COWLES COMMISSION
FOR RESEARCH IN ECONOMICS

REPORT FOR PERIOD
JANUARY 1, 1948–JUNE 30, 1949

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 present report covers an eighteen-month period due to a change in the fiscal year of the Commission.

The Report in Brief*

The research of the Cowles Commission is organized along two main lines. One of these is the study of actual economic behavior, particularly in the causation of business cycles. The ultimate objective of this line of research is to predict the effect of different factors upon economic activity and thus to provide a scientific basis for the formulation of public and private economic policy. The other principal topic of research of the Commission is the study of optimal economic behavior. Here objectives are stated and rules of behavior are derived whereby those objectives can best be obtained. The theory of resources allocation is being investigated for the insight it gives in evaluating the effectiveness of an individualistic market economy. It is studied also for the direction it gives to allocative decisions within a large administrative organization where the guideposts of a market are lacking.

Other special research studies are in various stages of completion, including a study of the economic aspects of atomic energy as a source of power and a study of the economics of transportation.

From the viewpoint of research method, the Commission's particular field of specialization is econometrics: the formulation of precise economic theories of practical relevance and the submission of these to statistical tests. The Commission conducts and promotes research into those economic problems in which mathematical forms of expression and statistical techniques are important aids to a solution, with the purpose of developing economics as a well-articulated, verifiable, and useful science. Advances have been made in empirical investigation, in the revision of economic fundamentals, and in the improvement of statistical methodology, and work is continuing along these lines.

The Cowles Commission is particularly well equipped to cope with the manifold aspects of these problems. Its research activities are characterized by cooperation among research workers with a variety of background 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 team work is implemented by frequent staff meetings and by occasional conferences at which the resident staff is joined by research workers from other institutions. Also participating in these discussions are advanced students and research fellows from other American and foreign academic centers. The effectiveness of these research efforts is furthered by a staff

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

which provides library, computational, editorial, and secretarial facilities. The organization as a whole includes about forty individuals, working full- or part-time. Their efforts correspond to the full-time equivalent of about 16 research workers and about 11 office workers.

The Commission conducts semi-monthly seminars devoted to varying topics related to the measurement 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, and the Bureau of Business Research of the University of Illinois. The Commission or its members have rendered consultative services to the U.S. Bureau of the Budget and to The RAND Corporation, a nonprofit research organization under contract with the United States Air Force. In addition, the Commission has recently organized a research conference at the University of Chicago in which representatives from universities, government agencies, and independent research organizations participated. This conference was devoted to the problem of best utilization of resources in production and to the methods of programming the interdependent activities of a large organization. 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 research output of the Commission is made available through publication of books and through reprints of papers in various journals. Interested research workers and students have access to the work of the Commission through these media, as well as through invitations to staff meetings, attendance at its seminars, use of the library of the Cowles Commission, and through the courses offered in various universities by members of the staff.

The period covered by this report has been one of reorganization and expansion. The University of Chicago has given increased support and recognition to the Commission. Increased support has also been given by the Rockefeller Foundation to the work on economic behavior and business cycles. The new project on best allocation of resources is supported by a subcontract with The RAND Corporation. In addition, the study on economic aspects of atomic power, initiated by the Social Science Research Council in 1946, benefited during the period from grants from the Rockefeller Foundation and the Life Insurance Association of America. As a result of these favorable circumstances, the scale of operations has almost doubled over the last two years. At the same time a more extensive publication program is being undertaken.

The Study of Economic Behavior

Economic events, fluctuations, trends, are the outcome of a multitude of actions taken by individuals, in the same manner in which the behavior of a gas, its turbulence, its expansion, is reducible to the behavior of the molecules of which it is composed. Does this analogy help us in our attempts to understand the working of the economy, to predict economic change, or to appraise the effectiveness of economic policies or institutions?

A moment's reflection will make us see important differences between the economist's situation and that of the physicist. The physicist experiments; the economist only observes. The physicist does not assume differences between the properties of molecules of the same kind. The economist is faced with wide variety between individuals, in tastes and in modes of response. He finds further that these individual characteristics are modified by environment and experience.

In these respects the economist appears to be at a disadvantage in our comparison. There is one, partly compensating, advantage. Because the economist is himself one of the "molecules," one of the individual actors in the economic play, he can examine his own motivations. Also, by questioning and other forms of contact, he can directly observe the economic behavior of other individuals and explore their motives, in a way no physicist can get at his molecules. The possibility of sympathetic observation of individual economic behavior must be fully exploited to make up for the impossibility, in our institutional framework, of making experiments with the economy as a whole for the purpose of gaining knowledge of it.

There are economic decisions of many different kinds, several of which may be made by the same individual. Consumers decide how much of their income to spend, how much to save. They decide how to distribute their expenditure over a period of time, and between commodities. Workers choose an occupation and negotiate collectively for wages and hours of work. Businessmen make a great variety of additional decisions: how much to invest, at what time and in what type of plant, equipment or inventory; how much to borrow or lend; how much to produce of a variety of goods and with what combination of labor, materials, and equipment; at what prices to sell and buy. Decisions are always made in response to current economic circumstances as understood by the individual. The businessman expands his plant when and because the market situtation promises good profits. The consumer delays a purchase because he reads the signals as portending a fall in price.

Actual Behavior

To obtain a satisfactory explanation of economic fluctuations and developments it is necessary to study whatever regularities exist in *actual economic behavior*, the actual response of individual persons or firms to their economic circumstances. It is a basic assumption of scientific economics that such regularities will become apparent, if not in the comparison of a few individuals' decisions, then in the study of large representative samples of individuals; if not in the comparison of responses to a few different economic situations, then in the systematic exploration of behavior in the wide variety of situations and combinations of circumstances covered by historical and statistical records.

Since "behavior" is "response to circumstances," it is natural and useful to describe it by a mathematical relationship. Such a "behavior equation" specifies how a decision variable (the rate of output, or the amount of investment, or the selling price, or the rate of consumption) of an individual depends on the state of the environment. By environment we mean natural factors, such as weather, soil and other natural resources, as well as conditions created by other men's earlier decisions, such as market prices, tax rates, etc. If equations describing the same type of decision by all individuals in a certain group (consumers, or steel producers, or agricultural workers) are assumed to be sufficiently alike, the notion of an aggregate or average behavior equation for that group is the next useful generalization. Studying economic behavior thus means studying the properties of individual behavior equations, or their summarization in aggregate relationships that describe the added or joint responses of many individuals.

There are various methods for the study of actual economic behavior. The most direct method is introspection. Next to it in directness is the interview method: asking economic actors what habits, rules, codes, motivations, and objectives they follow in the play. A technical problem in both methods is to insure proper representativeness of the sample of individuals involved. More fundamental problems are encountered in the formulation of the questions to be asked and in the interpretation of the answers. How conscious is the actor of his habits and motivations? How willing is he to state his objectives? What questions will best bring out relevant information about his behavior?

The introspective and interviewing methods supplement, and are supplemented by, another method, toward the development of which a good deal of the research of the Cowles Commission has been directed over the last five years. This is the measurement of behavior equations from statistical data reflecting past decisions. These data are primarily annual or

quarterly figures for such variables as national income, consumption expenditures, investment outlay, price index numbers, etc., sometimes also cross-section data for firms or households, such as are obtained from the biennial census of manufactures or from the consumers' purchases studies made from time to time.

This "statistical" method is indirect. It relies heavily on setting up in advance plausible hypotheses about each behavior equation, about the variables entering into the type of decision considered, and about the way in which the effects of these variables combine. For example, such hypotheses may say that, out of a certain income, consumers on the average spend 90% on consumption, but out of each dollar in excess (or short) of that income, they spend (or fail to spend) only 80 cents. Instead of 90% and 80 cents, these numbers may be introduced as unknown "behavior constants," the hypothesis saying only that these unknown numbers remain reasonably constant through a period of years.

The formulation of these hypotheses may be likened to the framing of questions in the interview method. The statistical data take the place of the answers to the interviewer's questions. To the interpretation of the answers corresponds the statistical testing of the hypotheses and the numerical estimation of the behavior constants by mathematical calculations performed on the data. "Interpretative" problems of a different kind also arise here. One of these is the identification of any particular behavior equation (that is, its proper separation from other relationships in which much the same variables participate). This is a necessary preliminary to testing the validity of the equation or to estimating its constants. Both the identification and the subsequent testing or estimation of a behavior equation are helped by narrowing down the initial hypothesis about it. If we take for a moment as certain that fluctuations in the volume of profits have a consistent and proportionate effect on investment in plant and equipment, we have a better chance to determine whether and to what extent there exists an additional and separate influence of the rate of interest on such investment. If we assume that consumers' demand for cotton depends on consumers' incomes, the price of cotton, and the price of wool, we are in a better position to determine whether and to what extent it depends on the price of rayon besides.

Thus the "statistical" method depends on some minimum of prior information about economic behavior which is not derived from the numerical data to which the statistical method is applied. There are three main sources of this prior information: direct observation, possibly systematized in the interview method; broad experience gained from periods, countries or industries other than those being studied; and eco-

nomic theory, i.e., logical deduction from some general principle of behavior. (A fourth possible source, experimentation, has so far been of very limited usefulness.) The interview method will supply correct information to the extent that it observes accurately; experience is valuable where circumstances are comparable; the deductive method will yield realistic conclusions to the extent that the assumed principle of behavior is realistic.

The principle most fully elaborated in economic theory is that of *rational economic behavior*. This principle assumes that the individual makes decisions so as to reach, from among the alternatives open to him, that position which ranks highest in some appropriate scale of value. To the entrepreneur, this scale may be given by the amount of profits earned. To the consumer, it may be satisfaction or happiness.

Rational Behavior

The principle has considerable appeal as a first approximation to actual behavior. Nevertheless, critics have pointed to the strength of habits, imitation, prejudice, or ignorance in shaping decisions. Thus, as a means in the study of actual behavior, the assumption of rational behavior must be regarded as an approximation, indicating the outcome of those decisions where informed consideration or calculation prevails over habit or prejudice. Whenever deductions from the principle of rational behavior can be confronted with facts, the test should be made in order to enlarge our experience with regard to the validity of the principle.

To those who feel that little rational behavior, in the sense described, is found in economic reality, an additional and different justification for the theoretical study of the principle can be given. Such study yields valuable advice to the individual who desires to attain highest profits or to reach highest satisfaction. This second justification becomes more important as the theory becomes more complicated. To conduct a large, integrated enterprise in a world full of uncertainties so as to make the highest profit achievable over an extended period is by no means a simple task. Thus, according as the theory places heavier requirements on managerial thinking and planning, it gains in value as advice at the same time that it loses in value as an explanation of the actual economic behavior of a majority of firms or individuals.

We are still speaking here of advice to the individual, to help him attain a position that is best from his individual point of view. It has not been said or implied that the outcome of each individual's striving for a situation that looks best to him would also be most desirable for society as a whole. Whether this is true, or under what conditions it is true, is a

question that has held the constant attention of economists for a long time. The idea of harnessing all individuals' pursuit of their individual objectives to some common good is fascinating and has inspired much of the best thinking that has gone into economic theory.

