAL STUDIES

### *Economic Aspects of Atomic Power*

This study, codirected by Schurr and Marschak, reached the publication stage during the period of this report (*Economic Aspects of Atomic Power*, Princeton: Princeton University Press, 1950, about 307 pp., \$6.00). The contents of the volume are as follows:

PART I. ECONOMIC COMPARISONS OF ATOMIC AND CONVENTIONAL POWER: 1. Economic Characteristics of Atomic Power; 2. The Cost of Electricity from Conventional

†To be included in Monograph 13 (see pp. 30-31).

‡To be included in Monograph 14 (see pp. 30-31).

Energy Sources (including world maps of electricity cost and of the distribution of solid fuels and water power).

PART II. ATOMIC POWER IN SELECTED INDUSTRIES: 3. The Industry Analyses: A Summary View; 4. Aluminum; 5. Chlorine and Caustic Soda; 6. Phosphate Fertilizers; 7. Cement; 8. Brick; 9. Flat Glass; 10. Iron and Steel; 11. Railroad Transportation; 12. Residential Heating.

PART III. ATOMIC POWER AND ECONOMIC DEVELOPMENT: 13. The Effects of Atomic Power on National or Regional Economies; 14. Atomic Power and the Industrialization of Backward Areas. (Analytical Table of Contents; References; Index)

### *Econometric Interpretation of History*

This project, described in earlier reports, has been advanced during the past year. The distribution of income for England in 1086 has been obtained from the statistical data of the Domesday Book of William the Conqueror. Charles G. Slater, of Northwestern University, working in collaboration with Harold T. Davis, has used acres-of-income to determine the income distribution from the lowest class (cotters) to the king. Ten income classes were recognized. For the first nine classes (cotters to barons) the income was Paretian with an index of 1.58. The king's income was found to be excessive and this was interpreted to portend the conflict between king and barons which finally culminated in the events associated with the granting of the Magna Carta.

The problem of interpreting the economic events of the sixteenth, seventeenth, and eighteenth centuries has been greatly facilitated by a study of the voluminous data included in a six-volume work by Nina Bang (d. 1928) on navigation passing the Sound between the North Sea and the Baltic between the years 1497 and 1783. Various graphical representations of the data have been made. These data, among other things, indicate the magnitude of the conflict between the commercial activities of England and the Netherlands, the effect of plague upon commerce, the disastrous effect of the Thirty Years War upon European economies, and the importance of many other lesser historical events. A study of the relationship between the evidence of these series and the behavior of prices, where they are available, is the next project suggested by these data.

### *Nonlinear Differential Equations*

The increasing need for more information about nonlinear equations has suggested a study of the six types of equations known as Painlevé transcendents. Under a grant of funds from the graduate school of Northwestern University a study of the first of these equations, namely,  $u'' = 6u^2 + x$ , has been undertaken by Davis. The transcendental function involved is related to the elliptic function  $sn x$ . Nonlinear equations, as in the theory of the growth of conflicting populations, appear in econometric literature.

## COOPERATION WITH OTHER GROUPS

As in other years, the Cowles Commission or its staff members cooperated with other institutions or agencies in research of common interest.

Within the University the Commission has several joint appointments with the Department of Economics. It also has joint appointments with the Agricultural Economics Research group (Hildreth) and with the Committee on Statistics (Gurland, Koopmans).

The Commission maintains informal contact with various centers of empirical work. Through Modigliani the Commission is in close contact with a joint project of the National Opinion Research Center of the University of Chicago and the Bureau of Business Research of the University of Illinois to study businessmen's expectations and decision making. Related to this is the work of Jean Bronfenbrenner on survey data on investment plans, conducted for the Office of Business Economics, Department of Commerce. Through Lawrence R. Klein and others the Commission keeps in touch with the collection and analysis of survey data on consumer behavior being undertaken at the University of Michigan under the joint sponsorship of the Survey Research Center and the National Bureau of Economic Research. Insight into other problems of empirical research is gained through consultative activities by Hildreth at the Iowa Agricultural Experiment Station and the Department of Farm Economics of the University of Kentucky.

Several members of the Commission (Christ, Hurwicz, Koopmans, Marchak) participated in various ways in the Conference on Business Cycles Research sponsored by the National Bureau of Economic Research in November, 1949, through the Universities-National Bureau Committee. Christ took part in the Chrysler Corporation Conference held in Detroit in June. In addition, certain members of the staff served as consultants to The RAND Corporation during the year (Anderson, Arrow, Hurwicz).

Various institutions are also brought into a closer relationship than would otherwise be the case by virtue of having members of their staffs active as research consultants of the Cowles Commission. Included in this category are the Bureau of Labor Statistics, Carnegie Institute of Technology, Columbia University and its Bureau of Applied Social Research, Northwestern University, Stanford University, the University of Illinois, and the University of Oslo.

## TEACHING IN ECONOMETRICS, MATHEMATICAL ECONOMICS, ECONOMIC THEORY, AND STATISTICS AT THE UNIVERSITY OF CHICAGO

The following courses listed by the Department of Economics or by the Committee on Statistics (not all given every year) are particularly relevant to the area of interest of the Cowles Commission. Staff members of the

Cowles Commission participate in the teaching activities of the University of Chicago, especially in the fields of statistics and economic theory.

**NATIONAL INCOME AND RELATED AGGREGATES.** Subject matter includes: Survey of the sources and methods involved in estimating the economic structure. National income, capital formation, balance of payments, and the components of the input-output analysis. Formulation of national economic programs. Aggregates are related to the data and methods of both business and government accounting. Attention is given to students' practical work.

**USE OF ELEMENTARY MATHEMATICS IN ECONOMICS.** Discussion of students' solutions of problems pertaining to the dimensionality of economic magnitudes; to the presentation of economic theories as systems of quantitative relations; to the use of the maximization principle; to the aggregation over individuals and over commodities; to the formulation of dynamic theories; to the use of random variables in economics; and to the comparison of policy results.

**PROBLEMS IN MATHEMATICAL ECONOMICS.** Elements of advanced calculus and of ordinary and differential equations applied to fundamental economic problems. The material is arranged in the order of increasing mathematical difficulty.

**INTRODUCTION TO ECONOMETRICS.** Measurement of micro- and macroeconomic relations, both static and dynamic, such as demand and cost equations. Comparative statics and dynamics and the practical use of inference from nonexperimental data. The identification problem. Introduction to the estimation problem.

**STATISTICAL PROBLEMS OF MODEL CONSTRUCTION.** Discussion of problems arising when inference processes are directed to a postulated structure underlying the probability distribution of observed variables. Problems of identification of structural characteristics in a given model, of estimation of identifiable parameters, of estimation bias arising from incorrectly specified models, and of testing the specifications that define a model. Examples are drawn from econometrics, factor analysis, latent attribute analysis, and from the study of errors of observation.

**PRICE THEORY.** A systematic study of the pricing of final products and factors of production under essentially stationary conditions. Covers both perfect competition and such imperfectly competitive conditions as monopolistic competition, oligopoly, and monopoly.

**WELFARE ECONOMICS.** Description of conditions defining production and utility "possibilities." Implications of these conditions for appraising economic policies affecting resource allocation, income distribution, and the level of employment. Special applications are made in the appraisal of imperfect competition, various government fiscal policies, and alternative economic systems.

**ALLOCATION OF RESOURCES IN PRODUCTION.** Criteria for optimal resource allocation. Prices are introduced as marginal rates of substitution under efficient allocation of resources. The use of prices as guides to allocative decisions. Applications to a variety of production and pricing problems, including those of the transportation industry, and problems of industrial location.

**THE THEORY OF INCOME, EMPLOYMENT, AND PRICE LEVEL.** Government policies and other factors determining the employment of resources, the national income and its



use, and the levels of prices, wage rates, and interest rates. These problems are linked with the behavior of individual firms and households.

**MONETARY ASPECTS OF INTERNATIONAL TRADE.** Foreign payments and receipts. Classical and modern theories of adjustment of the balance of payments. Theories of exchange rates. Capital movements in the balance of payments. Postwar monetary plans.

**SEMINAR ON MODERN DEVELOPMENTS IN ECONOMIC THEORY.** Discussion of selected topics from recent literature.

**SCOPE AND METHOD OF THE SOCIAL SCIENCES.** The first of this sequence of three courses is an introduction to statistical methods as used in the social sciences.

**INTRODUCTION TO STATISTICS (for economists).** Elementary principles of statistics. Frequency distributions, averages, dispersion, index numbers, elements of the theory of statistical inference.

**STATISTICAL INFERENCE (sequence of three courses).** The first two courses survey the principles of statistical inference, with emphasis on techniques useful in applying these principles. Among the subjects treated are elements of probability; concepts of population, sample, and sampling distribution; choice of estimates; testing hypotheses; principles of sampling and sample design; analysis of proportions, means, and standard deviations; simple, partial, and multiple regression and correlation. The third course of the sequence deals with the extension and application of principles and techniques. The content varies from year to year; for example, members of the class individually or jointly may carry out a statistical investigation; or a series of published statistical studies may be analyzed in detail; or some special field of application may be studied.

**SAMPLE SURVEYS.** Theory of sampling from finite populations and its applications. Topics discussed include aspects of the representative method; random sampling; estimation, variances of estimates, uses of the standard tables; stratified and systematic sampling; optimum allocation of resources; the problem of nonresponse; subsampling; ratio and regression estimates.

**INTRODUCTION TO MATHEMATICAL PROBABILITY.** Fundamentals and axioms; combinatorial problems; probability distributions in one or more dimensions; random variables; moments; important specific distributions; marginal and conditional distributions; Bayes' theorem; Tchebycheff's inequality and generalizations; types of convergence; the law of large numbers; the central-limit theorem; characteristic functions. The relationship of mathematical probability to other branches of mathematics and to applied mathematics (particularly statistics) is described.

**MATHEMATICAL STATISTICS (sequence of two courses).** Surveys the logical and mathematical concepts of modern statistics. Topics include the scope of statistical problems and statistical theory; relationships between mathematics, statistics, and the empirical sciences; point estimation and associated criteria; testing of hypotheses; some standard tests and their power; likelihood ratio tests; confidence sets; multivariate normal distributions; correlation; tests of goodness of fit; Cramér-Rao inequality; order statistics; some typical nonparametric procedures; the idea of the general linear hypothesis.

