

REPORT *of*  
RESEARCH ACTIVITIES

*July 1, 1956–June 30, 1958*

COWLES FOUNDATION  
FOR RESEARCH IN ECONOMICS  
AT YALE UNIVERSITY

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## PURPOSE

**T**HE COWLES FOUNDATION FOR RESEARCH IN ECONOMICS AT YALE UNIVERSITY, *established as an activity of the Department of Economics in 1955, has as its purpose the conduct and encouragement of research in economics, finance, commerce, industry, and technology, including problems of the organization of these activities. The Cowles Foundation seeks to foster the development of logical, mathematical, and statistical methods of analysis for application in economics and related social sciences. The professional research staff are, as a rule, faculty members with appointments and teaching responsibilities in the Department of Economics and other departments.*

*The Cowles Foundation continues the work of the Cowles Commission for Research in Economics, founded in 1932 by Alfred Cowles at Colorado Springs, Colorado. The Commission moved to Chicago in 1939 and was affiliated with the University of Chicago until 1955. In 1955 the professional research staff of the Commission accepted appointments at Yale and, along with other members of the Yale Department of Economics, formed the research staff of the newly established Cowles Foundation.*

*The Econometric Society, an international society for the advancement of economic theory in its relation to statistics and mathematics, is an independent organization which has been closely associated with the Cowles Commission since its inception. The headquarters of the Society were moved from Chicago to Yale in 1955.*

## COWLES FOUNDATION FOR RESEARCH IN ECONOMICS AT YALE UNIVERSITY

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## NOTE ON REFERENCES TO PUBLICATIONS

The following abbreviations are used throughout this report in referring to publications or working papers of the Cowles Foundation and Cowles Commission:

CCNS: Cowles Commission New Series Papers (see p. 32)

CFP: Cowles Foundation Papers (see p. 32)

CFDP: Cowles Foundation Discussion Papers (see p. 40)

*Monographs* (see p. 30) are referred to by number, and *Special Publications* (see p. 31) by title.

The *other publications* of each staff member are designated by letter in the list on pp. 42–45, and are referred to by author and letter in the text.

## RESEARCH ACTIVITIES

*July 1, 1956—June 30, 1958*

THE research activities of the Cowles Foundation during this period are continuations of studies outlined in the previous Report, where introductory explanations of these projects and accounts of earlier work may be found.

For support of the research reported in these pages, the Cowles Foundation is indebted to a variety of donors. The nucleus of support is provided by Alfred Cowles and other members of the Cowles Family and by the University. Much of the research on the theory of organization, decision-making under uncertainty, economic equilibrium, and management economics (sections 1–3) has been conducted under contract with the Office of Naval Research. A grant from the Ford Foundation has financed the Yale Workshop in Quantitative Economic Research (section 5), which is not part of the Cowles Foundation but overlaps it in personnel, location, and interests. The National Science Foundation is supporting Summers' research on statistical estimators (section 6), and the Rockefeller Foundation the research program in economic forecasting (section 7). In addition, mention is made below of the aid in computation given various projects by the Watson Laboratory, New York, the Yale University Computing Center, and the Massachusetts Institute of Technology Computation Center.

### *1. Theories of Organization and Decision-Making under Uncertainty*

#### *Theory of teams*

An organization can be defined as a group of persons who follow rules supposed to further their common interests. A rule, or rôle, states how a given member should act upon the outside world, or what he should communicate to other members, upon receiving given information. The organizational form is a set of such rules.

In general, there is no complete solidarity of interests among the members. The theory of games, and in particular of "coöperative games with pre-play communication" tries to spell out what deter-

mines the outcome of bargaining between persons who must agree on how to divide the fruits of coöperation or else lose those benefits altogether. During 1957–58 at Yale both Harsanyi and Schelling contributed greatly to clarifying this problem. It focuses on the allocation of benefits among the members of an organization rather than on the choice of the organizational form most beneficial to the group. As a matter of research strategy, it is expedient to separate these two difficult questions. To study the circumstances under which some organizational forms are better than others, it is expedient to address oneself, at the initial stages of research, to the special, idealized case (called “team”) where the divergence of interests is negligible.