Optimal Behavior

The study of *optimal economic behavior* in its widest sense is also known as "welfare economics." This is a normative science: it starts with the accurate formulation of some objective to be regarded as economically good for society and derives rules of behavior from that objective. We can distinguish, although not always separate in analysis, an objective for the decisions with regard to production, and an objective with regard to the distribution of goods, or of income, among people. The formulation of the latter is no doubt the more difficult problem, in which deep philosophical, ethical, and social issues are involved. Efficiency in production can be judged more readily once the quantities and types of goods desired are regarded as given. To see whether available resources in land, labor and capital equipment are used and combined in the manifold productive activities in the most efficient manner, we apply a criterion based on the following question: If the output quantities of all final products but one are to be held at the given levels, is there any way to raise the output of the one remaining final product by reshuffling and differently combining intermediate products or available primary resources? If there is, full efficiency has not yet been attained.

This criterion is formulated in an institutional vacuum, so to say. It is applicable to any form of society in which production occurs, including the one-man society of Robinson Crusoe. It can be used to appraise the economic performance of a planned economy as well as to evaluate the effectiveness of an individualistic market economy. It also provides a yardstick for productive decisions within a large administrative organization in situations where the guideposts of a market are lacking. Examples of such situations are the production scheduling of an integrated concern, the routing of railroad cars, the conservation policies of the nation, or the programming of the activities of the military establishment.

Appraisal of the functioning of the individualistic market economy is one of the most important tasks of economics as an applied science. Few economists in our day contend that the individualistic pursuit of individual economic ends produces a distribution of income which is most desirable for society. The wide support given to progressive taxation is evidence of a different conviction. However, the view is widely held that with some institutional changes, notably effective curbs on monopolistic pricing, individual pursuit of highest profit or highest satisfaction can

bring about efficient allocation of resources in production. The validity of this view is well established for a static society in which there are no business cycles, no new inventions and new processes; a society in which the best method to combine resources in production is adopted once and for all, without need for revision because of changed circumstances. But the real world is not made that way. It will be necessary to examine further the problems of best use of resources in a dynamic world. Only the first beginnings of a dynamic welfare economics have been made.

In a narrower sense, the problem of optimal economic behavior can be said to include the discussion of economic policies of governments. Such a discussion is normative with respect to the behavior of the government, but is realistically descriptive with respect to the behavior of all other parties that make economic decisions. Given knowledge of the actual behavior, the actual mode of response, of businessmen, consumers and workers, it is asked by what policies can governments best achieve any given economic objective of society. While "political economy" in this sense is older than welfare economics, again its problems have been solved only in small parts, particularly with regard to the dynamic aspects of economic life. A realistic knowledge of actual behavior is a prerequisite for a useful discussion of public economic policy.

Report on Research Activities

The research activities of the Cowles Commission are characterized by cooperative teamwork among research workers with a variety of background and training. It is believed that the product of this type of teamwork is better than what could be achieved by each member working separately. While individual authors or co-authors remain ultimately responsible for their publications, they receive the benefit of critical discussion and evaluation of each piece of work by their colleagues.

During the last few years the Commission's main efforts have been directed toward a project, "Econometric foundations of rational economic policy," and research on this project was continued during the report period. In addition, a new project on the "Theory of resources allocation" was started at the beginning of 1949. A special study on the economic aspects of atomic energy was completed in the report period and the manuscript is being prepared for publication. Other special studies are being continued.

The report on the work under the two main projects will be arranged under the headings "Actual," "Rational," and "Optimal" behavior used in the introduction, but it will be convenient to change the order of the first two headings. Under an additional heading, "Study and Develop-

ment of Methods," the work on construction and evaluation of research tools will be described.

Research on Rational Behavior

Various staff members were interested in the logic of rational behavior of people as a means of explaining, if only as an approximation, the facts of production, markets, and business fluctuations. For example, there is a need for a theory of liquid assets, of inventories, and of plant expansion. Clearly, the sum of the decisions of individual firms as to what should be the best balance sheet of each firm, at a given time, affects the flow of orders and the rate of output and construction, and is of great importance for the general level of employment and of prices. Equally important are the consumers' choices of various ways of using their incomes, including decisions to buy houses and securities or to insure one's life. All these decisions are based on judgments about the future, generally an uncertain future. Decisions which leave a free hand for the future are preferred to detailed commitments. Koopmans used this principle in discussing decisions of which the effects extend over a long period of time (seminar of May 26, 1949). Marschak has studied the preference for liquid assets, in particular the effect of varying degrees of uncertainty upon the firms' propensity to enter into commitments characterized by different degrees of "convertibility." In more uncertain times, short contracts are preferred to those for long term, and the demand for liquid assets rises relative to that for finished goods. Fluctuations in inventories must be related to the logic of planning for the future. Classical economic theory assumed that buyers and sellers knew the future and therefore could balance demand and supply by adjusting prices very quickly. What can then explain the considerable changes of inventories (other than those occurring seasonally)? Rather than neglect the fact of uncertainty, it is more useful to ask how rational buyers and sellers should behave when the future is uncertain. By what process of trial and error should they adjust prices and vary their production and sales programs?

In one branch of activity of a modern firm, rational rules of behavior under uncertainty have actually been developed. This is the statistical inspection of the quality of product. Inspection errors are inevitable. Good products may be rejected or bad ones accepted. But the modern statistician designs the experiment, the sample, and the formulas in such a way that in the long run the loss caused to his firm by such errors, added to the cost of inspection, should be smaller than if any other designs were used. It is rational to extend the same principle to other plans and designs of a firm, including its marketing strategy, the setting of prices, and formation of inventories. This was pointed out by Arrow, who is also a

contributor to recent advances in the theory of statistical designs. Allen has formulated a rational theory of decisions on inventories as a part of a model constructed to explain actual fluctuations in the linseed oil industry. In the section on actual behavior more will be said on this study and also on Modigliani's inquiry into the actual motivation underlying the expansion of a plant. Modigliani, too, has prepared the ground for his empirical work by formulating hypotheses on the rational behavior of firms. Another theoretical analysis of investment motives and their implications for business cycle theory was done by Haavelmo.

The study of rational behavior, if it is not to bog down in vague platitudes, requires rigorous logical tools. In addition to the staff members already mentioned, Chernoff, Hildreth, Rubin and Savage (the latter of the Committee on Statistics, University of Chicago) contributed in this spirit to clarifying the fundamental issues of human choice under uncertainty; and a special series of Cowles Commission Seminars was devoted to the discussion of a pioneering book in this field, von Neumann and Morgenstern's *Theory of Games and Economic Behavior*. Some of the axioms of rational behavior proposed by these authors were reshaped by Marschak and Rubin to prove in a simple way that degrees of satisfaction can be made measurable, since men's choices between alternatives subject to numerical given probabilities—as in games of chance—can be recorded. Measurability of satisfaction simplifies the analysis of assets and, more generally, of behavior strategies.

From the behavior of individual firms in various industries, of individual consumers in various social groups, of individual workers, farmers, or landlords, borrowers, and lenders, etc., one can arrive at a theory of economic aggregates, which, if it agrees with facts, would explain the major changes in national income, or predict the effects of major policies. We call the technique of this transition from the economics of individuals to the economics of a social group, or a whole nation, "aggregation." In the past, a special part of this technique was developed under the name of "index numbers" (such as the Federal Reserve Board Production Index, or various indices of price level), but the problem is far from solved. Arrow has studied this, partly in connection with the problem of the existence of criteria of social welfare, of which more will be said under "Research on Optimal Behavior" and under "Study and Development of Methods" below.

With the response patterns of individuals properly aggregated, one would obtain a rationally derived model of the economy as a whole, or of a particular section of it. Assume over-all rationality but ignore, as the classical theory tends to do, men's concern with the future. Then dis-

turbing difficulties arise. If a man does not have savings, he must be indifferent to a doubling of all prices if accompanied by the doubling of his income; and a rational worker must be concerned with his real, not his money wage rate. It turns out that under these circumstances, the equating of all demand with all supplies, including the demand for and the supply of labor, becomes impossible. Patinkin, Haavelmo, and Marschak approached this apparent paradox from different angles: neither are people affected by current prices and incomes only—they are concerned with future changes, too; nor are demand and supply instantaneously equated—for example, a prolonged divergence between demand and supply has existed in our day in the markets for labor and for housing.

Similar problems arise in explaining the demand for labor, raw materials, etc., by a firm operating in competitive markets under conditions of "constant returns to scale." If the doubling of manpower and all other inputs doubles the output, any scale of output gives rise to the same unit profit, and the actual demand for labor by rational firms remains unexplained. This has occupied Christ and Marschak and has implications for the former's study of the actual working of the economic system.

On the borderline between the fields of "rational" and "actual" behavior is Simpson's exploration of the process of decision-taking, in which the effort of information-gathering and problem-solving is regarded as a cost which may be economized on, rationally or not, by shortcuts or rules-of-thumb.

The following staff papers indicate the discussions held during the report period in the field of rational behavior. The problems are arranged approximately in the same order as in the text above.*

The Role of Liquidity under Complete Information (P): *Marschak*
The Theory of Price Adjustment: *Arrow*
Discussion of Price Adjustment: *Melvin Reder*, University of Pennsylvania
Measurable Utility and the Theory of Assets (P): *Marschak*
Theory of the Firm: Some Suggestions: *William W. Cooper*, Carnegie Institute of Technology
On a Rational Selection of a Decision Function: *Chernoff*
The Determination of Many-Commodity Preference Scales by Two-Commodity Comparisons: *Arrow*
Involuntary Unemployment (with Mathematical Appendix) (P): *Patinkin*
Homogeneous Functions in Mathematical Economics: *G. Tintner*, Iowa State College
Homogeneous Systems in Mathematical Economics: *Arrow*
Remarks on Arrow's paper above: *Marschak*
A Note on the Theory of Investment: *Haavelmo*

* The letter (P) indicates items which staff members have published or presented in meetings or lectures during this report period. The place and date of publication or presentation of such items will be found in the section "Staff Notes and Publications" which also includes the discussion topics and papers which were mentioned in the 1947 report, but reached the publication stage in 1948–49.

Logical Relations between Production Functions and Demand Equations for Factors: *Christ*
Is the Production Function Redundant?: *Marschak*
Maximizing the Profit Integral under Imperfect Competition: *Klein*

Research on Actual Behavior

When L. R. Klein's *Economic Fluctuations in the United States, 1920–1941,* was being prepared as a Cowles Commission monograph, the tentative nature of this effort was recognized by the author as well as by the rest of the staff. Some of Klein's hypotheses about the responses of various social groups (consumers, entrepreneurs, etc.) to changes in incomes, prices, wages, and interest rates were formulated before the theoretical problems of rational behavior were more fully explored. Possibly even more important, Klein's data were limited to twenty interwar years during which some variables that showed great changes after World War II remained stable. It was therefore realized that advantage must be taken of new data as soon as they become available, thus helping to revise the findings. Andrew Marshall was able to compare the actual figures for 1946 and 1947 with the figures which would have been obtained if Klein's equations were true. Following Marshall's findings, and on the basis of further theoretical thought, Christ is proceeding to modify the model. Thus Marshall found a strong discrepancy between the actual and the predicted consumption level, and Christ assumes that this was due to Klein's having neglected the possible effect which consumers' hoards of money and war bonds may have upon their spending, an effect not allowed for in Klein's equation. Marshall found that Klein's equation explaining the demand for labor did not apply well to the later data; Christ will modify the equation; and so on. As a longer-range project, Christ is constructing a new model for the United States. This new model will necessarily have certain marked similarities to the Klein models. It is intended that certain variables left "unexplained" by Klein will be "explained" as a result of the addition of some behavior equations. The chief usefulness to be expected of an aggregative model for the whole economy, in addition to predicting future economic trends, is in determining the effect of particular economic policies. If this purpose is to be served well, it is necessary that the instruments of the important alternative policies be incorporated in the model. This means that it would be desirable to include policy variables to represent tax schedules and transfer-payment schedules, consumer credit regulations, bank credit restrictions, open market operations of the Federal Reserve Board, farm price supports, etc., in addition to those appearing in Klein's model.