**STATISTICAL THEORY OF DECISION MAKING.** Critical review of modern statistical viewpoints, emphasizing general ideas as opposed to techniques. Interpretations of

probability; the probabilistic utility theory; critique of Bayes' theorem; methods proposed for avoiding Bayes' theorem, especially Wald's theory of minimum risk and the Neyman-Pearson theory; randomization; sufficient statistics and likelihood ratios; de Finetti's theory of personal probability.

**THEORY OF MINIMUM RISK.** A mathematical exposition of Wald's theory of minimum risk. Where practical, illustrations are drawn from standard statistical tests and estimates, but the treatment is for the most part on an abstract level. Existence theorems; general techniques of solution; simple dichotomies; asymptotic point estimation; symmetrical problems; sequential decisions.

**NONPARAMETRIC INFERENCE.** Problems of estimation and testing hypotheses when the functional form of the population distribution is unknown. Confidence intervals for quartiles; tolerance limits; estimation of distribution functions and their regular functionals; the sign test; tests based on permutations of the observations; the problem of two samples.

**MATHEMATICAL TECHNIQUES OF STATISTICS.** Trains students already acquainted with statistical methodology in the use of some of the mathematical techniques which have proven most useful in the development of statistical theory. It is organized with reference to these techniques rather than to the statistical ideas to which they apply. The techniques covered are derivation by straightforward integration; Fourier integrals; Euler-MacLaurin formula; and combinations.

**STATISTICS SEMINAR.** Reports are made by staff members, students, and visitors on their researches and on current literature.

## SEMINARS

The Commission conducts a series of seminars devoted to varying topics within the broad area of quantitative method. Papers are presented by research workers from this and other centers of learning and are followed by a critical discussion of the material by seminar participants. The seminars have proved to be of particular value in suggesting new associations of ideas and in developing a more receptive attitude toward quantitative techniques. To facilitate this, invitations to seminars are extended to research personnel in a wide variety of fields as well as to the public and to interested graduate students. During the period covered by this report the following Cowles Commission seminars were held:

1949

October 6. TIBOR SCITOVSKY, Department of Economics, Stanford University, "The Meaning of National Product Estimates."

October 20. ANATOL RAPOPORT, Committee on Mathematical Biology, University of Chicago, "Outline of a Mathematical Approach to Animal Sociology."

November 3. NICOLAS RASHEVSKY, Committee on Mathematical Biology, University of Chicago, "Suggestions for a Mathematical Biology of Imitative Behavior."

November 17. CARL CHRIST, "Econometric Models and Predictions for the United States."

December 8. LEONID HURWICZ, "Estimation Bias Due to Incorrect Choice of Model" (jointly with the Statistics Club, University of Chicago).

December 15. TJALLING C. KOOPMANS, "Efficient Allocation of Resources."

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January 5. CHARLES J. HITCH, The RAND Corporation, "Planning Defense Production."

January 12. A. W. TUCKER, Department of Mathematics, Princeton University, "Feasibility, Existence, and Duality Theorems of Linear Programming."

February 2. CHAUNCY D. HARRIS, Department of Geography, University of Chicago, "Theory of Location and Soviet Planning."

February 9. ERICH SCHNEIDER, Department of Economics, University of Kiel, Germany, "The Problem of Replacement of Industrial Equipment."

March 2. TJALLING C. KOOPMANS, "Identification of Structure in Factor Analysis and in Econometrics" (jointly with the Statistics Club, University of Chicago).

March 16. ROBERT H. STROTZ, Department of Economics, Northwestern University, and N. FRANK MOREHOUSE, Aerial Measurements Laboratory, Northwestern University, "The Application of the Electro-Analog Computer to Problems in Economic Dynamics."

March 30. JULIUS MARGOLIS, Program of Education and Research in Planning, University of Chicago, "National Economic Accounting and Economic Policy."

April 13. GERHARD TINTNER, Department of Economics, Iowa State College, "External Economies in Consumption."

April 27. EARL J. HAMILTON, Department of Economics, University of Chicago, "Four Centuries of Spanish Prices."

May 11. FRANCO MODIGLIANI, "Empirical Studies of Expectations and Investment Decisions."

May 18. LAWRENCE R. KLEIN, Survey Research Center, University of Michigan, and National Bureau of Economic Research, "Sample Surveys and Household Behavior."

May 25. A. J. BROWN, Department of Economics, University of Leeds, England, "Some Recent Examples of the Price-Wage Spiral."

June 15. ERIC LUNDBERG, Institute of Conjunction, Stockholm, Sweden, "Wage Policy and Full Employment—With Special Reference to Swedish Experience."

#### COWLES COMMISSION PAPERS

At the end of 1943 the policy was adopted of having reprints of papers by members of the Commission's research staff bound in special covers as Cowles Commission Papers, New Series (for econometric research), and Cowles Commission Special Papers (for special studies). Of the following list of Cowles Commission Papers, Nos. 38 and 40-43 have been issued since July 1, 1949. Nos. 32-34, 36, and 39 are in preparation and will be issued in the latter part of 1950. A limited supply is available of those papers which are marked by an asterisk, and copies will be furnished to in-

dividuals who request particular items. (Of the papers not marked with an asterisk, those which are reprinted from *Econometrica* may be obtained by purchasing the back issues in which they appear from the Econometric Society, University of Chicago, Chicago 37, Illinois. Price \$2.50 per issue.)

#### NEW SERIES

No. 1. OSCAR LANGE, "The Theory of the Multiplier," *Econometrica*, Vol. 11, July-October, 1943, pp. 227-245.

No. 2. GEORGE KATONA, "The Role of the Frame of Reference in War and Post-War Economy," *American Journal of Sociology*, Vol. 49, January, 1944, pp. 340-347.

No. 3. LEONID HURWICZ, "Stochastic Models of Economic Fluctuations," *Econometrica*, Vol. 12, April, 1944, pp. 114-124.

No. 4. TRYGVE HAAVELMO, "The Probability Approach in Econometrics," *Econometrica*, Vol. 12, Supplement, July, 1944, viii+118 pp.

No. 5. JACOB MARSCHAK AND WILLIAM H. ANDREWS, JR., "Random Simultaneous Equations and the Theory of Production," *Econometrica*, Vol. 12, July-October, 1944, pp. 143-205.

\*No. 6. ALFRED COWLES, "Stock Market Forecasting," *Econometrica*, Vol. 12, July-October, 1944, pp. 206-214.

No. 7. GEORGE KATONA AND DICKSON H. LEAVENS, "Price Increases and Uptrading," *Journal of Business*, Vol. 17, October, 1944, pp. 231-243.

No. 8. OSCAR LANGE, "The Stability of Economic Equilibrium," Appendix from Cowles Commission Monograph 8, *Price Flexibility and Employment*, pp. 91-109.

No. 9. JACOB MARSCHAK, "A Cross Section of Business Cycle Discussion," *American Economic Review*, Vol. 35, June, 1945, pp. 368-381.

No. 10. HERMAN RUBIN, "On the Distribution of the Serial Correlation Coefficient," *Annals of Mathematical Statistics*, Vol. 16, June, 1945, pp. 211-215.

No. 11. TJALLING C. KOOPMANS, "Statistical Estimation of Simultaneous Economic Relations," *Journal of the American Statistical Association*, Vol. 40, December, 1945, pp. 448-466.

No. 12. TRYGVE HAAVELMO, "Multiplier Effects of a Balanced Budget," *Econometrica*, Vol. 13, October, 1945, pp. 311-318.

No. 13. LEONID HURWICZ AND JACOB MARSCHAK, "Games and Economic Behavior, Two Review Articles," *American Economic Review*, Vol. 35, December, 1945, pp. 909-925, and *Journal of Political Economy*, Vol. 54, April, 1946, pp. 97-115.

No. 14. LAWRENCE R. KLEIN, "Macroeconomics and the Theory of Rational Behavior," *Econometrica*, Vol. 14, April, 1946, pp. 93-108.

No. 15. G. HABERLER, R. M. GOODWIN, EVERETT E. HAGEN, AND TRYGVE HAAVELMO, "Multiplier Effects of a Balanced Budget, Notes Supplementary to Cowles Commission Paper, New Series, No. 12," *Econometrica*, Vol. 14, April, 1946, pp. 148-158.

No. 16. LEONID HURWICZ, "Theory of the Firm and of Investment," *Econometrica*, Vol. 14, April, 1946, pp. 109-136.

No. 17. JACOB MARSCHAK, LEONID HURWICZ, TJALLING C. KOOPMANS, AND ROY BERGH LEIPNIK, "Estimating Relations from Nonexperimental Observations" (abstracts of papers presented at Cleveland, January 25, 1946), *Econometrica*, Vol. 14, April, 1946, pp. 165-172.

No. 18. LAWRENCE R. KLEIN, "A Post-Mortem on Transition Predictions of National Product," *Journal of Political Economy*, Vol. 54, August, 1946, pp. 289-308.

No. 19. KENNETH MAY, SHOU SHAN PU, AND LAWRENCE R. KLEIN, "The Problem of Aggregation," *Econometrica*, Vol. 14, October, 1946, pp. 285-312; Vol. 15, January, 1947, pp. 51-63.

\*No. 20. NANCY BRUNER AND DICKSON H. LEAVENS, "Notes on the Doolittle Solution," *Econometrica*, Vol. 15, January, 1947, pp. 43-50.

\*No. 21. R. B. LEIPNIK AND T. W. ANDERSON, "Three Papers on Serial-Correlation Coefficients and Oscillatory Time Series," *Annals of Mathematical Statistics*, Vol. 18, March, 1947, pp. 80-87; *Journal of the American Statistical Association*, Vol. 42, March, 1947, pp. 187-188; *Econometrica*, Vol. 15, July, 1947, pp. 105-122.

\*No. 22. TRYGVE HAAVELMO, "Methods of Measuring the Marginal Propensity to Consume," *Journal of the American Statistical Association*, Vol. 42, March, 1947, pp. 105-122.