Optimal organizational forms are those that, on the average, further the interests of the team best. Some organizational forms (called, vaguely, “centralized” ones) would be best, save for the “costs” of difficult decision-making and of extensive communications. The comparative advantages of a particular organization form depend on the properties of the following givens:

1. The “*payoff function*” that states how the interests of the team (e.g., the profits of a firm) are affected by any given set of its members’ actions, for a given state of external conditions. An important property of the payoff function influencing the value of a given organization form is the degree of “complementarity”: i.e., the extent to which one member’s action influences the effectiveness of another member. There is more complementarity, for example, between the actions of individual railway station managers than between the actions of branch managers of a chain store company. A high degree of complementarity calls for more extensive communication.

2. The *probability of various possible states* of the team’s environment. Of the several variables characterizing the environment, it is the less predictable variables that need most to be observed and communicated. To some extent high correlation, positive or negative, between a pair of variables reduces the need for communication, as one variable can be predicted from the other.

3. The *cost* (in human effort) involved in each rule of action and communication, given the state of the world. Relevant are the limitations of the memory and of the decision-making, problem-solving, and communicating capacities of a given person. All these capacities are possibly amenable to psychometric measurements.



As an extension of the economic theory of the single-person firm, one can study the effect of variations in the givens upon the nature of preferable organization forms for a multi-person firm. In complicated cases theory can merely provide computational procedures (such as linear programming) that can be applied when data are available. Such data—from physical and psychological technology—are scarce at present but can be collected through further orientation of research. With rough data, theory can only help to frame hypotheses as to why certain organizational forms have survived or proved advantageous under certain observed conditions.

The monograph on *Economic Theory of Teams* outlined in the previous Report is still under preparation by Marschak in collaboration with Roy Radner, now at the University of California. CFDP 32 and 33 contain some partial results.

McGuire began a study of simple real-life economic organizations to see how well the team models of Marschak and Radner describe existing systems of observation, communication, and decision assignment and to determine whether these models can lead to useful statements about the effects of certain organizational changes. He looked at the sales and distribution organizations found in wholesale bakeries where each day, for each type of product, production decisions must be formed from the salesmen's decisions about what amounts of products to place in their respective markets on the following day. Since the demand in each market is uncertain, and since marginal cost of production increases with the total amount produced, a "perfect" decision on the part of any one salesman calls for information both about the probability distribution of demand in his own market and about the orders submitted by the other salesmen. Their decisions, in other words, are complementary. Except in a completely centralized organization (none such was found in practice), decisions must be made on the basis of incomplete information. However, some efforts are made to coördinate the salesmen's decisions, and much of the activity of the central sales office is concerned with this task. McGuire devised a mathematical "team" model [CFDP 53] which attempted to describe "best" decision rules for the salesmen under systems involving different amounts of centralization. The work is still in progress.

Beckmann has been concerned with the problem of imputing value

to information. For a team or a single decision-maker a "value of added information" may be defined by imputing the increment in payoff to the additional information, *ceteris paribus*. The calculation of this value is simple on the assumption that the organization or decision-maker makes optimal use of it, which implies in particular that there are no other limits on decision-making capacity. As one would expect, the value of information thus measured is quite different from the "amount of information" (entropy) used in communications engineering and theory.

In organization theory another aspect of information assumes importance. Unlike other commodities, information is not used up when it is passed on to other decision-makers. This refusal of information to obey the "law of conservation of matter" is a source of great analytical difficulties in imputing the value of information among all its users within the organization. Beckmann uses linear programming methods to bring out the imputation of values implied by an optimal allocation of information among decision-makers. Thus the value of information at the source equals its value to any decision-maker at this source plus the value of messages to other decision-makers. The value of an incoming message equals in turn the value of the information to the decision-maker plus the values of any outgoing messages. In this way the initial value of information is allocated to all users. The allocation is made determinate by the further conditions that the marginal value of information to a decision-maker equal its marginal contribution to the expected payoff, and that the marginal value of a message must equal the marginal cost of its transmission [CFDP 20].

### *Homo stochasticus and cardinal utility*

The problem of casting the basic theory of economic choice in probabilistic terms was discussed in the last Report.