On similar lines, Cooper tested behavior hypotheses on demand and

supply of agricultural and nonagricultural products, and the demand for labor in and outside of agriculture. He used data on aggregate production, labor, etc., for each of the twenty years between the two world wars. The estimates obtained for some economic magnitudes proved extremely unstable. For example, the predicted change in output resulting from a given change in manpower differs widely depending on whether the relation between output and manpower was assumed to be linear or of some other form. These results point to the importance of prior information (see p. 7) used in the analysis. A different type of data has been used with more positive results by Hildreth, whose study, like that of Cooper's, is concerned with factors affecting farm production. Hildreth's analysis is based on "cross-section" data: records of numerous farms in Iowa for one year. This has the advantage of a large sample, compared with the short time series of national aggregates used by Cooper. But, to be used for prediction of national figures, the sample should be nationally representative. Accordingly, Hildreth is now examining data from other regions and is studying the possibility of combining time series and cross-section data.

One of the least charted fields of economic behavior is the subject of inventory fluctuations. To get more information on which to base a general theory, Allen has selected a specific industry sector (the firms producing and consuming linseed oil) and has applied the general theory of the firm to its circumstances and characteristics in order to formulate and measure the main behavior relationships entering into the determination of inventories. The specializing of econometric models to particular markets and commodities is of interest in itself, while at the same time the testing of inventory behavior relations for specific industries adds to our knowledge of inventory fluctuations in general.

In connection with the determination of the conditions under which currency depreciation has a favorable effect on the balance of trade, Harberger is seeking to estimate an aggregate elasticity of demand for imports by the United States, by finding the demand relations for each of a number of commodities or commodity groups unrelated in demand, and then taking a suitably weighted average of the individual elasticities.

Modigliani, in his capacity as the director of research on the project "Expectations and Business Fluctuations" organized by the University of Illinois, has been investigating (a) the formation and change of economic expectations in the firm; (b) the relation of investment plans to actual investment; (c) the role of expectations in the formation of investment plans. Two sources of information will be utilized in these studies; historical data comprising past surveys of expectations and

records of individual firms and industries, and surveys of the attitudes of business managers obtained by the "interview method." At present, Modigliani is concentrating on historical data. He has obtained permission from *Fortune* magazine to analyze the returns of their "Executive Forecast" poll. Jointly with the Department of Commerce, he will study the quarterly data on investment plans collected by that Department and by the Security and Exchange Commission.

Staff papers related to the above include:

A Critical Appraisal of Klein's Model: *Domar*
A Test of Klein's Model III for Changes of Structure: *Marshall* (M.A. thesis, University of Chicago, 60 pp.)
Further Comments on Klein's Model: *Christ*
Preliminary Results on Mobility of Labor: *G. Cooper*
A Cross-Section Study of Agricultural Production Functions: *Hildreth*
Theory and Measurement of Production Functions: *D. van Dongen Torman*, Netherlands Economic Institute, Rotterdam
Inventory Fluctuations in Flaxseed and Linseed Oil: *Allen*
Index Number Problems in the Empirical Determination of Import Demand Functions: *Harberger*
Plan of Research on Physical Investment by the Firm: *Modigliani*
20 Lectures on Income, Employment and Price Level (P): *Marschak*
Money Illusion, Price Level and Employment (P): *Marschak*
Some Experiments in Demand Analysis: *Alan Prest*, Department of Applied Economics, University of Cambridge

Research on Optimal Behavior

The discussion of governmental economic policies engaged the attention of several members of the staff. Marschak classified the "short-run" objectives and instruments of such policies as follows: Objectives: high real national income, limited fluctuation in the general price level, small discrepancy between the demand for and the supply of labor. Instruments: monetary, fiscal, and wage policy. The effect of each of the instruments upon each of the objectives is to be inferred from the study of behavior relationships, with due regard to changes in the structure (institutions, habits, technology) that have occurred or are expected or intended. The current controversy on inflationary and deflationary measures and on Keynesian vs. pre-Keynesian economics is clarified with the help of some models based on broad experience. The ultimate quantitative answers must be based on detailed studies like those listed in the section on actual behavior.

On similar lines, a joint study by Cooper and Reiter discusses the question: How long will it take for a given monetary and fiscal policy to raise real income from one pre-assigned level to another and in particular to the level at which there is involuntary unemployment? Harberger dis-

cussed the effects of currency depreciation on employment and the balance of trade.

Bjerve reported on policy problems in the Scandinavian countries and gave valuable suggestions toward the construction of econometric models suited for the discussion of economic policies.

The following papers deal with various aspects of governmental economic policies.

Use of Comparative Macro-Economics (P): *Marschak*
Time Price Flexibility and the Friedman Proposal: *Cooper and Reiter*
Models of International Trade and the Effects of Depreciation: *Harberger*
Comments on the Question: What Kind of Econometric Research Is Required for Economic Policy? *P. J. Bjerve*, University of Oslo
Forecasting the Effects of Government Fiscal Policy: *Arrow*
Maximum Welfare and Price Flexibility: *R. Dehem*, McGill University, Montreal

Optimal behavior was also studied extensively on a more abstract level, that is, without reference to the question as to which individual or authority implements the behavior or decisions regarded as optimal, and in what institutional framework. Some attention was also given to competitive organization as a device to attain optimal behavior.

Arrow continued a study begun at the RAND Corporation in the summer of 1948, concerning the aggregation of individual value judgments. If such aggregation were feasible, it would be possible to arrive democratically and rationally at policy objectives with regard to the income distribution, the choice between present and future consumption, and other economic issues of a social character. By an analysis employing the methods of mathematical logic, Arrow showed that a social valuation reflecting individual valuations consistently and fairly is possible only if individual valuations are sufficiently similar to each other. The implications of these results were clarified by general discussions in staff meetings.

Social Choice and Individual Values: *Arrow* (Ph.D. thesis, Columbia University, hectographed, 116 pp.)
Contributions to the Discussion of Social Choice: *Modigliani*

Other work on optimal behavior was concerned mainly with the allocation of resources in production. Koopmans continued and extended his work on productive systems in which each elementary productive activity is characterized by fixed ratios between inputs and outputs. Starting from a criterion of efficiency of allocation mentioned on page 9, he derived rates of substitution indicating by how much the production of one final product can be increased by a decrease of one unit in the production of another final product, or by an increase of one unit in the availability of some primary factor. He discussed the use of steering prices as an al-

locative device toward efficient production by independent productive units. Samuelson discussed limitations upon the effectiveness of this device under various circumstances of technology and of consumers' demand.

Simon has employed production models of this type for the discussion of technological change and its effects on cost and on outputs. Reiter is exploring the limitations inherent in the assumption of constant returns to scale, made in the production models considered so far. Gerstenhaber is studying the mathematical properties of models involving fixed input-output ratios.

Leontief reported in staff meetings on his work on inter-industry relations models, which is in many ways related to the models studied by Cowles Commission staff members. Arrow and Koopmans collaborated with Samuelson on the role of substitution possibilities in Leontief's models.

A Mathematical Model of Production: *Koopmans*
Allocation of Resources in Production (P): *Koopmans and Reiter* (lectures by the former)
Limitational Factors of Production and the Allocation of Resources, *N. Georgescu-Roegen*, Harvard University
On "Playing the Game of Competition" as an Allocative Device: *P. Samuelson*, Massachusetts Institute of Technology
Invention and Cost Reduction in Technological Change: *Simon*
Theory of Input-Output Models: *W. Leontief*, Harvard University
Capital Requirements in Input-Output Models: *Leontief*
Comments on the Input-Output Technique: *Koopmans*
Contribution to the Discussion of Leontief's Paper "Recent Developments in the Study of Inter-Industrial Relationships" (P): *Koopmans*
Proof of Samuelson's Theorem Regarding the Ineffectiveness of Substitution in the Leontief Model: *Koopmans*
On Samuelson's Theorem for Leontief's Model: *Arrow*
Computational Suggestions for Maximizing a Linear Function Subject to Linear Inequalities: *Koopmans*

The work on production and allocation models is carried out in close contact with parallel projects in other centers, including the Harvard Economic Project on the Structure of the American Economy. In addition, contacts are maintained with the development of programming methods in the Department of the Air Force by Dantzig and Wood (see articles by these authors in *Econometrica*, Vol. 17, July–October, 1949), with the work on computation methods for programming by The RAND Corporation (G. Brown) and at Princeton University (O. Morgenstern and A. W. Tucker). A conference on linear programming was held at the Commission on June 20–24, 1949. The following papers were presented

or circulated and discussed, in addition to some of the papers already mentioned above.

Leontief's Open Input-Output Models: *Harlan Smith*, Brown University

Competition and Monopoly in Linear Models: *David Hawkins*, University of Colorado

The Programming of Interdependent Activities: Mathematical Model: *G. B. Dantzig*, Department of the Air Force

The Programming of Interdependent Activities: General Discussion: *M. K. Wood*, Department of the Air Force, and *G. B. Dantzig*

Development of Dynamic Models for Program Planning: *Wood* and *Geisler*, Department of the Air Force

A Simple Mathematical Model of Aircraft Production Representing Growth Rates and Cost Functions in a Linear Structure: *Wood* and *Harris*, RAND Corporation.

Suggestions on the Classification Problem in Linear Programming: *G. B. Dantzig*

Systems of Linear Production Functions: *Koopmans*

Recent Developments in the Study of Inter-Industrial Relationships, published in the *American Economic Review: Leontief*

Relaxation Phenomena and Linear Dynamic Models: *Georgescu-Roegen.*

The Aggregate Linear Production Function and Its Applications: *Georgescu-Roegen*

Four Equivalent Linear-Convex Problems: *D. Gale, H. W. Kuhn, A. W. Tucker*, Princeton University

A Theorem on Convex Cones: *D. Gale*

Relation Between Linear Programming and Game Theory: *D. Gale, H. W. Kuhn, A. W. Tucker*

On Koopmans' Model of Production: *A. W. Tucker*

A Proof of the Equivalence of the Programming Problem and the Game Problem: *G. B. Dantzig*

The Accuracy of Economic Observations: *O. Morgenstern*, Princeton University

Remarks on Reduction and Aggregation: *Koopmans*

Stocks and Flows in Linear Programming: *Koopmans*

Abstract of Theorem Concerning Substitutability in Leontief Systems: *P. Samuelson*

Market Mechanisms and Maximization, Parts I and II: *P. Samuelson*

Comments on Samuelson's Paper "Market Mechanisms and Maximization": *Abba P. Lerner*, Roosevelt College

A Procedure for Maximizing a Linear Function Subject to Linear Inequalities: *G. B. Dantzig*

Application of the Simplex Method to a Game Problem: *R. Dorfman*

Computational Suggestions for Maximizing a Linear Function Subject to Linear Inequalities: *Koopmans*

Some Computation Methods for Linear Systems Involving Inequalities: *G. W. Brown*

Optimum Utilization of the Transportation System: *Koopmans*

Application of the Simplex Method to the Koopmans Transportation Problem: *G. B. Dantzig*

Invention and Cost Reduction in Technological Change: *Simon*

A monograph containing a selection of the papers presented at this conference is in preparation.