No. 23. LAWRENCE R. KLEIN, "The Use of Econometric Models as a Guide to Economic Policy," *Econometrica*, Vol. 15, April, 1947, pp. 111-151.

No. 24. M. A. GIRSHICK AND TRYGVE HAAVELMO, "Statistical Analysis of the Demand for Food: Examples of Simultaneous Estimation of Structural Equations," *Econometrica*, Vol. 15, April, 1947, pp. 79-110.

No. 25. Two Review Articles: TJALLING C. KOOPMANS, "Measurement without Theory," and JACOB MARSCHAK, "On Mathematics for Economists," *Review of Economic Statistics*, Vol. 29, August, 1947, pp. 161-172; November, 1947, pp. 279-273.

No. 26. Three Papers on Econometrics of Consumption: LAWRENCE R. KLEIN AND HERMAN RUBIN, "A Constant-Utility Index of the Cost of Living," *Review of Economic Studies*, Vol. 15, 1948, pp. 84-87; PAUL A. SAMUELSON, "Some Implications of Linearity," *Review of Economic Studies*, Vol. 15, 1948, pp. 88-90; TRYGVE HAAVELMO, "Family Expenditures and the Marginal Propensity to Consume," *Econometrica*, Vol. 15, October, 1947, pp. 335-341.

No. 27. Two Papers on Econometric Models: TRYGVE HAAVELMO, "Quantitative Research in Agricultural Economics: The Interdependence between Agriculture and the National Economy," and GERSHON COOPER, "The Role of Econometric Models in Economic Research," *Journal of Farm Economics*, Vol. 29, November, 1947, pp. 910-924; Vol. 30, February, 1948, pp. 101-116.

No. 28. DON PATINKIN, Two Papers on Relative and Absolute Prices and the Demand for Money: "Relative Prices, Say's Law, and the Demand for Money" and "The Indeterminacy of Absolute Prices in Classical Economic Theory," *Econometrica*, Vol. 16, April, 1948, pp. 135-154; Vol. 17, January, 1949, pp. 1-27.

\*No. 29. RUTLEDGE VINING AND TJALLING C. KOOPMANS, "Methodological Issues in Quantitative Economics," "A Reply," and "A Rejoinder," *Review of Economics and Statistics*, Vol. 31, May, 1949, pp. 77-94.

No. 30. T. W. ANDERSON, "On the Theory of Testing Serial Correlation," *Skandinavisk Aktuarietidskrift*, Vol. 31, 1948, pp. 88-115.

\*No. 31. TJALLING C. KOOPMANS, "Identification Problems in Economic Model Construction," *Econometrica*, Vol. 17, April, 1949, pp. 125-144.

No. 32. JACOB MARSCHAK, "Statistical Inference from Nonexperimental Observations: Economic Example," *Proceedings of the International Statistical Conferences*, Vol. 3.

No. 33. EVSEY DOMAR, "Capital Accumulation and the End of Prosperity," *Proceedings of the International Statistical Conferences*, Vol. 5 (to be issued as a Supplement to *Econometrica*, Vol. 17, 1949).

No. 34. TJALLING C. KOOPMANS, "Optimum Utilization of the Transportation System," *Proceedings of the International Statistical Conferences*, Vol. 5 (to be issued as a Supplement to *Econometrica*, Vol. 17, 1949).

\*No. 35. Approaches to Business Cycle Analysis: ROBERT A. GORDON, "Business Cycles in the Interwar Periods: The Quantitative-Historical Approach"; TJALLING C. KOOPMANS, "The Econometric Approach to Business Fluctuations"; and discussion by J. W. ANGELL, A. F. BURNS, AND G. HABERLER, *Proceedings Supplement of the American Economic Review*, Vol. 39, May, 1949, pp. 47-88.

No. 36. T. W. ANDERSON AND HERMAN RUBIN, "Estimation of the Parameters of a Single Equation in a Complete System of Stochastic Equations," *Annals of Mathematical Statistics*, Vol. 20, March, 1949, pp. 46-63, and "The Asymptotic Properties of Estimates of the Parameters of a Single Equation in a Complete System of Stochastic Equations" (to be published in *Annals of Mathematical Statistics*).

\*No. 37. JACOB MARSCHAK, "Role of Liquidity under Complete and Incomplete Information," *Proceedings Supplement of the American Economic Review*, Vol. 39, May, 1949, pp. 182-195.

\*No. 38. Two Papers on Involuntary Economic Decisions: TRYGVE HAAVELMO, "The Notion of Involuntary Economic Decisions," *Econometrica*, Vol. 18, January, 1950, pp. 1-8; DON PATINKIN, "Involuntary Unemployment and the Keynesian Supply Function," *Economic Journal*, Vol. 59, September, 1949, pp. 360-383.

No. 39. Three Papers on Identification Problems: OLAV REIERSØL, "On the Identifiability of Parameters in Thurstone's Multiple Factor Analysis," *Psychometrika*, Vol. 15, June, 1950, pp. 121-149; OLAV REIERSØL AND TJALLING C. KOOPMANS, "The Identification of Structural Characteristics," *Annals of Mathematical Statistics*, Vol. 21, June, 1950, pp. 165-181; OLAV REIERSØL, "The Identifiability of Linear Relations between Two Variables Which Are Subject to Error" (to be published in *Econometrica*).

\*No. 40. K. J. ARROW, D. BLACKWELL, AND M. A. GIRSHICK, "Bayes and Minimax Solutions of Sequential Decision Problems," *Econometrica*, Vol. 17, July-October, 1949, pp. 213-244.

\*No. 41. ARNOLD C. HARBERGER, "Currency Depreciation, Income, and the Balance of Trade," *Journal of Political Economy*, Vol. 58, February, 1950, pp. 47-60.

\*No. 42. R. L. ANDERSON AND T. W. ANDERSON, "Distribution of the Circular Serial Correlation Coefficient for Residuals from a Fitted Fourier Series," *Annals of Mathematical Statistics*, Vol. 21, March, 1950, pp. 59-81.

\*No. 43. Papers on the Theory of Choice: JACOB MARSCHAK, "Rational Behavior, Uncertain Prospects, and Measurable Utility," and abstracts of papers presented at Boulder by TJALLING C. KOOPMANS and JACOB MARSCHAK, *Econometrica*, Vol. 18, April, 1950, pp. 111-141; pp. 174-175.

#### SPECIAL PAPERS

\*No. 1. JOHN R. MENKE, "Nuclear Fission as a Source of Power," *Econometrica*, Vol. 15, October, 1947, pp. 314-333.

\*No. 2. JACOB MARSCHAK, SAM H. SCHURR, AND PHILIP SPORN, "The Economic Aspects of Atomic Power," *Bulletin of the Atomic Scientists*, Vol. 2, Nos. 5 and 6, September, 1946, pp. 1-4; *Proceedings Supplement of American Economic Review*, Vol. 37, No. 2, May, 1947, pp. 98-117.

## COWLES COMMISSION MONOGRAPHS

The Commission publishes a series of monographs containing research work done by members of the Cowles Commission staff. A complete list of these monographs is given on the back cover of this report. Monographs 10 and 11 were published during the period, and Monographs 12, 13, and 14 are in the process of publication by John Wiley and Sons. The contents of these publications are indicated below.

### MONOGRAPH 10: STATISTICAL INFERENCE IN DYNAMIC ECONOMIC MODELS

edited by TJALLING C. KOOPMANS

I. Statistical Inference in Economics: An Introduction, *J. Marschak*.

#### PART ONE: SIMULTANEOUS EQUATION SYSTEMS

II. Measuring the Equation Systems of Dynamic Economics, *T. C. Koopmans, H. Rubin, and R. B. Leipnik*.

*Problems of Identification*: III. Note on the Identification of Economic Relations, *A. Wald*; IV. Generalization of the Concept of Identification, *L. Hurwicz*; V. Remarks on Frisch's Confluence Analysis and Its Use in Econometrics, *T. Haavelmo*.

*Problems of Structural and Predictive Estimation*: VI. Prediction and Least Squares, *L. Hurwicz*; VII. The Equivalence of Maximum-Likelihood and Least-Squares Estimates of the Regression Coefficients, *T. C. Koopmans*; VIII. Remarks on the Estimation of Unknown Parameters in Incomplete Systems of Equations, *A. Wald*; IX. Estimation of the Parameters of a Single Equation by the Limited-Information Maximum-Likelihood Method, *T. W. Anderson, Jr.*

*Problems of Computation*: X. Some Computational Devices, *H. Hotelling*.

#### PART TWO: PROBLEMS SPECIFIC TO TIME SERIES

*Trend and Seasonality*: XI. Variable Parameters in Stochastic Processes: Trend and Seasonality, *L. Hurwicz*; XII. Nonparametric Tests against Trend, *H. B. Mann*; XIII. Tests of Significance in Time-Series Analysis, *R. L. Anderson*.

*Estimation Problems*: XIV. Consistency of Maximum-Likelihood Estimates in the Explosive Case, *H. Rubin*; XV. Least-Squares Bias in Time Series, *L. Hurwicz*.

*Continuous Stochastic Processes*: XVI. Models Involving a Continuous Time Variable, *T. C. Koopmans*.

#### PART THREE: SPECIFICATION OF HYPOTHESES

XVII. When Is an Equation System Complete for Statistical Purposes? *T. C. Koopmans*; XVIII. Systems with Nonadditive Disturbances, *L. Hurwicz*; XIX. Note on Random Coefficients, *H. Rubin*. (Principles of Notation, References, Index)

### MONOGRAPH 11: ECONOMIC FLUCTUATIONS IN THE UNITED STATES, 1921-1941

by LAWRENCE R. KLEIN

*Chapters*: I. Model Building—General Principles; II. Economic Theory; III. Statistical Model; IV. Adequacy of the Available Data. (Appendix, Index)

## MONOGRAPH 12: SOCIAL CHOICE AND INDIVIDUAL VALUES

by KENNETH J. ARROW

*Chapters:* I. Introduction; II. The Nature of Preference and Choice; III. The Social Welfare Function; IV. The Compensation Principle; V. The General Possibility Theorem for Social Welfare Functions; VI. The Individualistic Assumptions; VII. Similarity as the Basis of Social Welfare Judgments.

## MONOGRAPH 13: ACTIVITY ANALYSIS OF PRODUCTION AND ALLOCATION

Proceedings of a Conference, edited by T. C. KOOPMANS

Introduction, *T. C. Koopmans*.

PART I. THEORY OF PROGRAMMING AND ALLOCATION: 1. The Programming of Interdependent Activities: I. General Discussion, *M. K. Wood and G. B. Dantzig*; 2. The Programming of Interdependent Activities: II. Mathematical Model, *G. B. Dantzig*; 3. Production as an Efficient Combination of Activities, *T. C. Koopmans*; 4. The Aggregate Linear Production Function and Its Application to von Neumann's Economic Model, *N. Georgescu-Roegen*; 5. Relaxation Phenomena in Linear Dynamic Models, *N. Georgescu-Roegen*; 6. Uses of Leontief's Open Input-Output Models, *H. Smith*; 7. Abstract of a Theorem Concerning Substitutability in Open Leontief Models, *P. A. Samuelson*; 8. Alternative Proof of the Substitution Theorem for Leontief Models in the Case of Three Industries, *T. C. Koopmans*; 9. Alternative Proof of the Substitution Theorem for Leontief Models in the General Case, *K. J. Arrow*; 10. Some Properties of a Generalized Leontief Model, *N. Georgescu-Roegen*.

PART II. APPLICATIONS OF ALLOCATION MODELS: 1. On the Choice of a Crop Rotation Plan, *C. Hildreth and S. Reiter*; 2. Development of Dynamic Models for Program Planning, *M. K. Wood and M. A. Geisler*; 3. Representation in a Linear Model of Nonlinear Growth Curves in the Aircraft Industry, *M. K. Wood*; 4. A Model of Transportation, *T. C. Koopmans and S. Reiter*; 5. Effects of Technological Change in a Linear Model, *H. A. Simon*, with comments by *A. Coale* and *Y. Brozen*; 6. The Accuracy of Economic Observations, *Oskar Morgenstern*.

PART III. MATHEMATICAL PROPERTIES OF CONVEX SETS: 1. Convex Polyhedral Cones and Linear Inequalities, *D. Gale*; 2. Theory of Convex Polyhedral Cones, *M. Gerstenhaber*; 3. Linear Programming and the Theory of Games, *D. Gale, H. W. Kuhn, and A. W. Tucker*; 4. A Proof of the Equivalence of the Programming Problem and the Game Problem, *G. B. Dantzig*.

PART IV. PROBLEMS OF COMPUTATION: 1. Maximization of a Linear Function of Variables Subject to Linear Inequalities, *G. B. Dantzig*; 2. Application of the Simplex Method to a Game Theory Problem, *R. Dorfman*; 3. Application of the Simplex Method to a Transportation Problem, *G. B. Dantzig*; 4. Iterative Solution of Games by Fictitious Play, *G. W. Brown*; 5. Computational Suggestions for Maximizing a Linear Function Subject to Linear Inequalities, *G. W. Brown and T. C. Koopmans*. (Bibliography, Index)

## MONOGRAPH 14: ECONOMETRIC METHODS

by COWLES COMMISSION RESEARCH STAFF  
edited by WM. C. HOOD AND T. C. KOOPMANS

*Tentative Table of Contents:* I. Economic Measurements for Policy and Prediction, *J. Marschak*; II. Identification Problems in Economic Model Construction, *T. C.*



*Koopmans*; III. Methods of Measuring the Marginal Propensity to Consume, *T. Haavelmo*; IV. The Estimation of Simultaneous Linear Economic Relations, *T. C. Koopmans and Wm. C. Hood*; V. Statistical Analysis of the Demand for Food: Examples of Simultaneous Estimation of Structural Equations, *M. A. Girshick and T. Haavelmo*; VI. Asymptotic Properties of Limited-Information Estimates under Generalized Conditions, *H. Rubin and H. Chernoff*; VII. An Example of Loss of Efficiency in Structural Estimation, *S. G. Allen*; VIII. On Specification Errors in Model Construction, *L. Hurwicz*; IX. Source and Size of Least-Squares Bias in a Two-Equation Model, *J. Bronfenbrenner*; X. The Computation of Maximum-Likelihood Estimates of Linear Structural Equations, *H. Chernoff and N. J. Divinsky*.

#### STAFF NOTES AND PUBLICATIONS

Since 1945 the duties of research personnel have been defined as follows: research associates and research fellows devote most of their time to the research work of the Cowles Commission, aided by full-time or half-time research assistants; research consultants cooperate in the work of the Commission by participating in staff meetings, by correspondence, or by other occasional contributions. Only active members are retained on the list of the staff of the Cowles Commission. A summary follows of the activities of staff members during the period of this report.

##### STEPHEN G. ALLEN

Stephen Allen (see 1948-49 report for biographical notes) continued as a research assistant with the Cowles Commission until the end of 1949. His participation in the work of the Commission continued, however, until March, 1950, at which time he received his M.A. in economics from the University of Chicago. He is currently engaged in research at Stanford University.

##### T. W. ANDERSON, JR.

Anderson (see previous reports for biographical details) continued as research consultant of the Cowles Commission during the period of this report. In addition he continued to teach mathematical statistics at Columbia University, including a course in stochastic difference equations, and was promoted to associate professor as of July 1, 1950. As consultant to the Bureau of Applied Social Research he devoted further study to probability methods for analyzing time changes in attitudes, a project arranged by Professor Paul F. Lazarsfeld and sponsored by the Social Science Research Council and The RAND Corporation. He also served directly as a consultant for The RAND Corporation. The American Statistical Association elected Anderson as a Fellow at the New York meeting in December, 1949. He was also elected editor of the *Annals of Mathematical Statistics* by the Council of the Institute of Mathematical Statistics and assumed his new duties on January 1, 1950. He has been appointed to an intersociety committee to study the mathematical training appropriate for social scientists. The following are his papers, published or presented during this period:

"Model Building and Statistical Inference," presented August 30, 1949, in the symposium on "The Mathematical Training of Social Scientists," sponsored by the Econometric Society, Institute of Mathematical Statistics, and Mathematical Association of America, Boulder, Colorado. (Abstract in *Econometrica*, Vol. 18, April, 1950, pp. 201-202.)

"Classification by Multivariate Measures," presented December 30, 1949, before the American Statistical Association, American Psychological Association, Institute of Mathematical Statistics, and Psychometric Society, New York City.

"Distribution of the Circular Serial Correlation Coefficient for Residuals from a Fitted Fourier Series" (with R. L. Anderson), *Annals of Mathematical Statistics*, Vol. 21, March, 1950, pp. 59-81. (Cowles Commission Papers, New Series, No. 42.)

See also paper contributed to *Statistical Inference in Dynamic Economic Models*, Cowles Commission Monograph 10.

#### KENNETH J. ARROW

Kenneth J. Arrow, who joined the Cowles Commission as a research associate in April, 1947 (see previous reports for biographical notes), became a research consultant of the Commission upon accepting appointment as assistant professor of economics and statistics at Stanford University in July, 1949. In addition he has served as a consultant to The RAND Corporation in Santa Monica, California. He is currently program chairman for the Berkeley meeting of the Econometric Society. The following papers were presented or published by him during this period:

"Bayes and Minimax Solutions of Sequential Decision Problems" (with D. Blackwell and M. A. Girshick), *Econometrica*, Vol. 17, July-October, 1949, pp. 213-244. (Cowles Commission Papers, New Series, No. 40.)

"Homogeneous Systems in Mathematical Economics: A Comment," *Econometrica*, Vol. 18, January, 1950, pp. 60-62.

"A Logical Difficulty in the Concept of Social Welfare," presented May 1, 1950, at the Economics Faculty Seminar, Stanford University.

Reviews of "Programming of Interdependent Activities: I. General Discussion," by Marshall K. Wood and George B. Dantzig, and "Programming of Interdependent Activities: II. Mathematical Model," by George B. Dantzig, *Mathematical Reviews*, Vol. 11, March, 1950, p. 193.

#### JEAN BRONFENBRENNER

Mrs. Jean Andrus Bronfenbrenner (see 1948-49 report for biographical notes) continued as a research assistant with the Cowles Commission until October, 1949, at which time she accepted a position with the Office of Business Economics, Department of Commerce. In this work she cooperates with the research project on expectations and business fluctuations conducted by Franco Modigliani, research consultant of the Commission.

#### HERMAN CHERNOFF

Herman Chernoff (see previous reports for biographical notes) continued as a research associate of the Cowles Commission until late September, 1949. At present he is assistant professor of mathematics and statistics at the University of Illinois. He presented the following papers during the period:

"Remarks on a Rational Selection of a Decision Function," presented August 31, 1949, at a joint session of the Econometric Society and Institute of Mathematical Statistics, Boulder, Colorado. (Abstract in *Bulletin of the American Mathematical Society*, Vol. 55, November, 1949, pp. 1075-1076, and *Econometrica*, Vol. 18, April, 1950, p. 182.)

"Some Recent Results in the Theory of Decision Functions," presented March 21, 1950, at the Statistics Seminar, University of Illinois.

#### CARL CHRIST

Carl Christ (B.S. in physics, 1943) joined the Cowles Commission as a research associate in September, 1949, although informally he had participated as a regular staff member during the preceding year. He is concurrently Fellow of the Social Science Research Council, 1948-50. Earlier he was a junior physicist with the Manhattan Project, 1943-45, and instructor in physics at Princeton University, 1945-46. He participated in the Chrysler Corporation Conference on Business Management, June 12-23, 1950, in Detroit. Papers presented by him during the period are as follows:

"Econometric Models and Predictions for the United States, 1921-1947," presented November 17, 1949, at the Cowles Commission Seminar.

"A Revised Klein Econometric Model for the United States, 1921-1947," presented November 25, 1949, at the Universities-National Bureau Conference on Business Cycles Research, New York City.

"Construction and Testing of Econometric Models," presented January 19, 1950, at the Department of Political Economy Seminar, Johns Hopkins University.