The Study and Development of Methods

Activities under this heading were concerned with general methodological questions in the quantitative formulation and analysis of economic behavior, with the particular question of summarizing individual behavior characteristics through aggregation, and with problems of statistical methods appropriate to the measurement of economic relations.

Koopmans gave a general presentation (New Series, 35)* of the econometric approach to business fluctuations. He also participated in an exchange of views (New Series, 29) with Rutledge Vining about the role of economic theory as an aid in statistical measurement of economic behavior. Marschak's lectures at the University of Buffalo provided a nontechnical introduction to econometric methods.

In the study of economic behavior, one of the principal difficulties is the great number of different activities involved. It is necessary to summarize the data in a few measures in order that they may be grasped by the mind. Though the practice of aggregation is as old as empirical economic work, the rationale behind it is still imperfectly explored. Arrow has suggested the following formulation of the problem: the constants of the basic relationships which describe or limit the actions of individuals (such as preference scales or production functions) will vary between individuals but they may be supposed to have a smooth distribution which can be described by a few distributional parameters. The aggregative problem then becomes that of estimating these distributional parameters.

The concept of social welfare is the result, in the field of optimal behavior, of an aggregation of individual tastes, and a problem of normative aggregation, analogous to the above problem of descriptive aggregation, arises. (See page 17.)

Further light is thrown on the problem of descriptive aggregation by Harberger's work on the elasticity of demand for imports, in which he has shown that the estimation of this quantity by use of aggregate indices of total imports and prices involves a bias.

Bjerve gave an exposition of the economic circulation diagram developed at Oslo by Frisch in association with Bjerve and Aukrust. This is a diagrammatic method of insuring consistency in the use of the various aggregative concepts associated with national income analysis which appear in macroeconomic models.

Staff discussions on the descriptive aggregation problem were stimulated by the following papers:

A Formal Theory of Aggregation: *Arrow*

* See List of New Series papers, pp. 27–30.

Index Number Problems in the Empirical Determination of Import Demand Functions: *Harberger*

Some Comments on Ragnar Frisch's Ecocirc-system: *P. J. Bjerve*, University of Oslo

Remarks toward a Dynamic Theory of Income Distribution: *Klahr*

Some Notes on Aggregation and Cross-Section Studies: *Marschak*

The work on statistical methods has further elaborated the implications of the fact that economic fluctuations are described by the simultaneous existence of several relationships. A prerequisite for the separate statistical measurement of each economic relationship is its identification (see page 7). This problem was discussed for various models by Anderson, Hurwicz, and Koopmans (New Series, 31), Reiersøl, and Rubin. The latter two and Anderson also studied corresponding problems arising in the application of "factor analysis" to the interpretation of psychological test data. Staff discussions on identification problems were stimulated by:

Some Results on Identification in Lagged Shock-Error Models: *Hurwicz*

Identification in a Two-Variable Error Model: *Reiersøl*

Identification Problems with Serially Correlated Disturbances: *Rubin*

Bronfenbrenner evaluated and discussed the bias that arises if the least squares method of estimation is applied to one behavior equation taken out of its context of a system of relationships. Anderson and Rubin prepared for publication their work on consistent methods of estimating a single equation which is part of a system of equations. Both have worked on extensions to the simultaneous estimation of several equations belonging to a complete system. Rubin's work in particular aims at increasing the flexibility of estimation methods, by the inclusion of nonlinear relationships, and by diminishing the restrictiveness of the assumptions made about that part of the equation system which is not estimated. He has studied especially the large-sample properties of the estimates.

Serial correlation in a single series, and in the disturbances in a single regression equation, was studied by T. W. Anderson (New Series, 30), in part jointly with R. L. Anderson. This work has relevance to the treatment of seasonal variation. Serial correlation in the disturbances in each of the equations of a system was explored in its identification and estimation aspects by Rubin and in its computation aspects by Chernoff.

The following papers relate particularly to problems of estimation and statistical testing:

Statistical Problems in Forecasting from Econometric Models: *Arrow*

Extent of Least Squares Bias in Estimating a Single Stochastic Equation in a Complete System: *Bronfenbrenner*

On the Decomposition of a Series of Observations Composed of a Trend, a Periodic Movement with Known Period and Stochastic Variable by Means of a Moving Average: *A. Hald,* University of Copenhagen

Statistical Methods of Measuring Economic Relationships: *Koopmans* and *Allen* (lectures by the former)

The Approximate Distribution of Calculated Disturbances: *Rubin*

Identification of the Parameters of Linear Stochastic Difference Equations and Asymptotic Properties of Their Maximum- and Quasi-Maximum-Likelihood Estimates: *Rubin*

Methods of computation of estimates of behavior parameters have had the attention of Chernoff and Bronfenbrenner and earlier of De Vries. Among the contributions in this area are a general discussion of gradient methods of maximization (with special reference to the iterative "Newton method"), expository discussions or outlines of the computation methods involved, as well as the daily supervision of computation work for the research of other members or for experiments in computation methods.

Computational Methods Used in Limited Information Treatment of a Set of Linear Stochastic Difference Equations: *Bronfenbrenner* and *Chernoff*

Gradient Methods of Maximization: *Chernoff*

Comparision of Computing Machines: *Chernoff*

The Effect of a Small Error in Observations on the Limited Information Estimates of a Stochastic Equation: *Chernoff*

Computation of Maximum Likelihood Estimates of the Parameters of Linear Stochastic Difference Equations in the Case of Serially Correlated Disturbances: *Chernoff*

Note on Computation of Sampling Variances and Covariances in the Case of Reduced Form Estimation: *De Vries*

Observations on the Computation Procedure for Maximum-Likelihood Estimates: *Rubin*

Cowles Commission Monograph 10, *Statistical Inference in Dynamic Economic Models,* on which work was completed in previous years, will appear in the course of 1949.

Special Studies

Economic Aspects of Atomic Power

This study was started in October, 1946, and is sponsored by the Social Science Research Council, the Rockefeller Foundation, and (since 1948) the Life Insurance Association of America. The manuscript of the book is in the final stages of revision. The table of contents is as follows:

PART I. Economic Comparisons of Atomic and Conventional Power: 1. Economic Characteristics of Atomic Power; 2. Atomic Energy in the Fuel and Power Economy of Various Regions (includes 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-Caustic Soda; 6. Phosphate Fertilizers; 7. Cement (Including Appendix on Brick); 8. Flat Glass; 9. Iron and Steel; 10. Railroad Transportation; 11. Residential Heating.

PART III. Atomic Power and Economic Development: 12. The Over-all Economic Effects of Atomic Power; 13. Atomic Power and the Industrialization of Backward Areas.

Schurr and Marschak are codirectors of the study, and Schurr is also author of a large part of the manuscript. Draft chapters were also contributed by Edward Boorstein, George Perazich, Milton Searl, Herbert Simon, and Harold Wein; some of these workers were full-time associates, while others were part-time consultants. Robert Carmin of the Department of Geography and Geology, Michigan State College, helped as cartographer. About thirty experts are to be credited for commenting extensively upon various parts of the manuscript.

The Economics of Transportation

This study by Koopmans is now being continued as a special case of the study of linear models of production and allocation, described on pages 16–18.

Econometrics and Medieval History

H. T. Davis has continued his investigation into the problem of interpreting historical movements by economic and statistical methods. A preliminary work entitled *Political Statistics* has indicated some of the progress attained in this interpretative study. Work has continued in the collection of statistical information pertaining to various types of time series observed in earlier times. During the year considerable attention has been given to the *Domesday Book* of William the Conqueror where an attempt has been made to find the distribution of wealth and income which prevailed in England toward the end of the eleventh century. This should be of considerable interest since very little data have been published relating to the medieval period.

Mathematical Tables

A volume giving the properties, the applications, and tables for the incomplete Gamma function, the complete and incomplete Beta functions, and related functions, is in the final stages of preparation by H. T. Davis. He has, in addition, completed a bibliography of mathematical tables together with an extensive index indicating the nature of the content of the tables listed. This will appear in due time in mimeographed form.

Cooperation with Other Groups

In various ways, 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 has made joint research appointments (Cooper, Hildreth) with the Agricultural Economics Research Unit. One of its members (Koopmans) has participated in the organization of a Committee on Statistics in the University. 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. Some members of the staff (Chernoff, Rubin) have held appointments at Illinois Institute of Technology concurrently with their appointment with the Commission.

During the first half of 1948 Arrow continued to serve as a consultant with the Bureau of the Budget on methods of forecasting in relation to fiscal policies. During the summer Arrow and Koopmans served as consultants with The RAND Corporation. The former worked on a variety of economic and statistical problems including the aggregation of preferences and the theory of games. The latter worked on linear allocation models and their use in programming the interdependent activities of a large organization.

From June 20 to 24 a Conference on "Linear Programming" was held in Chicago, at the invitation of the Cowles Commission. In this conference 35 economists and 15 mathematicians from 12 universities and an equal number of government agencies or independent research agencies participated. A report of the subject matter of, and the papers discussed at, this conference is given on pages 17–19.

Teaching in Econometrics, Mathematical Economics, Economic Theory, and Statistics at the University of Chicago

Staff members of the Cowles Commission participate in the teaching activities of the University of Chicago, especially in the field of statistics and economic theory. The following courses listed by the Department of Economics or by the Committee on Statistics (but not all given every year) are particularly relevant to the area of interest of the Cowles Commission.

Main Economic Magnitudes. 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.

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 METHODS OF MEASURING ECONOMIC RELATIONS. Systems of economic relationships. Prediction and structural estimation. Criteria for identifiability and methods of estimation of economic relations. Problems connected with time lags.

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.

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 to 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.

INTRODUCTION TO STATISTICS. Elementary principles of statistics. Main topics: frequency distributions, averages, dispersion, index numbers, elements of the theory of statistical inference.

STATISTICAL INFERENCE. A survey of the principles of statistical inference, with emphasis on the techniques useful in applying these principles to the analysis of social, economic, and business data. Among the subjects treated will be: elements of probability; concepts of population, sample, and sampling distribution; choice of estimates in the light of their sampling properties; testing hypotheses with reference to specified alternatives; principles of sampling and sample design; analysis of proportions, means, and standard deviations; simple, partial, and multiple regression and correlation.

APPLICATIONS OF STATISTICAL INFERENCE. The content of this course will vary from one year to another, but will concern applications of statistics to business, economic, and social data. For example, members of the class individually or jointly may carry through a statistical investigation; or a series of published statistical studies in economics or business may be analyzed in detail; or some special field of application may be studied.

MATHEMATICAL STATISTICS I. This course, together with the one which follows it, surveys the logical and mathematical concepts of modern statistics. Together they are intended as an introduction to statistics for students of mathematics and the physical sciences, and as advanced instruction for other students who already have some acquaintance with statistics. The principal topics of the first course are: probability, distribution functions, the general problem of statistical inference, point estimation, confidence intervals.

MATHEMATICAL STATISTICS II. Tests of hypotheses, regression, analysis of variance, correlation, confidence regions, the design of experiments.

ADVANCED MATHEMATICAL STATISTICS. A few topics selected according to the interests of the class are discussed. Among the possibilities are: characteristic functions, time series, order statistics, nonparametric problems, multivariate analysis, sequential analysis.

COWLES COMMISSION SEMINARS

The Commission holds fortnightly seminars which are 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, some jointly with the Statistical Techniques Group of the Chicago Chapter of the American Statistical Association or with the Program of Education and Research in Planning:

1948

January 29. TJALLING C. KOOPMANS, "Welfare Economics of Transportation and Location" (in collaboration with the Program of Education and Research in Planning).

February 12. ANATOL RAPOPORT, Research Associate in Mathematical Biology, and ALPHONSO SHIMBEL, Research Associate in Mathematical Biology, "Suggestions for Measuring the Satisfaction Functions of Animals."

February 24. EWAN CLAGUE, U.S. Commissioner of Labor Statistics, "Productivity, Wages, and the American Standard of Living" (jointly with the Chicago Chapter of the American Statistical Association).

February 26. FREDERICK MOSTELLER, Associate Professor of Social Relations, Harvard University, "Graphical Analysis of Data Obtained by Counting."

March 18. GERHARD TINTNER, Professor of Economics, Iowa State College, "Foundations of Probability and Statistical Inference" (jointly with the Statistical Techniques Group, Chicago Chapter, American Statistical Association).

April 15. MELVIN G. DE CHAZEAU, Professor of Business Economics and Marketing, University of Chicago, "Interviewing of Businessmen."

April 29. KARL MENGER, Professor of Mathematics, Illinois Institute of Technology, "A Geometric Theory of Index Numbers."

May 13. H. GREGG LEWIS, Assistant Professor of Economics, University of Chicago, "Observations on Duopoly."

May 27. L. H. C. TIPPETT, Statistician to the British Cotton Industry Research Association and Visiting Lecturer, Massachusetts Institute of Technology, "Investigations of Industrial Efficiency."

June 10. JACOB MARSCHAK, "Money Illusion, Price Level, and Employment."

October 21. LLOYD A. METZLER, Associate Professor of Economics, University of Chicago, "Tariffs, the Terms of Trade and the Distribution of National Income."

November 4. WILLIAM E. HENRY, Assistant Professor in the Committee on Human Development, University of Chicago, "Personality and the Performance of Executives."

November 18. PETTER J. BJERVE, Chief of Economic Planning Division, Norwegian Ministry of Trade, "Government Economic Planning in Norway" (jointly with the Program of Education and Research in Planning).

December 9. TJALLING C. KOOPMANS, "The Econometric Approach to Business Fluctuations."

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January 6. L. J. SAVAGE, Research Associate in Mathematics, University of Chicago, "The Theory of Games: Zero-Sum Games."

January 20. KENNETH J. ARROW, "The Theory of Games: Multi-Person Games."

February 17. KENNETH J. ARROW, "The Theory of Games: Applications to Economics."

March 3. JACOB MARSCHAK, "The Theory of Games: Measurable Utility."

March 10. M. A. GIRSHICK, Professor of Statistics, Stanford University, "The Theory of Games: Continuous Games."

March 31. L. J. SAVAGE, "The Theory of Games: Application to Statistical Inference."

April 14. HERBERT A. SIMON, "The Theory of Games: Application to Politics and Administration."

May 12. HERMAN RUBIN, "Statistical Treatment of Nonlinear Econometric Models."

May 26. TJALLING C. KOOPMANS, "Utility Analysis of Decisions Involving Future Periods."

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. 26–31, 35 and 37 have been issued since January 1, 1948. The intermediate papers are in preparation and will be issued in the latter part of 1949. A limited supply is available of those papers which are marked by an asterisk, and copies will be furnished to individuals who request particular items. (Those not marked with an asterisk 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 $2.25 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," *The 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," *The Journal of Business*, Vol. 17, October, 1944, pp. 231–243.

No. 8. Oscar Lange, "The Stability of Economic Equilibrium," appendix from Cowles Commission Monograph No. 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. TJALLING C. KOOPMANS AND JACOB MARSCHAK, "Two Review Articles: 'Measurement without Theory' and 'On Mathematics for Economists,'" *Review of Economic Statistics*, Vol. 29, August, 1947, pp. 161–172; November, 1947, pp. 269–273.

*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, No. 4, 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," *Journal of Farm Economics*, Vol. 29, No. 4, November, 1947, pp. 910–924; GERSHON COOPER, "The Role of Econometric Models in Economic Research," *Journal of Farm Economics*, Vol. 30, No. 1, February, 1948, pp. 101–116.

*No. 28. Two Papers on Relative and Absolute Prices and the Demand for Money. Don Patinkin, "Relative Prices, Say's Law, and the Demand for Money, *Econometrica*, Vol. 16, 1948, pp. 135–154. "The Indeterminacy of Absolute Prices in Classical Economic Theory," *Econometrica*, Vol. 17, No. 1, 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. 1.

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 Marshak, "Role of Liquidity under Complete and Incomplete Information," *Proceedings Supplement of the American Economic Review*, Vol. 39, May, 1949, pp. 182–195.

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. Although no monographs were published during the period, work was completed on Monographs 10 and 11 (the contents of which are described below), and

these books are expected to be published in the fall of 1949. In addition, plans have been developed for several more monographs to appear in the near future.

MONOGRAPH 10: STATISTICAL INFERENCE IN DYNAMIC ECONOMIC MODELS

I. The Distinct Character of Statistical 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 a Single Equation by the Reduced-Form Method, *T. W. Anderson.*

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

PART TWO: PROBLEMS SPECIFIC TO TIME SERIES

Trend and Seasonal: 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.*

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

STAFF NOTES AND PUBLICATIONS

Since 1945 the duties of research personnel have been defined as follows: research associates 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.

Stephen G. Allen, Jr.

Stephen Allen (University of Texas, 1941–44, U.S. Naval Reserve, 1944–46, University of Chicago, 1946–49), a graduate student in the Department of Economics, joined the Cowles Commission as a research assistant in January, 1949. He is engaged in a study on "Inventory Fluctuations in Flaxseed and Linseed Oil."

Theodore W. Anderson

Anderson continued as research consultant of the Cowles Commission during the period of this report. He did research work as a Guggenheim Fellow at the Institute of Mathematical Statistics, University of Stockholm (September, 1947—April, 1948), and at the Department of Applied Economics, University of Cambridge (April–June, 1948). Thereafter he returned to teaching duties at Columbia University where he is an assistant professor of mathematical statistics and consultant to the Bureau of Applied Social Research. The following are his papers, published or presented during this period:

"Some Problems of Time Series Analysis," presented February 9, 1948, at the University Institute of Economics, Oslo, Norway.

"Theory for Testing Serial Correlation," presented in Swedish, March 17, 1948, at the Institute of Mathematical Statistics, University of Stockholm.

"The Asymptotic Distribution of Certain Characteristic Vectors," presented May 14, 1948, at the University of Manchester.

"On the Theory of Testing Serial Correlation," presented May 20, 1948, at the University of Cambridge.

"Estimating Linear Relations," presented May 25, 1948, at the University of Cambridge.

"Use of Structural Equations in Constructing Economic Models," presented June 9, 1948, at the Department of Applied Economics, University of Cambridge.

"Estimating Linear Restrictions on Regression Coefficients for Multivariate Normal Distributions," presented December 30, 1948, at a meeting of the Institute of Mathematical Statistics and American Statistical Association, Cleveland, Ohio.

"Applications of Multivariate Analysis," presented March 8, 1949, at a meeting of the Metropolitan Chapter of the American Statistical Association in New York.

"Applications of Multivariate Analysis to Problems in Psychology and Education, I and II," presented April 12 and 13, 1949, at Iowa State College.

"Estimation of Linear Restrictions on Regression Coefficients and Applications to Econometric Models," presented April 14, 1949, at Iowa State College.

"On the Theory of Testing Serial Correlation," *Skandinavisk Aktuarietidskrift*, Vol. 31, 1948, pp. 88–115. (Cowles Commission New Series Paper, No. 30.)

"The Asymptotic Distributions of the Roots of Certain Determinantal Equations," *Journal of Royal Statistical Society*, Series B, Vol. 10 (1948), pp. 132–139.

"Review of *Metoder att Uppskatta Noggranheten vid Linje- och Provyte taxering* by Bertil Matern," *Journal of American Statistical Association*, Vol. 44, 1948, pp. 323–325.

"Estimation of the Parameters of a Single Equation in a Complete System of Stochastic Equations" (with Rubin), *Annals of Mathematical Statistics*, Vol. 20, March, 1949, pp. 46–63. (Cowles Commission New Series Paper, No. 36.)

Kenneth J. Arrow

Kenneth J. Arrow, who joined the Cowles Commission as a research associate in April, 1947 (see 1942–46 report for biographical notes), was appointed assistant pro-

fessor in the Department of Economics, The University of Chicago, in October, 1948, and, as such, cooperates in the editing of the *Journal of Political Economy*. In addition to regular teaching and research duties, he did consultative work during the winter of 1948 with the U.S. Bureau of the Budget under a contract which the Commission had with that agency and during the summer of 1948 served as a consultant to Project RAND in Santa Monica, California. The following papers were presented or published by him during this period:

Review of C. Radhakrishna Rao, "Tests of Significance in Multivariate Analysis," *Mathematical Reviews*, Vol. 9, November, 1948, p. 602.

"The Possibility of a Social Welfare Index," presented December 27, 1948, at Cleveland before the Econometric Society (abstract in *Econometrica*, Vol. 17, April, 1949, p. 157).

"Review of M. N. Ghosh, 'On the Problem of Similar Regions,' " *Mathematical Reviews*, Vol. 10, February, 1949, pp. 135–136.

"Review: Raymond Florin, *Dynamique Économique*," *American Economic Review*, Vol. 39, March, 1949, pp. 517–519.

"On the Use of Winds in Flight Planning," *Journal of Meteorology*, Vol. 6, No. 2, April, 1949, pp. 150–159.

"Review of Sten Malmquist, 'A Statistical Analysis of the Demand for Liquor in Sweden,' " *Mathematical Reviews*, Vol. 10, May, 1949, pp. 313–314.

Jean Bronfenbrenner

Mrs. Jean Andrus Bronfenbrenner (B.A. in economics, University of Chicago, 1939; M.A. in mathematics, University of Colorado, 1945; M.A. in economics, University of Chicago, 1948) became a research assistant with the Cowles Commission in July, 1948. She was a teaching assistant in mathematics at the University of Colorado, 1943–44; instructor in mathematics at the University of Arizona, 1945–46; and a teaching assistant in mathematics and statistics at the University of Wisconsin, 1947–48. Mrs. Bronfenbrenner has published or presented the following papers during the period of this report:

"An Incentive Tax Proposal for Alleviation of the Housing Shortage," *National Tax Journal*, Vol. 1, No. 1, March, 1948, pp. 51–61.

"Incentive versus *Ad Hoc* Controls in Handling Economic Shortages" (co-speaker: Franco Modigliani), presented November 29, 1948, at the Political Economy Club, University of Chicago, and on March 7, 1949, at the Economics Faculty Group, Northwestern University.

"Extent of Bias in Least Squares Estimation of a Single Stochastic Equation in a Complete System," presented April 22, 1949, at the Midwest Economics Association, St. Louis, Missouri.