#### HAROLD T. DAVIS

Harold T. Davis, professor of mathematics at Northwestern University, continued as a research consultant of the Cowles Commission and as an associate editor of *Econometrica*. Biographical notes are given in the 1942-46 report. Preliminary drafts were prepared by him during the year for a volume on the calculus of probability and statistics and for a paper on finite groups with special reference to the Galois theory. He is a member of the program committee for the December meeting of the Econometric Society in Chicago. Addresses presented and papers published by him during the report period include:

Review of "Coefficients for Facilitating Trigonometric Interpolation" by H. E. Salzer, *Mathematical Tables and Other Aids to Computation*, Vol. 3, July, 1949, pp. 472-473.

"Mathematics and Politics," presented August 30, 1949, before the National Council of Teachers of Mathematics, University of Denver, and November 8, 1949, to Pi Mu Epsilon (mathematical fraternity), Northwestern University.

"The Approximation of Logarithmic Numbers," presented October 6, 1949, at the Mathematical Colloquium, Northwestern University.

"Some Mathematical Adventures in Social Science," presented December 6, 1949, before the Chicago Alumni Chapter of Eta Kappa Nu Association (electrical engineers).

"Ancient Prices and Their Interpretation," presented December 29, 1949, before the Econometric Society, New York City.

*A Bibliography and Index of Mathematical Tables* (with Vera Fisher), Evanston, Illinois, 1949, xxii+286 pp. (mimeographed).

"What Is Einstein Talking About?" presented March 4, 1950, before the University Club of Evanston, Illinois, and May 19, 1950, before the Men's Mathematics Club of Chicago.

"Some Reflections on Power," presented March 5, 1950, before the Northwestern University Chapter of Eta Kappa Nu.

"Continuous Spectra in the Theory of Statistics," presented May 25, 1950, at the Statistics Seminar, University of Chicago.

#### GERARD DEBREU

Gerard Debreu (Agrégé de l'Université, 1946) joined the Cowles Commission as a research associate in June, 1950, upon completion of a Rockefeller fellowship under which he studied at Harvard University, at the University of California at Berkeley, and at the Universities of Chicago, Uppsala, and Oslo. Earlier he studied at the Ecole Normale Supérieure (1941-44) prior to serving in the French army (1944-45). From October, 1946, to December, 1948, he was attaché de recherches at the Centre National de la Recherche Scientifique, assistant professor of mathematics at the Conservatoire National des Arts et Métiers, professor at the Ecole d'Application de l'Institut National de la Statistique et des Etudes Economiques at the Collège Libre des Sciences Sociales et Economiques, and director of a seminar on economic theory at the Ecole Nationale Supérieure des Mines. He presented or published the following papers during the period of this report:

"Les Fins du Système Economique," *Revue d'Economie Politique*, Vol. 59, September-December, 1949, p. 600-615.

"Les Centres de Recherche Economique aux Etats-Unis," presented January 5, 1950, at a Seminar of Professor Allais, Paris, France.

"Valuation of the Social Loss Associated with an Economic Change," presented March 7, 1950, at the Institute of Economics, Uppsala, Sweden.

"Les Grands Chapitres de l'Economie Moderne," presented May 11, 1950, at the Ecole Normale Supérieure, Paris, France.

#### NATHAN J. DIVINSKY

Divinsky (see previous report for biographical notes) continued as a research associate during the period of this report and has been supervising the computational work of the Commission. In this connection he participated in a conference on computing machines at Harvard University in September, 1949. In addition to his work for the Commission, Divinsky completed his research for the Ph.D. in mathematics, which degree he received from the University of Chicago in June. He was elected to Sigma Xi in March, 1950. Divinsky presented the following paper during the year:

"Power Associative Crossed Extension Algebras," presented April 28, 1950, before the American Mathematical Society, Chicago, Illinois.

#### MURRAY GERSTENHABER

Murray Gerstenhaber (see biographical details in previous report) continued as a research assistant until December, 1949, and has since cooperated with the Commission in connection with the mathematical aspects of the study on the theory of resource allocation. In addition, he served as a research assistant in the department of mathematics at the University of Chicago from September, 1949, until June, 1950, at which time he accepted an Atomic Energy Commission Predoctoral Fellowship. He presented the following paper during the period:

"Convex Cones," presented February 7, 1950, before the Junior Mathematics Club, University of Chicago.

#### JOHN GURLAND

John Gurland (M.A. in mathematics, University of Toronto, 1942; Ph.D. in mathematical statistics, University of California, Berkeley, 1948) was appointed assistant professor in September, 1949, jointly in the Cowles Commission and in the Committee on Statistics of the University of Chicago. Earlier he was at the Dominion Bureau of

Statistics, Ottawa, in 1944, and on a war research project at the Statistical Laboratory of the University of California in 1945. During 1948-49 he was Benjamin Peirce Instructor in Mathematics at Harvard University. His addresses during the period are as follows:

"Theory of Statistical Hypotheses," Course Lectures, Autumn, 1949, University of Chicago.

"Minimum Chi-Square as a Criterion of Estimation," presented January 26, 1950, at the Seminar of the Committee on Statistics, University of Chicago.

"Theory of Statistical Estimation," Course Lectures, Winter, 1950, University of Chicago.

#### TRYGVE HAAVELMO

Trygve Haavelmo (see previous reports for biographical details) continued as a research consultant of the Commission during the period of this report. He lectured at the University of Oslo, where he is professor of economics, as well as at the Universities of Aarhus and Copenhagen. In January, 1950, he served as delegate to the United Nations Economic and Employment Commission, during which time he also visited the Cowles Commission and participated in staff discussions. His addresses and papers for the period are as follows:

"Welfare Economics," Six Lectures, Universities of Aarhus and Copenhagen, September, 1949.

"A Note on the Theory of Investment," *Review of Economic Studies*, Vol. 16 (2), No. 40, 1949-50, pp. 78-81.

"Welfare Economics," Course Lectures, University of Oslo.

"The Theory of Long-Term Economic Tendencies," Course Lectures, University of Oslo.

"Okonomisk Likevekt og Okonomisk Velferd," *Statsøkonomisk Tidsskrift*, Oslo, 1950. (Stencil-memo 15, Universitetets Sosialøkonomiske Institutt, Oslo, October, 1949.)

"The Notion of Involuntary Economic Decisions," *Econometrica*, Vol. 18, January, 1950, pp. 1-8. (Cowles Commission Papers, New Series, No. 38.)

See also paper contributed to *Statistical Inference in Dynamic Economic Models*, Cowles Commission Monograph 10.

#### ARNOLD HARBERGER

Arnold Harberger (see 1948-49 report for biographical notes) remained at the Commission as a research assistant until October, 1949, at which time he became assistant professor of economics at Johns Hopkins University. From June to September, 1950, he will serve as economist for the International Monetary Fund, and will then return to his post at Johns Hopkins. He presented the following paper and addresses during the year:

"Some Index Number Problems in Measuring the Elasticity of Demand for Imports," presented December 27, 1949, at a joint session of the Econometric Society and American Statistical Association, New York City.

"Currency Depreciation, Income, and the Balance of Trade," *Journal of Political Economy*, Vol. 58, February, 1950, pp. 47-60. (Cowles Commission Papers, New Series, No. 41.)

"International Trade," "Statistics," and "Economic Analysis," Course Lectures, October, 1949-June, 1950, Johns Hopkins University.

#### CLIFFORD HILDRETH

Clifford Hildreth (see 1948-49 report for biographical details) continued in his joint appointment with the Cowles Commission and the department of economics, and becomes associate professor as of July 1, 1950. In addition to giving the courses indicated below, he engaged extensively in consultation on research problems with members of the Agricultural Economics Research group of the University of Chicago, with members of the staff of the Iowa Agricultural Experiment Station, and with Professor Glenn Johnson of the University of Kentucky. He is program chairman for the December, 1950, meetings of the Econometric Society. His papers and addresses during the period are as follows:

"The Use of Survey Data in Econometric Studies," paper presented September 1, 1949, before the Econometric Society, Boulder, Colorado. (Abstract in *Econometrica*, Vol. 18, April, 1950, pp. 186-187.)

"A Model of Seasonal Fluctuations in Hog Supplies," presented January 20, 1950, at the Agricultural Economics Seminar, University of Chicago.

"Combining Technical and Survey Data on Crop Production," presented January 27, 1950, at the Agricultural Economics Seminar, University of Chicago.

"Introduction to Econometrics," Course Lectures, Winter, 1949-50, University of Chicago.

"Joint Use of Time Series and Cross-Section Data," presented May 26, 1950, at the Statistics Seminar, Iowa State College.

"Economic Statistics II," Course Lectures, Spring, 1950, Iowa State College.

#### WILLIAM C. HOOD

William C. Hood (Ph.D., University of Toronto, 1948) joined the Cowles Commission as research associate in September, 1949, at which time he also became a post-doctoral fellow in political economy at the University of Chicago. He was a member of the department of economics of the University of Saskatchewan, 1944-46, and of the department of economics of the University of Toronto, 1946-49. Earlier, during the war, he served as a meteorologist, attached to the Royal Canadian Air Force. Hood will rejoin the economics staff at the University of Toronto as assistant professor in July, 1950, at which time he will become a research consultant of the Cowles Commission. His addresses and publications during the year are as follows:

Review of "Economic Man in Relation to His Natural Environment" by C. Reinhold Noyes, *American Journal of Psychiatry*, Vol. 106, November, 1949, pp. 393-394.

"Expectation in Economics," presented January 31, 1950, before the Political Economy Club, University of Chicago, and February 13, 1950, at the Department of Economics Staff Seminar, Carnegie Institute of Technology.

#### LEONID HURWICZ

Leonid Hurwicz (see previous reports for biographical data) participated in the activities of the Cowles Commission as a research consultant throughout the period. In September, 1949, he joined the faculty of the University of Illinois as research professor of economics and mathematical statistics. During the year he served on the nominating committee and Midwest program committee of the Institute of Mathematical Statistics and on the program committee for the Harvard meeting of the Econometric Society. He has also been appointed to the intersociety committee on the mathematical training of social scientists. He presented or published the following papers during the period:

"Theory of Econometrics," presented in September, 1949, at the 26th International Statistical Conference, Berne, Switzerland. (Part I published in *Proceedings of the Conference*.)