Herman Chernoff

Herman Chernoff, who joined the Cowles Commission as a research assistant in June, 1947 (see biographical notes in 1947 report), became a research associate in the spring of 1948 and has been supervising the computational work of the Commission. He received a Ph.D. in applied mathematics from Brown University in June, 1948. In addition to his research work with the Commission, he taught mathematical statistics during the winter semester at the Illinois Institute of Technology. Papers presented or published by Chernoff include:

"Asymptotic Studentization in Testing Hypotheses," presented September 7, 1948, at Madison, Wisconsin, before the Institute of Mathematical Statistics. (*Annals of Mathematical Statistics*, Vol. 20 ,June, 1949.)

"Gradient Methods of Maximization in Estimating Economic Parameters," presented September 10, 1948, at Madison, Wisconsin, before the Econometric Society. (Abstract in *Econometrica*, Vol. 17, January, 1949, pp. 75–76.)

"Computation of Maximum Likelihood Estimates of Parameters of a Complete System of Linear Stochastic Difference Equations with Serially Correlated Disturbances," presented December 28, 1948, before the Institute of Mathematical Statistics in Cleveland. (Abstract in *Annals of Mathematical Statistics*, Vol. 20, March, 1949, p. 138.)

Gershon Cooper

Cooper continued as a research associate of the Commission until July, 1948. During the period covered by this report he presented the following papers:

"A Report on the Study 'Allocation of Labor between Agriculture and Nonagriculture,' with Emphasis on the Limitations of the Technique Employed," presented February 4, 1949, at the University of Chicago.

"The Role of Econometric Models in Economic Research," *Journal of Farm Economics*, Vol. 30, February, 1948, pp. 101–116. (Cowles Commission New Series Paper, No. 27.)

Harold T. Davis

Harold T. Davis, professor of mathematics at Northwestern University, continued as a research consultant of the Cowles Commission. Supplementing the biographical notes in the 1942–46 report, it may be noted that Davis was granted the degree of LL.D. at Colorado College in May, 1949. Addresses presented and papers published since the 1947 report include:

"A Note on Gravitation," presented February 19, 1948, at the Physics Colloquium of Northwestern University.

"A Problem in Operators," presented February 26, 1948, at the Mathematics Club of Illinois Institute of Technology.

"The Beneficent Price Inflation of the Renaissance and What Came of It," presented April 17, 1948, at the Chicago Renaissance Group, the Newberry Library, Chicago.

"A Problem in Polimetrics," presented May 7, 1948, at the Mathematical Biology Seminar, University of Chicago.

"The Mathematics of Politics," presented February 18, 1949, at the Men's Mathematics Club of Chicago.

"Population Cycles," presented March 4, 1949, at the Mathematical Biology Seminar, University of Chicago.

"History of the Proof of the Law of Mass-Energy," presented April 9, 1949, at the Chaos Club, Chicago, Illinois.

"The Liberal Arts College—Whither Bound?" presented May 6, 1949, at Colorado College, on the occasion of the 75th anniversary of the founding of the College and the inauguration of President W. H. Gill.

Political Statistics. 320 pages. 1948 (mimeographed edition).

The Equations of Mathematical Physics and Methods for their Solution. 308 pages. 1949 (mimeographed).

Essays in the History of Mathematics. 150 pages. 1949 (mimeographed edition).

"Review of Enzo Cambi, *Eleven and Fifteen-Place Tables of Bessel Functions of the First Kind, to All Significant Orders*," *Mathematical Tables and Other Aids to Computation*, Vol. 3, July, 1948, pp. 180–181.

"Review of K. L. Nielsen and L. Goldstein, 'An Algorithm for Least Squares,'

Journal of Mathematical Physics," *Mathematical Tables and Other Aids to Computation*, Vol. 3, October, 1948, pp. 302–303.

"Review of Herbert E. Salzer, *Table of Coefficients for Obtaining the First Derivative without Differences*," *Mathematical Tables and Other Aids to Computation*, Vol. 3, April, 1949, pp. 414–415.

Barend DeVries

Barend DeVries continued until July, 1948, as a research assistant with the Cowles Commission and as a graduate scholarship student in the Department of Economics at the University of Chicago. His work included supervision of computational work and further elaboration of a macroeconomic model for the U.S. Currently he is the holder of a fellowship in the Department of Economics at the Massachusetts Institute of Technology.

Nathan J. Divinsky

Nathan J. Divinsky (B.S., University of Manitoba, 1946; M.S., University of Chicago, 1947) joined the Commission as research associate in June, 1949. He was teaching assistant in the Department of Mathematics at the University of Chicago during 1948–49.

Evsey D. Domar

Evsey D. Domar (see 1947 report for biographical details) continued as a research associate with the Cowles Commission and as assistant professor of economics until July, 1948, when he became associate professor of political economy at the Johns Hopkins University. He taught at the College of the University of Chicago in the summer of 1948 and at the University of Buffalo in the spring of 1949. At present he is also consultant and director of the Russian Economics Project, Operations Research Office, Johns Hopkins University. Until about August, 1948, he was working on the general problem of capital accumulation. Since that date he has engaged in research in the field of soviet economics, sponsored by the Russian Research Center Harvard University. Papers presented and published during this period include:

"Capital Accumulation and Prosperity," presented in February, 1948, at the Political Economy Seminar, Johns Hopkins University.

"Causes of Economic Instability," presented in August, 1948, at a public lecture at the University of Chicago.

"The Problem of Capital Accumulation," *American Economic Review*, Vol. 37, December, 1948, pp. 777–794.

"Review of *Planning and Paying for Full Employment* edited by Lerner and Graham," *American Economic Review*, Vol. 37, September, 1948, pp. 666–670.

Françoise Ferdinand-Dreyfus

Françoise Ferdinand-Dreyfus, formerly of the Institute of Statistics, University of Paris, studied at the Cowles Commission from October, 1947 to July, 1948, as a Sarah Frances Hutchinson Cowles Fellow. She is now a member of the Econometric Seminar of the French Centre National de la Recherche Scientifique and is a statistician at the Institut National de Sécurité.

Murray Gerstenhaber

Murray Gerstenhaber (B.S., Yale, 1948; M.S., University of Chicago, 1949) joined the Commission as a research assistant in May, 1949. He has held a University fellowship in the Department of Mathematics at the University of Chicago. He will do mathematical research on the theory of allocation of resources.

Trygve Haavelmo

Trygve Haavelmo (see 1942–46 report for biographical details) continued as a research consultant of the Commission while a consultant to the Norwegian Department of Commerce and vice-chairman of the Norwegian Economic Coordination Council. In April, 1948, he was appointed professor of economics at the University of Oslo, where he lectured on modern theories of macroeconomics and on methods of econometrics. During the period covered by this report, he published or presented the following papers:

"Hva kan vi gjøre for å verge oss mot en konjunkturnedgang," in *Aktuelle økonomiske problemer*, Oslo, 1948.

"A Note on the Theory of Investment," University Institute of Economics, Oslo (mimeographed).

"Lectures on Modern Macro Theories" at the University of Oslo (mimeographed).

Numerous papers prepared for the Norwegian Government.

Arnold C. Harberger

Arnold C. Harberger (Johns Hopkins University, 1941–43; M.A., University of Chicago, 1947) joined the staff of the Commission as a research assistant on March 1, 1949. He was in the army between 1943 and 1946, after which he attended the University of Chicago on a scholarship during the academic year 1947–48 and on a Marshall Field Fellowship, 1948–49. He is engaged in an empirical study of the elasticity of demand for imports.

Clifford Hildreth

Clifford Hildreth (A.B., 1939, University of Kansas; M.S., 1941; Ph.D., 1947, Iowa State College) joined the staff on January 1, 1949, as assistant professor in the Cowles Commission and research associate in the Department of Economics under a joint appointment with the Agricultural Economics Research Group.

Prior to coming to the University of Chicago, he held appointments at Iowa State College as graduate assistant, 1939–41; as instructor and research associate, 1941–43, and 1946–47; as assistant professor (joint appointment with the Agricultural Experimental Station and Statistical Laboratory) 1947–48; and as associate professor, Department of Economics and Sociology, and research associate professor, Statistical Laboratory, 1948. From April, 1943 to January, 1946, he was on active duty with the U.S. Navy, and his principal tour of duty was Air Navigator with Naval Air Transport Service. Hildreth published or presented the following papers during the period of this report:

"Expectations and Plans in Agriculture," presented June 3, 1948, at the Conference on Uncertainty and Risk of the Agricultural Economics Research Group, University of Chicago.

"Mathematical Representation of Professor Boulding's Model," presented November 16, 1948, at the Economics Seminar, Iowa State College.

"Report on a Production Function Study," presented December 10, 1948, at the Statistics Seminar, Iowa State College.

"Problems in the Estimation of Agricultural Production Functions," presented December 28, 1948, before the Econometric Society in Cleveland, Ohio. (Abstract in *Econometrica*, Vol. 17, April, 1949, p. 163.)

"Discussion of 'Measurements of Agricultural Production,' " presented December 30, 1948, at a joint meeting of the American Statistical Association and American Farm Economics Association, published in *Journal of Farm Economics*, Vol. 31, April, 1949, pp. 231–232.

"Use of Farm Data to Estimate Resource Productivity," presented March 4 and 11, 1949, at the Agricultural Economics Seminar, University of Chicago.

"Some Aspects of Production Analysis," presented May 10, 1949, at the Economics Seminar, Carnegie Institute of Technology.

Leonid Hurwicz

Leonid Hurwicz (see 1942–46 report for biographical details) continued as research consultant of the Cowles Commission during the period of this report. During 1948 he was on the staff of the Research Division of the United Nations Economic Commission for Europe in Geneva, Switzerland, in connection with which he aided in the preparation of several reports and other documents. In particular, he studied problems in productivity measurement, capital formation and investment problems of the European countries. While he was in Geneva he also took part (and gave talks on econometric subjects) in an informal seminar composed of some members of the Research Division. He returned to Iowa State College in December, 1948, where he is associate professor in the Department of Economics and Sociology. There he participated in the annual extension conference panel on Europe and in a staff seminar on problems of economic stabilization. In September, 1949, Hurwicz will join the faculty of the University of Illinois as research professor of economics and mathematical statistics. His addresses or publications during the period of this report are as follows:

"Linear Programming and General Theory of Optimal Behavior," presented December 27, 1948, before the Econometric Society, Cleveland, Ohio. (Abstract in *Econometrica*, Vol. 17, April, 1949, p. 161.)

"European Economic Problems," presented March 28, 1949, before the United Nations Workshop of the League of Women Voters, Ames, Iowa.

"Planning in Europe," presented March 1, 1949, at the Economics and Sociology Seminar, Ames, Iowa.

"Problems of Economic Stabilization," presented April 19, 1949, at a staff seminar, Iowa State College, Ames, Iowa.

"Simultaneous Equation Models and Estimation Methods," presented April 21, 1949, at St. Louis meeting of the Mid-West Economic Association Meetings.

Carl N. Klahr

Carl N. Klahr (B.S., M.S. in physics, 1948, Carnegie Institute of Technology) was appointed a research consultant of the Cowles Commission in June, 1949.

He was a research assistant in econometrics, Carnegie Institute of Technology, 1947–48; Atomic Energy Commission Fellow, 1948–49; and is currently a Fellow in Economics in the Mellon School of Industrial Administration, Carnegie Institute of Technology. During the period covered by this report, and prior to joining the Commission, he was engaged in research in theoretical physics, especially solid state problems and nuclear physics, and in a project on the estimation of joint costs of production, being carried out by the economics staff of Carnegie Institute in connection with Westinghouse Electric Company.