Discussion of "Stabilization Problems," presented November 27, 1949, at the Universities National Bureau Conference on Business Cycles Research, New York City.

"Estimation Bias Due to Incorrect Choice of Model," presented December 8, 1949, at a joint Statistics Club and Cowles Commission Seminar, University of Chicago.

"A Theory of Stabilizing Business Fluctuations," presented December 28, 1949, before the Econometric Society, New York City.

"Mathematical Foundations of Economics," Lecture Series, 1949-50, University of Illinois.

"Theory of Games and Decision Functions," presented at the Mathematical Statistics Seminar, University of Illinois.

"Theory of Games," presented March 14, 1950, at the Statistics Seminar, University of Illinois.

"Theory of Games as a Way of Looking at Problems," presented March 24, 1950, before the Chicago Chapter of the American Statistical Association.

"Theory of Economic Planning," presented April 20, 1950, at the Economics Seminar, University of Illinois.

"Econometrics," Course Lectures, Winter, 1950, University of Illinois.

"Mathematical Introduction to Macro-economics," Course Lectures, Winter, 1950, University of Illinois.

"Some Implications of Electronic Thinking Organisms," *Current Economic Comment*, University of Illinois, May, 1950.

See also papers contributed to *Statistical Inference in Dynamic Economic Models*, Cowles Commission Monograph 10.

#### CARL N. KLAHR

Carl N. Klahr (see 1948-49 report for biographical information) remained a consultant of the Cowles Commission on its study of the theory of resource allocation until June, 1950. Concurrently he was a fellow in economics at the Graduate School of Industrial Administration, Carnegie Institute of Technology. He received his M.S. in economics and his D.Sc. in physics from Carnegie Institute in June, 1950. Klahr presented the following addresses during the year:

Discussion of "Economics and Technology: Production Functions," presented December 30, 1949, at a joint session of the Econometric Society and Section K of the American Association for the Advancement of Science, New York City.

"The Estimation of Market Demand," Course Lectures, Spring, 1950, Carnegie Institute of Technology.

#### TJALLING C. KOOPMANS

Tjalling C. Koopmans (see previous reports for biographical details) continued as director of research of the Cowles Commission and as professor of economics at the University of Chicago. In October, 1949, he was elected president of the Econometric Society for 1950. He is a member of a committee of the Social Science Research Council on the Social Implications of Atomic Energy and Technological Change. Temporarily he is a member of the Committee on Statistics of the University of Chicago. His addresses and publications during the period of this report are as follows:

"Utility Analysis of Decisions Affecting Future Well-Being," presented August 29, 1949, before the Econometric Society, Boulder, Colorado. (Abstract in *Econometrica*,

Vol. 18, April, 1950, pp. 174-175, and included in Cowles Commission Papers, New Series, No. 43.)

Discussion of "The Reformulation of Current Business Cycle Theories as Refutable Hypotheses" by J. Tinbergen, presented November 26, 1949, at the Universities-National Bureau Conference on Business Cycles Research, New York City.

"Convex Cones and the Theory of Production," presented November 29, 1949, at the Seminar on the Theory of Games, Department of Mathematics, Princeton University.

"Efficient Allocation of Resources," presented December 15, 1949, at the Cowles Commission Seminar, and December 29, 1949, at a joint session of the Econometric Society, American Economic Association, and American Statistical Association, New York City.

"Identification of Structure in Factor Analysis and in Econometrics," presented March 2, 1950, at a joint Statistics Club and Cowles Commission Seminar, University of Chicago.

"Allocation of Resources in Production," Course Lectures, Winter, 1950, University of Chicago.

"The Identification of Structural Characteristics" (with O. Reiersøl), presented April 29, 1950, at the Midwest Meeting of the Institute of Mathematical Statistics, Chicago. (*Annals of Mathematical Statistics*, Vol. 21, June, 1950, pp. 165-181.)

"Linear Graphs and the Economics of Transportation," presented May 6, 1950, before the Indiana Section, Mathematical Association of America, Wabash College, Crawfordsville, Indiana.

"Statistical Methods of Measuring Economic Relations," Course Lectures, Spring, 1950, University of Chicago.

See also papers contributed to *Statistical Inference in Dynamic Economic Models*, Cowles Commission Monograph 10, T. C. Koopmans, ed., New York: John Wiley and Sons, 1950, 438 pp.

#### HARRY MARKOWITZ

Harry Markowitz (M.A., University of Chicago, 1950) became a research assistant of the Cowles Commission in October, 1949. He holds a University of Chicago fellowship in the department of economics. In the year which follows he will continue his research as a Cowles Commission research fellow and Fellow of the Social Science Research Council.

#### JACOB MARSCHAK

Jacob Marschak (see previous reports for biographical details) taught as professor of economics at the University of Chicago and engaged in research as research associate of the Cowles Commission. He served as a member of the organizing and editorial committees of the Universities-National Bureau Conference on Business Cycles Research held in the fall of 1949. As codirector of the study on economic aspects of atomic power, Marschak saw the report of the research to the publication stage. He was active as a council member of the Econometric Society until the end of 1949, and currently is a member of the program committee for the meeting of the Society to be held at Harvard University in September, 1950. He is also a member of an intersociety committee to study the mathematical training appropriate for social scientists. He published or presented the following papers during this period:

"Optimal Investment of a Firm," presented August 29, 1949, before the Econometric



Society, Boulder, Colorado. (Abstract in *Econometrica*, Vol. 18, April, 1950, pp. 176-178, and included in Cowles Commission Papers, New Series, No. 43.)

Review of "Sopra un problema di massimo in meccanica economica" by Luigi Castoldi, *Mathematical Reviews*, Vol. 10, November, 1949, pp. 725-726.

Comments on "What Happens During the Business Cycle—A Progress Report" by Wesley C. Mitchell, presented November 25, 1949, at the Universities-National Bureau Conference on Business Cycles Research, New York City.

"The Rationale of Money Demand and of 'Money Illusion,'" presented December 27, 1949, before the Econometric Society, New York City.

Discussion of "Some Experiments with Statistical Indicators of Cyclical Revivals and Recessions" by Geoffrey H. Moore, presented December 28, 1949, before the American Statistical Association, New York City.

"The Theory of Income, Employment, and Price Level," Course Lectures (hctographed), Autumn, 1949, University of Chicago.

"Rational Decisions and Measurable Utilities," presented January 17, 1950, before the Department of Mathematics, Northwestern University.

"Why Have Cash?" presented January 17, 1950, before Pi Mu Epsilon (mathematical fraternity), School of Engineering, Northwestern University.

"Rational Behavior, Uncertain Prospects, and Measurable Utility," *Econometrica*, Vol. 18, April, 1950, pp. 111-141. (Cowles Commission Papers, New Series, No. 43.)

"Demand for Money in a Riskless Society," presented May 30, 1950, before the Department of Economics, University of Michigan.

Editor of (with Sam H. Schurr) and author of Preface to *Economic Aspects of Atomic Power*, Princeton: Princeton University Press, 1950.

Introduction to *Statistical Inference in Dynamic Economic Models*, Cowles Commission Monograph 10.

#### FRANCO MODIGLIANI

Franco Modigliani (see previous report for biographical data) continued his association with the Cowles Commission as a research consultant during the period of this report. He is associate professor in the Bureau of Economic and Business Research and member of the department of economics of the University of Illinois, and as such is director of a research project on expectations and business fluctuations. He is now serving on the executive committee for the National Conference on Income and Wealth of the National Bureau of Economic Research. He was elected a Fellow of the Econometric Society, January, 1950. The following papers were presented or published by him during the period:

"New Areas of Opinion Research: Economics," Proceedings of the American Association for Public Opinion Research, Fourth Annual Conference, June 15-22, 1949, *Public Opinion Quarterly*, Vol. 13, Winter, 1949-50, pp. 770-771.

"The Use of Sample Surveys of Businessmen's Expectations and Business Plans," presented March 23, 1950, at the Economics Faculty Seminar, University of Illinois.

"Empirical Studies of Expectations and Investment Decisions," presented May 11, 1950, at the Cowles Commission Seminar.

"The Influence of the Availability of Funds and Terms Thereof on Investment Decisions," presented June 21, 1950, at the Conference on Business Finance of the National Bureau of Economic Research, Haverford, Pennsylvania.

"Expectations and Decision Functions," two discussions with the economics faculty, Spring, 1950, University of Illinois.

#### OLAV REIERSØL

Olav Reiersøl (M.A., University of Oslo, 1935; Ph.D., University of Stockholm, 1945) joined the Commission as a research fellow for the summer period of 1949 after serving as visiting professor of mathematics at Purdue University, 1948-49. He is now assistant professor of mathematics at the University of Oslo. Reiersøl was a research assistant to Professor Frisch at the University Institute of Economics in Oslo, 1936-37, and then instructor in mathematical statistics at the University of Oslo, 1938-46, except for the latter part of the war when he took refuge in Sweden. In the spring of 1946 he studied at the University of Cambridge as a Fellow of the British Council. After that he received a Rockefeller fellowship under which he studied at Columbia University, University of North Carolina, University of Chicago, and University of California, Berkeley. During the period of the report he presented or published the following papers:

"Language Statistics and Statistical Studies in Linguistics," presented April 25, 1950, before the Norwegian Statistical Association, Oslo.

"Differential Equations of Sampling Distributions" (mimeographed, in Esperanto with English summary), University Institute of Economics, Oslo, April, 1950.

"On the Identifiability of Parameters in Thurstone's Multiple Factor Analysis," *Psychometrika*, Vol. 15, June, 1950, pp. 121-149. (Cowles Commission Papers, New Series, No. 39.)

"The Identification of Structural Characteristics" (with T. C. Koopmans), *Annals of Mathematical Statistics*, Vol. 21, June, 1950, pp. 165-181. (Cowles Commission Papers, New Series, No. 39.)