Tjalling C. Koopmans

Tjalling C. Koopmans, who joined the Commission as research associate in July, 1944 (see 1942–46 report for his biographical notes), was appointed director of research of the Cowles Commission July 1, 1948. In addition he holds an appointment as professor of economics at the University of Chicago and, as such, cooperates in the

editing of the *Journal of Political Economy*. In September, 1948, he was elected vice-president of the Econometric Society and in 1949 a Fellow of the American Statistical Association. During July, 1948, he participated as consultant in a conference organized by The RAND Corporation. His addresses and publications during the period of this report are as follows:

"Welfare Economics of Transportation and Location," presented March 4, 1948, at the Economics Department Seminar, Harvard University.

"Linear Graphs and the Theory of Transportation," presented April 12, 1948, before the Junior Mathematics Club, University of Chicago.

"Identification as a Problem in Inference," presented June 22, 1948, at the Berkeley meeting of the Institute of Mathematical Statistics.

"A Mathematical Model of Production," presented September 10, 1948, before the Econometric Society, Madison, Wisconsin. (Abstract in *Econometrica*, Vol. 17, January, 1949, pp. 74–75.)

"Allocation of Resources in a Linear Structure, presented November 16, 1948, at the Graduate School, Department of Agriculture, Washington, D.C.

"Econometric Models for the Study of Resource Allocation," presented November 17, 1948, at the Economics Department Seminar, Princeton University.

"Substitution in Input-Output Models," presented November 19, 1948, at the Economics Department Seminar, Harvard University.

"The Econometric Approach to Business Fluctuations," presented December 28, 1948, before a joint session of the American Economic Association, American Statistical Association, and the Econometric Society in Cleveland, Ohio. (Cowles Commission New Series Paper, No. 35.) (*Proceedings Supplement of the American Economic Review*, Vol. 39, May, 1949, pp. 64–72.)

"Contribution to the Discussion of Professor Leontief's Paper on 'Recent Developments in the Study of Inter-Industrial Relationships,' " presented at the Cleveland Meeting of the American Statistical Association and American Economic Association, December 29, 1948. (*Proceedings Supplement of the American Economic Review*, Vol. 39, May, 1949, pp. 234–235.)

"Identification Problems in Economic Model Construction," *Econometrica*, Vol. 17, April, 1949, pp. 125–144. (Cowles Commission New Series Paper, No. 31.)

"Reply to: 'Methodological Issues in Quantitative Economics,' " *Review of Economics and Statistics*, Vol. 31, May, 1949, pp. 86–91. (Cowles Commission New Series Paper, No. 29.)

"Models of Production and Allocation," presented May 13, 1949, at the Economics Department Seminar, University of Buffalo.

"Allocation of Resources in Production" (with Reiter), Course Lectures, University of Chicago, spring, 1949 (hectographed).

Jacob Marschak

Jacob Marschak, who was research director of the Cowles Commission since January, 1943 (see 1942–46 report for biographical details) resigned that post as of June 30, 1948. He continues as senior research associate of the Commission and as a professor of economics at the University of Chicago. During the winter quarter of 1948 Marschak was visiting professor at the National University of Mexico and at the University of Buffalo. In 1948 he was elected a member of the International Statistical Institute. He is an associate member of the editorial board of the *Journal of the American Statistical Association*, a member of the editorial board of the *Journal of Human Rela-*

tions, and cooperates in the editing of the *Journal of Political Economy*. He continued as a member of the Council of the Econometric Society and (until April, 1949) as a member of the Executive Committee of the Conference on Income and Wealth. In 1949 he served on the Committee on Technological Change of the Social Science Research Council. He published or presented the following papers during this period:

"Review of 'Alcune Considerazioni sulle curve dei redditi' by G. Giaccardi," *Mathematical Reviews*, Vol. 10, May, 1949, p. 314.

"Comparaison des conceptions capitalistes et sovietiques de l'enterprise" (translation of the Introduction to "Management in Russian Industry and Agriculture," quoted in the Five-Year Report of the Cowles Commission, 1942–46): *Hommes et Techniques*, Paris, Vol. 4, No. 37, 1948, pp. 15–22.

"Introduction to Econometrics," 24 Course Lectures, University of Buffalo, winter, 1948 (mimeographed).

"Introduction to Econometrics," 20 Course Lectures, University of Chicago, spring, 1949. Supplement to above listed lectures (hectographed).

"Lectures on Income, Employment and Price Level," 20 Course Lectures, University of Chicago, fall, 1948 (hectographed).

"Modern Theories of National Income and Price Level." Five lectures given at the National University of Mexico, January, 1948.

"Economic Measurements, Prediction and Policies." Five lectures given at the National University of Mexico, February, 1948.

"The So-called Money Illusion and the Theory of Employment and Prices," presented April 7, 1948, at the University of Toronto.

"What Do We Know about the Russian Economy?" (with P. Baran and S. Harris), presented March 7, 1948, at the University of Chicago Round Table.

"The Future of Economic Theory," presented May 24, 1948, at the University of Buffalo.

"Theory of Uncertainty," presented June 4, 1948, at the Conference on Uncertainty and Risk of the Agricultural Economics Research Group, University of Chicago.

"Measurable Utility and the Theory of Assets," presented September 7, 1948, before the Econometric Society, Madison, Wisconsin. (Abstract in *Econometrica*, January, 1949, Vol. 17, p. 63.)

"The Role of Liquidity under Complete and Incomplete Information," presented December 29, 1949, before the Econometric Society and American Economic Association. (*Proceedings Supplement of the American Economic Review*, Vol. 39, May, 1949.) (Cowles Commission New Series Paper, No. 37.)

"Use of Comparative Macro-Economics," presented January 18, 1949, at the Seminar on Linear Programming of the Graduate School of the U.S. Department of Agriculture, Washington, D.C.

"Economic Aspects of Atomic Energy" (with J. Arnold, M. Obst, and B. Rifas), presented March 20, 1949, at the Student Forum, University of Chicago.

Franco Modigliani

Franco Modigliani joined the Cowles Commission as research associate in September, 1948, at which time he also became a Fellow in Political Economy at the University of Chicago. He holds the degree of Doctor in Jurisprudence from the University of Rome, 1939, and the degree of Doctor in Social Sciences from the Graduate Faculty of Political and Social Science, New School for Social Research, 1944. During the academic year, 1941–42, he held the Halle Fellowship at the New School. He

was interim instructor in economics and statistics at the New Jersey College for Women (Rutgers University) in the spring of 1942 and was instructor at Bard College of Columbia University in the summer of that year and associate until 1945. In the summer of 1945 he returned to the New School for Social Research, where he had been on leave of absence since 1942, as lecturer, and in the fall of 1946 he became assistant professor, a post he retained until he came to the University of Chicago. During the same period he was a research associate and chief statistician for the Institute of World Affairs, New School for Social Research. In November, 1948, he resigned his fellowship at the University of Chicago to become associate professor at the Bureau of Economics and Business Research, University of Illinois, and director of a research project on expectations and business fluctuations. During the period covered by this report, his talks and papers were as follows:

"Alternatives to Rationing and Price Control," presented November, 1948, before the Political Economy Club, University of Chicago.

Discussion of the papers of J. Marschak and A. Hart. Joint Session of the American Economic Association and Econometric Society, Cleveland, Ohio, December 29, 1948. (*Proceedings Supplement of the American Economic Review*, Vol. 39, May, 1949, pp. 201–208; and *Econometrica*, Vol. 17, April, 1949, p. 183.)

"Business Expectations and the Process of Investment in Plant and Equipment," presented February 9, 1949, before the Economics Faculty Seminar, Carnegie Institute of Technology.

"Incentive versus *Ad Hoc* Controls in Handling Economic Shortages" (with Bronfenbrenner), presented November 29, 1948, at the Political Economy Club, University of Chicago, and on March 7, 1949, at the Economics Faculty Group, Northwestern University.

"Inquiry into the Process of Investment in Plant and Equipment," presented in February, 1949, before the Economics Seminar, University of Michigan.

"Expectations and Business Fluctuations: Outline of a Research Project," presented in March, 1949, before the Harvard Business School Alumni Club of Chicago.

"Fluctuations in the Saving Ratio: A Problem in Economic Forecasting," *Studies in Income and Wealth.* Volume 11 of the Conference on Research in Income and Wealth, National Bureau of Economic Research, New York, New York, 1949, pp. 371–438.

Don Patinkin

Don Patinkin continued as research associate of the Cowles Commission until June, 1948, when he was appointed associate professor of economics at the University of Illinois in Urbana. In February of 1949 he joined the economics faculty of the Hebrew University in Jerusalem. A list of his papers during the period of this report is as follows:

"Relative Prices, Say's Law, and the Demand for Money," *Econometrica*, Vol. 16, April, 1948, pp. 135–54. (Cowles Commission New Series Paper, No. 28.)

"Price Flexibility and Full Employment," *American Economic Review*, Vol. 38, September, 1948, pp. 543–64.

"The Indeterminacy of Absolute Prices in Classical Economic Theory," *Econometrica*, Vol. 17, January, 1949, pp. 1–27. (Cowles Commission New Series Paper No. 28.)

Stanley Reiter

Stanley Reiter, a graduate student in economics at the University of Chicago, assisted the Commission during the summer of 1948 and rejoined the Commission as

research assistant in March of this year. He was at Queen's College from 1941 to 1943, and again from 1945 to 1947, and received his B.A. with honors in economics in the latter year. From 1943 to 1945 he served in the army. Reiter's work with the Commission will be part of the study of the theory of allocation of resources. He collaborated in writing the following during the period of this report:

"Allocation of Resources in Production" (with Koopmans), Course Lectures, University of Chicago, spring, 1949 (hectographed).

Herman Rubin

Herman Rubin rejoined the Cowles Commission in September, 1948, as a research associate after spending the 1947–48 academic year at the Institute for Advanced Study as a National Research Council Fellow. While there he completed his work for the Doctor's degree (Ph.D., Chicago, 1948) and cooperated with the Commission as a research consultant. In addition to his work with the Commission, he taught mathematical statistics at Illinois Institute of Technology during the winter semester, 1948–49, and mathematics during the spring semester, 1949. Rubin published or presented the following papers during the period of this report:

"Some Results on Axiomatic Integration Theory," presented November 23, 1948, before the Mathematics Club, University of Chicago.

"Review of 'Cohomology Theory of Lie Groups and Lie Algebras,' by C. Chevalley and S. Eilenberg," presented December 9 and 16, 1948, before the 400 Club (Mathematics Seminar), University of Chicago.

"Review of 'Additive Set Functions in Abstract Spaces,' by A. D. Alexandroff," presented April 14 and 21, 1949, before the 400 Club (Mathematics Seminar), University of Chicago.

"Some Extensions of the Central Limit Theorem to Dependent Variables," presented April 17, 1948, at the American Mathematical Society, New York. (Abstract in *Bulletin of the American Mathematical Society*, Vol. 54, July, 1948, p. 644.)

"Some Results on the Asymptotic Distribution of Maximum- and Quasi-Maximum-Likelihood Estimates," presented September 7, 1948, to the American Mathematical Society and the Institute of Mathematical Statistics, Madison, Wisconsin. (Abstract in *Bulletin of the American Mathematical Society*, Vol. 54, November, 1948, p. 1080, and in *Annals of Mathematical Statistics*, Vol. 19, December, 1948, p. 598.)

"Properties of Maximum- and Quasi-Maximum-Likelihood Estimates of Parameters of a System of Linear Stochastic Difference Equations with Serially Correlated Disturbances," presented December 27, 1948, to the Institute of Mathematical Statistics, Cleveland. (Abstract in *Annals of Mathematical Statistics*, Vol. 20, March, 1949.)

"Estimation of the Parameters of a Single Equation in a Complete System of Stochastic Equations" (with Anderson), *Annals of Mathematical Statistics*, Vol. 20, March, 1949, pp. 46–63. (Cowles Commission New Series Paper, No. 36.)

"A Constant-Unity Index of the Cost of Living" (with Lawrence R. Klein), *The Review of Economic Studies*, Vol. 15, No. 38, 1947–48, pp. 84–87. (Cowles Commission New Series Paper, No. 26.)

Sam H. Schurr

Sam H. Schurr (for biographical details see 1942–46 report) continued his work as co-director of the study on Economic Aspects of Atomic Power as research associate until December, 1948, and is now a research consultant. He published or presented the following papers during the period:

"Economic Aspects of Atomic Power," presented September 29, 1948, before the Joint Committee on Investment Research of the American Life Convention and the Life Insurance Association of America, New York.

"Economic Aspects of Atomic Power," presented December 2, 1948, before the Chicago Chapter, American Statistical Association.

"Changes in Technology, with Special Reference to Atomic Energy," three lectures presented June 18 and 20, 1949, at the Life Officers Investment Seminar, American Life Convention Association with the University of Chicago School of Business, at Beloit, Wisconsin.

"Atomic Power in Selected Industries," *Harvard Business Review*, Vol. 27, July, 1949, pp. 459–479.

Herbert A. Simon

Herbert A. Simon (see 1942–46 report 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. Until June, 1949, he was professor of political science and chairman of the Department of Political and Social Science at Illinois Institute of Technology. During the summer of 1948 he was acting chief of the Management Engineering Branch of the Economic Cooperation Administration. In September, 1949, he will join the faculty of Carnegie Institute of Technology as head of the Department of Industrial Administration. The following are his papers published or presented during the period of this report:

"Definition of Technological Change," presented May 1, 1948, before the Economics Seminar, Carnegie Institute of Technology, Pittsburgh, Pa.

"Invention and Cost Reduction in Technological Change," presented December 28, 1948, before the Econometric Society, Cleveland. (Abstract in *Econometrica*, Vol. 17, April, 1949, p. 173.)

"Measurement of Municipal Activities," presented December 30, 1948, before the American Political Science Association, Chicago.

"Industrialization of Backward Areas," presented March 10, 1949, before the Economics Seminar, Carnegie Institute of Technology, Pittsburgh, Pa.

"Work Measurement in Public Administration," presented March 12, 1949, before the American Society for Public Administration, Washington, D.C.

"The Axioms of Newtonian Mechanics," *Philosophical Magazine*, Series 7, Vol. 38, 1948, pp. 888–905 (December 1947 issue published in 1948).

Co-editor, *Local Planning Administration* (revised edition), published by the International City Managers Association, Chicago, 1948, approx. 600 pp.

"Review of Ronald D. Shuman, *The Management of Men*," *Public Personnel Review*, Vol. 10, January, 1949, 55–56.

"Review of E. F. L. Brech, *Management: Its Nature and Significance*," *Management Review*, Vol. 38, January, 1949, p. 54.

William B. Simpson

William B. Simpson joined the staff of the Cowles Commission as research associate and assistant director of research in May, 1948. In September, 1948, he was elected secretary of the Econometric Society, and in January, 1949, he became managing editor of *Econometrica*.

Simpson received his B.A. degree in mathematics from Reed College (1942) and his M.A. degree in mathematical economics and mathematical statistics from Columbia

University (1943). He was research assistant in statistics (1940–41) and teaching assistant in economics and statistics (1941–42) at Reed College; prepared comparative wage studies in the lumber industry for the National Defense Mediation Board, winter, 1941; and revised the statistical techniques employed in forest management administration for the General Land Office of the Department of Interior, summer, 1942. During the war, he was a special agent for the Military Intelligence Division of the War Department, serving among other things as head of the banking and economic section of the Manila Counter Intelligence Office. In late 1945 and 1946 he had responsibilities in Japan in connection with the War Department and the War Crimes Commission and was a special representative of the Supreme Commander of Allied Powers on political affairs and labor relations in northern Honshu. From September, 1946, until joining the Cowles Commission in 1948, he was engaged in research in economics as a Fellow of the Social Science Research Council at the University of Chicago, except for temporary duty during late 1947 with the Legal Section in Tokyo as consultant to the Secretary of the Army.

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.

Petter Jakob Bjerve, assistant professor at the University of Oslo and chief of the national economic planning unit in the Norwegian Ministry of Trade, was with the Commission from September, 1948 to April, 1949, as a Rockefeller Fellow. Carl Christ, Social Science Research Council Fellow for 1948–49, was formally a guest throughout the period of his fellowship, though informally he participated as a regular staff member. His fellowship has been renewed for another year during which he will hold an appointment as a research associate at the Cowles Commission. From November, 1948 to February, 1949, Anders Hald, professor of statistics at the University of Copenhagen, was a guest of the Commission as a Rockefeller Fellow. Andrew Marshall, a graduate student in the Department of Economics at the University of Chicago, worked closely with the Commission from September, 1948, to March, 1949, in a study of the Klein model, the subject of his M.A. thesis in economics. Alan Prest of the Department of Applied Economics, University of Cambridge, was at the Commission as a Rockefeller Fellow in the fall of 1948. Erik Ruist of the Swedish Institute for Industrial, Economic and Social Research was a guest from January to May, 1949. Dick van Dongen Torman was a guest of the Commission as a Rockefeller Fellow from Rotterdam in late 1947 and early 1948. Jaroslav Tuzar, a Rockefeller Fellow from Charles University, Prague, came to the Commission in November, 1948, and will remain until the fall of 1949.

In addition to the above, the following also participated in the work of the Commission: Helge Anderson, Denmark; Jaakko Railo, Rocke-

feller Fellow, University of Helsinki, Finland; Roger Dehem, McGill University, Canada; John A. Sawyer, Canada, Fellow in the Department of Economics, University of Chicago; Malcolm C. Urquhart, Queen's University, Canada, and Fellow in Political Economy, University of Chicago; and Simon Yang, Rockefeller Fellow from National Peking University, China.

Cowles Commission Library

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 271 books, 518 pamphlets, and 69 bound volumes of journals. About 108 periodicals are received currently. The total collection consists of 2281 books, 4023 pamphlets, 445 bound journal volumes. In addition, the library of the late Professor Henry Schultz which contains 950 books and 1,750 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 Managerial Committees

Following discussions with the Dean of the Division of the Social Sciences in the spring and summer of 1948, 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; and its administrative affairs are under the supervision of a Managerial 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. In addition, acknowledgment is made to the Rockefeller Foundation and the Life Insurance Association of America for financial assistance given to the special research project on the economic aspects of atomic power. 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 of the research staff have held fellowships from the Guggenheim 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.

Perhaps the most critical problem facing the Cowles Commission has been the shortage of office space for its personnel. The need exists for developing a fund which can be drawn upon for the acquisition and maintenance of additional space suitable to the work of the staff. This would enable the Commission, moreover, to offer more adequate facilities to the interested and eager group of advanced students and research fellows which is drawn to the Commission (as indicated in section on Guests above).

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.

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 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. In addition, the publication of *Econometrica*, the journal of the society, again became a function of the Chicago office when Dickson H. Leavens retired as managing editor at the end of 1948 and was succeeded by William B. Simpson. Leavens was with the Cowles Commission from 1936 until the summer of 1947 when he moved to Colorado Springs. He has since been elected an honorary member of the Econometric Society.

Several members of the Cowles Commission staff hold offices in the Society. Tjalling C. Koopmans helped organize the meeting of the Society in Madison in September, 1948, was chairman of the program committee for the December meeting in Cleveland in 1948, and became vice-president of the Econometric Society in 1949. Simpson aided in organizing the Madison and Cleveland meetings of the Society and is currently on the program committee for this year's meetings in Boulder, Colorado, and New York City. He was elected secretary of the Society in September, 1948, succeeding Alfred Cowles. 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 and served as program chairman for the summer meeting. Jacob Marschak is a member of the Council of the Econometric Society and has contributed much toward the organization of the meetings of the Society.

Starting in September, 1948, the practice has been adopted of holding the American summer meeting of the Econometric Society in conjunction with the meetings of the American Mathematical Society, the Mathematical Association of America, and the Institute of Mathematical Statistics, with emphasis being placed upon papers of a mathematical and technical nature. In 1948 this meeting was held at the University of Wisconsin in Madison, Wisconsin. In 1949 it will be held at the University of Colorado in Boulder, Colorado, with additional sessions being planned so that it may also serve as a regional meeting.

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 Cleveland, Ohio, in December, 1948 (with a total attendance for all participating societies of over 2,400), and is planned for New York City in December of 1949. The American Association for the Advancement of Science, with Section K of

which the Econometric Society is affiliated, will meet in New York City at the same time. 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, and attendance at particular sessions ranges from 25 to over 300.

The yearly European meetings of the Society which were interrupted by the war were resumed in September, 1948, at The Hague. In 1949 the European meeting will take place in a French locality adjoining Switzerland, at a time and place arranged 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.

An affiliation between the Econometric Society and the International Statistical Institute was formally completed in March, 1949. The Society continues its consultative status with the Economic and Social Council of the United Nations.

During 1948, Volume 16 of *Econometrica* was published, consisting of four quarterly issues totaling over 400 pages. Volume 17 will consist of three regular issues supplemented by a 350-page volume containing the econometric papers which were presented at the International Statistical Conferences in Washington, D.C., in September, 1947. The distribution date of the Supplement is uncertain due to delays in printing the material in India. A total of 239 new members joined the Econometric Society during the eighteen months covered by this report. The active mailing list as of June, 1949 (including members who are out of contact), consisted of approximately 900 members of the Society and 750 nonmember subscribers, chiefly libraries. Of these, about half the members and subscribers are in the United States and the remainder in 50 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 (1) stock prices, (2) stock prices adjusted for reinvestment of cash dividends, and (3) yield expectations; and annual indexes of (4) yields, (5) dividend payments, (6) earnings-price ratios, and (7) earnings; all for 69 industry groups or combinations of 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. A full account of the history and use of this method for the analysis of time series. Certain new devices of treatment are presented, and extensive tables are given to aid calculations.

No. 6. THE ANALYSIS OF ECONOMIC TIME SERIES, by HAROLD T. DAVIS. 1941. 620 pages. Price $5.00. This book reviews the historical development of the subject, describes the methods used, and makes applications to a variety of economic phenomena.

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

No. 8. PRICE FLEXIBILITY AND EMPLOYMENT, by OSCAR LANGE. 1944. 114 pages. Price $2.00. The author aims at the 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, 1942–44.

No. 10. STATISTICAL INFERENCE IN DYNAMIC ECONOMIC MODELS, edited by TJALLING C. KOOPMANS, with INTRODUCTION by JACOB MARSCHAK, to be published in 1949. This monograph contains 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. To be published October, 1949. This study applies the methodology of econometric model construction to business cycle analysis with possible implications for prediction and policy making.

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.