#### STANLEY REITER

Stanley Reiter (see 1948-49 report for biographical information) continued as a research assistant of the Commission until the end of December, at which time he became a research associate. In September, 1950, he will join the economics staff at Stanford University. For papers prepared by Reiter during the year see the contents of the monograph on *Activity Analysis of Production and Allocation*.

#### HERMAN RUBIN

Herman Rubin (see earlier reports for biographical data) remained with the Commission as a research associate until September, 1949, at which time he joined the faculty of Stanford University. He presented or published the following papers during the period:

"Postulates for the Existence of Measurable Utility and Psychological Probability," presented September 1, 1949, before the American Mathematical Society, Boulder, Colorado. (Abstract in *Bulletin of the American Mathematical Society*, Vol. 55, November, 1949, pp. 1050-1051.)

"Postulates for Generalizations of Hilbert Space" (with M. H. Stone), presented October 29, 1949, before the American Mathematical Society, New York City.

"An Axiomatic Approach to Integration" (abstract), *Bulletin of the American Mathematical Society*, Vol. 55, November, 1949, p. 1064.

"Measures and Axiomatically Defined Integrals" (abstract), *Bulletin of the American Mathematical Society*, Vol. 55, November, 1949, p. 1064.

"Convergence of Probability Measures on Completely Regular Spaces," presented November 8, 1949, before the joint Stanford-Berkeley Statistics Colloquium, Berkeley, California, and April 20, 1950, at the Mathematics Seminar, Stanford University.

"On the Existence of Nearly Locally Best Unbiased Estimates," presented December 29, 1949, before the American Mathematical Society, Institute of Mathematical Statistics, and American Association for the Advancement of Science, New York City. (Abstract in *Annals of Mathematical Statistics*, Vol. 21, March, 1950, pp. 143-144, and *Bulletin of the American Mathematical Society*, Vol. 56, March, 1950, p. 182.)

See also papers contributed to *Statistical Inference in Dynamic Economic Models*, Cowles Commission Monograph 10.

#### SAM H. SCHURR

Sam H. Schurr (see earlier reports for biographical details) was a research consultant to the Cowles Commission during the year, and saw the manuscript of the Commission's study on the economic aspects of atomic power to the publication stage. He was Chief, Manufacturing and Mining Branch, Division of Interindustry Economics, Bureau of Labor Statistics, U. S. Department of Labor, until June, 1950, at which time he became Chief Economist of the U. S. Bureau of Mines. Concurrently he was associate director of the Teaching Institute of Economics of American University. His publications and addresses during the year are as follows:

"Economic Aspects of Atomic Power," presented September 1, 1949, on "District Viewpoint" over WMAL-TV, Washington, D. C.

"Economic Aspects of Atomic Power," Course Lectures, October, 1949-June, 1950, Teaching Institute of Economics, American University, Washington, D.C., 1949-50.

"The Cowles Commission Atomic Power Cost Estimates: A Reply," *Review of Economics and Statistics*, Vol. 32, February, 1950, pp. 100-102.

*Economic Aspects of Atomic Power* (with J. Marschak *et al.*), Princeton: Princeton University Press, 1950.

#### HERBERT A. SIMON

Herbert A. Simon (see earlier reports for biographical details) continued as research consultant with the Commission during the period of this report, working both on the study of economic aspects of atomic power and on the study of the theory of resources allocation. He resigned as professor of political science and chairman of the department of political science at Illinois Institute of Technology in the summer of 1949 and joined the faculty of Carnegie Institute of Technology as professor of administration and head of the department of industrial management. The following are his papers published or presented during the period of this report:

"Note: Some Conditions of Macroeconomic Stability" (with David Hawkins), *Econometrica*, Vol. 17, July-October, 1949, pp. 245-248.

"The Bases of Political Science," five panel discussions, presented December 28-30, 1949, before the American Political Science Association, New York City.

"Organization and Management," presented December 29, 1949, before the American Statistical Association and Society for Advancement of Management, New York City.

Discussion of "Development of Public Administration Theory during the Past Decade," presented March 11, 1950, before the American Society for Public Administration, Washington, D.C.

"Mathematical Models in Administrative Theory," presented May 4, 1950, at the Seminar on Measures of Organization, Columbia University.

"Discussion: The Semantics of Political Science," *American Political Science Review*, Vol. 44, June, 1950, pp. 407-411.

*Public Administration* (with Donald W. Smithburg and Victor A. Thompson), New York: Alfred A. Knopf, 1950, 582 pp.

Chapters XIII and XIV in *Economic Aspects of Atomic Power*, J. Marschak and S. H. Schurr, eds., Princeton: Princeton University Press, 1950.

#### WILLIAM B. SIMPSON

William B. Simpson (see 1948-49 report for biographical data) continued as research associate and assistant director of research of the Cowles Commission during the year. In October, 1949, he was re-elected secretary of the Econometric Society for 1950. In addition he serves as managing editor of *Econometrica*.

#### MORTON L. SLATER

Morton L. Slater (B.A., Swarthmore College, 1941; M.A., University of Wisconsin, 1942; Ph.D., Harvard University, 1949) was appointed a research associate of the Cowles Commission (with the rank of assistant professor) on January 1, 1950, to engage in research on the mathematical theory of allocation of resources. Prior to joining the Commission he was with Ordnance Research Group No. 1 in Chicago as senior mathematician from September, 1948, to December, 1949. In July, 1949, he participated in a symposium at the University of California at Los Angeles on the "Monte Carlo" method. In addition, he taught mathematics at Illinois Institute of Technology in the fall of 1949. Earlier he was employed by Westinghouse Electric and Manufacturing Company in East Pittsburgh as a statistician from June, 1942, to January, 1943, after which he served in the U. S. Naval Reserve until May, 1946. He presented the following addresses during the period:

"Functional Inequalities Suggested by Game Theory" (with M. J. Norris and C. J. Thomas), presented November 25, 1949, before the American Mathematical Society, Chicago, Illinois. (Abstract in *Bulletin of the American Mathematical Society*, Vol. 56, January, 1950, p. 51.)

"Differential Equations," Course Lectures, Autumn, 1949, Illinois Institute of Technology.

#### GERHARD STOLTZ

Gerhard Stoltz (Cand. oecon., University of Oslo, 1947) became a research assistant of the Cowles Commission in October, 1949, in connection with the study of resource allocation. Concurrently he holds a fellowship from the Norwegian Department of Education and the Nationalgaven til Chr. Michelsen Foundation, 1949-50. Earlier he engaged in research at the Chr. Michelsen Institute, Bergen, Norway, 1947-48, and at the Institute of Sociology, University of Oslo, 1948-49.

#### ERLING SVERDRUP

Erling Sverdrup (Cand. act., University of Oslo, 1945), a Rockefeller Foundation fellow for the years 1949 and 1950, was appointed a research fellow of the Cowles Commission in January, 1950. During the earlier portion of his Rockefeller fellowship he visited Columbia University and the Universities of California and Chicago. Sverdrup worked on problems in mathematical statistics at the University Institute of Economics in Oslo under Professor Frisch in 1946, and later taught, first as a lecturer, 1946-48, and then as an acting professor, 1948-49, at the University of Oslo. He presented the following paper during the period:

"A Theorem in Multivariate Statistical Analysis and Its Application to the Derivation of the Wishart Distribution," presented February 23, 1950, before the Statistics Club, University of Chicago.

## GUESTS

The presence at the Cowles Commission of advanced students and fellows from this and other research centers has both stimulated the work of the Commission and aided in spreading the results of its research.

Earl F. Beach, professor of commerce, McGill University, Canada, maintained contact with the work of the Commission throughout the year. George H. Borts, Social Science Research Council Fellow for 1949-50, was accorded research facilities at the Commission in November, 1949, and will continue at the Commission until late summer of 1950. Karl Brunner, of the Handelshochschule, St. Gallen, Switzerland, and the Swiss Watch Chamber of Commerce, participated in the work of the Commission under a grant from the Rockefeller Foundation from January, 1950, until July, 1950, and will return to the Commission later in the year to complete his study under the grant. Carl Christ, Social Science Research Council Fellow for 1948-50, was a guest of the Commission until September, 1949, at which time he formally became a member of the research staff. Gerard Debreu, Centre National de la Recherche Scientifique, Paris, was at the Commission in late 1949 while a Rockefeller Fellow. In June, 1950, he returned from France to join the Commission as a research associate. Erling Sverdrup, of the University of Oslo, was at the Commission in the late summer of 1949 while on a Rockefeller Fellowship. In January, 1950, he returned to the Commission under a joint appointment as Cowles Commission research fellow and Rockefeller Fellow. Jaroslav Tuzar, a Rockefeller Fellow from Charles University, Prague, continued as a guest of the Commission until January, 1950.

The following also participated in the seminars and staff meetings of the Commission during the year: Ernest P. Billeter, Statistical Office of Zurich, Switzerland; Donald J. Daly, Department of Trade and Commerce, Ottawa, Canada; Jules Leveugle, Institut National de la Statistique, Paris, France; Pierre Maillet, Stagiaire, de Recherches au Centre National de la Recherche Scientifique, Paris, France; David W. Slater, Queens University, Canada, and the University of Chicago; and Robert H. Strotz, Northwestern University. The Cowles Commission also benefited from the brief visits of a number of distinguished guests in addition to those mentioned above.

## OFFICE AND LIBRARY

The activities of the Cowles Commission (and of the Econometric Society which shares its offices) are carried out with the aid of an office staff of approximately ten full-time and several part-time persons. Miss Helen Docekal, who joined the staff in January, 1949, is Administrative Secretary and as such is responsible for various administrative matters as well as the super-

vision of the office. The publication programs of the Commission and of the Econometric Society are the concern of Mrs. Jane Novick, Editorial Secretary. Mrs. Florence Goldwasser was in charge of the library until June, 1950, at which time she was succeeded by Miss Jean Curtis. The balance of the group includes mathematical technicians, editorial assistants, bookkeepers, secretaries, and technical typists.

The offices and library of the Cowles Commission are located in the Social Science Research Building on the quadrangles of the University of Chicago, overlooking the Midway Plaisance. The Commission has a working library specializing on material pertinent to its investigations, particularly in the fields of quantitative economics, statistics, mathematics, economic theory, and descriptive data. Additions to the library during the period covered by this report total 168 books, 1213 pamphlets, and 149 bound volumes of journals. About 134 periodicals are received currently. The total collection consists of 2449 books, 5236 pamphlets, and 594 bound journal volumes. In addition, the library of the late Professor Henry Schultz, which contains 950 books and 1750 pamphlets, is kept in the Commission's offices. The library is open to members of the Department of Economics as well as to advanced students by arrangement.

#### EXECUTIVE AND ADMINISTRATIVE COMMITTEES

The Commission runs its academic affairs under the supervision of an executive committee consisting of the Dean of the Division of the Social Sciences (Ralph W. Tyler), the Chairman of the Department of Economics (Theodore W. Schultz), the President of the Cowles Commission for Research in Economics, the Director of Research (as Chairman), and the Assistant Director of Research. Its administrative affairs are under the supervision of an administrative committee consisting of the last three mentioned above.

#### FINANCIAL SUPPORT

Acknowledgment is made to the Rockefeller Foundation and the University of Chicago for financial assistance in the Commission's research on the econometric foundations of rational economic policy. The study on the theory of allocation of resources is conducted on a cost basis under a subcontract with The RAND Corporation. As in previous years, a substantial contribution toward the support of the Commission has been made by its founder, Mr. Alfred Cowles, and by members of the Cowles family.

Several members of the research staff have held fellowships from the Rockefeller Foundation, the Social Science Research Council, or the University of Chicago. It should also be added that the Cowles Commission has on

occasion derived much benefit from visits of Fellows of the Rockefeller Foundation.

#### PRESENT NEEDS AND FUTURE PROSPECTS

The present effectiveness and future development of the research activities of the Cowles Commission will depend to a considerable extent upon the provision of additional financial assistance, primarily for purposes which are not provided for under the present grants.

Publication of the research output of the Commission has been limited in extent and considerably delayed by the high cost of printing technical material. Additional financial support for the publication program of the Commission would remove this difficulty by enabling the Commission to bear some of this higher cost, thus assuring wider distribution of its specialized materials among research workers and interested students.

There is also a problem of a more long-run nature, namely, the problem of an endowment which would assure to the Commission a permanent source of income. The need also exists for developing a fund which can be drawn upon for the acquisition and maintenance of additional space adequate for the interested group of advanced students and research fellows which is drawn to the Commission.

Under such circumstances, and were the necessary funds available, the work of the Commission could be further diffused through a program of scholarships and grants-in-aid whereby both graduate students and mature scholars would be able to familiarize themselves with the work of the Cowles Commission and the techniques which it is developing, through periods of resident cooperation with the research staff.

The Cowles Commission is a not-for-profit corporation and money invested in its activities is devoted to the furtherance of the social welfare, now and in the years to come.

## THE ECONOMETRIC SOCIETY

The Cowles Commission offices have continued to serve as headquarters of the Econometric Society, an international society for the advancement of economic theory in its relation to statistics and mathematics.

Several members of the Cowles Commission staff hold offices in the Society. Tjalling C. Koopmans was vice-president of the Econometric Society until the end of 1949, at which time he became president. William B. Simpson was re-elected secretary of the Econometric Society and continues as managing editor of *Econometrica*. He has been active in organizing the various meetings of the Society. Alfred Cowles continued as treasurer of the Society and also as the business manager of *Econometrica*. Harold T. Davis is an associate editor of the journal. Jacob Marschak was a member of the Council of the Econometric Society during 1949 and was active in organizing the Boulder Symposium on Mathematical Training of Social Scientists.

Various members of the staff served on program committees or presented papers or discussion in connection with the meetings of the Society. Others are members of a study committee which was an outgrowth of the symposium on mathematical training mentioned above. One member of the Commission, Franco Modigliani, was elected a Fellow of the Econometric Society during the year.

Starting in September, 1948, the practice was adopted of holding the American summer meeting of the Econometric Society in conjunction with the meetings of the American Mathematical Society, Mathematical Association of America, and Institute of Mathematical Statistics, with emphasis being placed upon papers of a mathematical and technical nature. In 1949 this meeting was held at the University of Colorado in Boulder, Colorado, with additional sessions arranged in order that it could also serve as a regional meeting. In 1950 the Econometric Society will meet at Harvard University, August 31 to September 5, concurrently with the International Congress of Mathematicians.

The practice of holding a regional meeting of the Econometric Society on the West Coast has been initiated this year. The first meeting will be on the Berkeley campus of the University of California, August 1-5, 1950, in conjunction with the second Berkeley Symposium on Mathematical Statistics and Probability and the meeting of the Institute of Mathematical Statistics.

The American winter meeting of the Society is usually held at the same time and place as the meetings of the American Economic Association, American Statistical Association, Institute of Mathematical Statistics, and other components of the Allied Social Science Associations, and some joint sessions are arranged. This was held in New York City in December, 1949, with a total attendance of all participating societies of over 4,300. A session



also was held jointly with Section K of the American Association for the Advancement of Science, with which section the Econometric Society is affiliated. Sessions of the Econometric Society are open to all its members as well as to the members of the other organizations and the general public. Attendance at particular sessions ranges from 25 to over 300. The 1950 meeting with the social science organizations will be in Chicago, December 27-30.

In 1949 the European meeting of the Econometric Society was held at Colmar, France, in September so as to permit participation by members of the Econometric Society in both the meeting of the Income and Wealth Conference at Cambridge, England, and the meeting of the International Statistical Institute at Berne, Switzerland. It is planned this year for Varese, Italy, September 6-8.

Asiatic meetings of the Econometric Society will be held this year in Tokyo, Japan, in connection with the annual meeting of the Japanese Statistical Association, and in India in connection with the meeting of the Indian Economic Association and related organizations.

The Society continues its consultative status with the Economic and Social Council of the United Nations, and its affiliation with the International Statistical Institute. The Society appointed a representative to the United Nations Scientific Conference on the Conservation and Utilization of Resources, and a report of the conference was published in *Econometrica*. In addition, the Society will be represented at a round-table conference of the newly organized International Economic Association at Monaco in September.

During 1949, Volume 17 of *Econometrica* was published, consisting of three regular issues supplemented by a 350-page volume containing econometric papers which were presented at the International Statistical Conferences in Washington, D. C., in September, 1947. The distribution of the supplement has been delayed, but will be completed in the near future.

The active mailing list of the Econometric Society as of September 30, 1950, the end of the current fiscal year for the Society, will include approximately 1,300 members and 750 nonmember subscribers, chiefly libraries. About half of the membership joined the Society during the 18 months preceding that date, a fact which is indicative of the rapid growth which the Society has recently experienced. Slightly over one-half the members and subscribers are in the United States and the remainder are in 64 other countries.

## COWLES COMMISSION MONOGRAPHS

No. 1. DYNAMIC ECONOMICS, by CHARLES F. ROOS. 1934. 275 pages.

No. 2. NRA ECONOMIC PLANNING, by CHARLES F. ROOS. 1937. 596 pages.

No. 3. COMMON-STOCK INDEXES, by ALFRED COWLES AND ASSOCIATES. Second Edition, 1939. 499 pages. Price \$6.00. New monthly indexes of stock prices, stock prices adjusted for reinvestment of cash dividends, and yield expectations; and annual indexes of yields, dividend payments, earnings-price ratios, and earnings; for 69 industry groups, 1871-1938.

No. 4. SILVER MONEY, by DICKSON H. LEAVENS. 1939. 439 pages. Price \$4.00. A sketch of the history of the monetary use of silver, followed by more detailed consideration of recent developments.

No. 5. THE VARIATE DIFFERENCE METHOD, by GERHARD TINTNER. 1940. 175 pages. Price \$2.50. The history and use of this method for the analysis of time series, with new devices of treatment and extensive tables to aid calculations.

No. 6. THE ANALYSIS OF ECONOMIC TIME SERIES, by HAROLD T. DAVIS. 1941. 620 pages. Price \$5.00. The historical development of the analysis is reviewed, methods are described, and applications made to economic phenomena.

No. 7. GENERAL-EQUILIBRIUM THEORY IN INTERNATIONAL TRADE, by JACOB L. MOSAK. 1944. 187 pages. Price \$2.50. The modern theory of economic equilibrium (as stated by J. R. Hicks and others) applied to an important field.

No. 8. PRICE FLEXIBILITY AND EMPLOYMENT, by OSCAR LANGE. 1944. 114 pages. Price \$2.00. A clarification of important concepts that have had much currency in the practical discussion of depressions and wars but remained too vague to allow of useful treatment.

No. 9. PRICE CONTROL AND BUSINESS, by GEORGE KATONA. 1945. 246 pages. Price \$3.00. A study of the working of price control based on field studies among producers and distributors of consumers' goods in the Chicago area, 1942-1944.

No. 10. STATISTICAL INFERENCE IN DYNAMIC ECONOMIC MODELS, edited by TJALLING C. KOOPMANS, with Introduction by JACOB MARSCHAK. 1950. 438 pages. Price \$6.00. Original contributions from many authors concerning statistical problems encountered in economic model construction.

No. 11. ECONOMIC FLUCTUATIONS IN THE UNITED STATES, 1921-1941, by LAWRENCE R. KLEIN. 1950. 174 pages. Price \$4.00. The methodology of econometric model construction is applied to business cycle analysis with possible implications for prediction and policy making.

No. 12. SOCIAL CHOICE AND INDIVIDUAL VALUES, by KENNETH J. ARROW. Price \$2.50. Forthcoming. Methods of symbolic logic are applied to the question whether a social valuation of alternatives can be consistently derived from given, partly conflicting, individual valuations.

No. 13. ACTIVITY ANALYSIS OF PRODUCTION AND ALLOCATION, Proceedings of a Conference, edited by TJALLING C. KOOPMANS. Forthcoming. Contributions from economists and mathematicians on the theory and techniques of efficient allocation of resources and programming of activities.

Orders for Monographs 3-9 (1 and 2 are out of print) should be sent to THE PRINCIPIA PRESS, INC., Bloomington, Indiana. Orders for subsequent monographs should be sent to JOHN WILEY AND SONS, 440 Fourth Avenue, New York 16, New York.