The discussion of cardinal utility in economics made clear long ago that the basis of the theory must be a fourfold relation among the objects of choice of the form "*a* is preferred to *b* more than *c* is preferred to *d*." A major difficulty was to give an operational content to such a relation. Von Neumann and Morgenstern\* suggested the in-

\* J. VON NEUMANN and O. MORGENSTERN, *Theory of Games and Economic Behavior*, Princeton University Press, 1947, Chapter I and Appendix.

terpretation: an even-chance of  $a$  and  $d$  is preferred to an even-chance of  $b$  and  $c$ . Another interpretation has been given by Davidson and Marschak [CFDP 22]. Let  $p(a,b)$  be the probability that the subject chooses  $a$  when he is constrained to choose one of the two objects  $a$  and  $b$ . Their interpretation of the required fourfold relation is  $p(a,b) > p(c,d)$ . Debreu gives an axiomatic treatment of cardinal utility based on this interpretation [CFDP 39].

In the testing of the cardinal utility theory of von Neumann and Morgenstern subjects seem to be unable to grasp the significance of complex uncertain prospects. Davidson and Marschak therefore propose to present subjects only with the simplest possible type of uncertain prospects, namely even-chance mixtures of pairs of sure prospects. Debreu has given an axiomatic construction of cardinal utility in this context [CFDP 57]. Block and Marschak [CFDP 42] studied the logical relation between the probabilities of choices—such as  $p(a,b)$  defined above—and the hypothesis of “random orderings,” i.e., the idea that tastes vary according to a probability distribution.

## 2. *Theory of Economic Equilibrium*

Debreu's fundamental reformulation of theories of economic equilibrium, described in the previous Report, will be published in 1959 under the title, *Theory of Value*, as Cowles Foundation Monograph No. 17. During the past two years, he has extended his previous results to the case of uncertainty (Chapter 7 of the monograph). The starting point of the analysis may be briefly described. The general form of a contract for the transfer of goods and services between two economic agents is the following: the first agent shall deliver to the second (who shall accept delivery) a specified quantity of a particular good or service at specified date and location if a well-defined exogenously determined event occurs; the price of the conditional commodity defined in this fashion is agreed upon and paid at the instant when economic plans are made. This generalization of the concept of commodity (which had its origin in K. Arrow's 1952 paper, CCNS 77) allows one to obtain a theory of uncertainty free from any probability concept and identical in its form to the theory of certainty. Thus the fiction that futures markets exist for all goods and services, which was found to be so convenient in the analysis of time in economics, is carried one step further here.

More specific characterization of economic equilibrium over time requires more restrictive assumptions than are made in Debreu's broad theory. Efficiency in the allocation of production over time, and the implications of efficiency for capital goods prices and interest rates, have been discussed in the first essay of Koopmans' book (*Three Essays on the State of Economic Science*, pp. 105–126), building on the fundamental article of E. Malinvaud [CCNS 71]. The purpose of Koopmans' present research in this area is to build theoretical models of equilibrium growth in which a simple structure of preference over time is combined with a simple representation of production possibilities (such as was used in von Neumann's well-known model of proportional growth). Through such an analysis, it is hoped, it will be possible to characterize the capital stock—in terms of amounts of various types of plant and equipment—which is in equilibrium with a given preference structure and a given technology. A slow approach to such a capital stock from an initial disequilibrium may also be studied.

How prices are determined in markets with forward trading is a classical problem on whose solution few investigators are agreed. Beckmann has considered the following case, which appears to be the simplest situation that retains the essential aspects of uncertainty: Consider the market of a storeable crop commodity whose production each year is determined by an independent drawing from the same probability distribution, known to all traders. Speculative demand is then the outcome not of differences in expectations but only of differences in risk preference. The spot price must be a function of stocks after harvest, and the problem becomes that of determining this function. This can be done by a recursive analysis from which some inferences can be drawn about the shape of its curve [CFDP 19].

### 3. *Management Economics*

As stated in the previous Report, the problems created by uncertainty, indivisibilities, and economies of scale have been the major concerns of the Cowles Foundation's researches in management science. Manne completed his paper on the optimal degree of excess capacity to be built into a new facility such as a pipeline or a super-highway. Both uncertainties in demand and economies of scale in construction enter into this problem. The study stems from an opti-

mizing model originally suggested by Hollis Chenery\* for predicting investment behavior. The generalizations discussed here are of two types: (a) the use of a probabilistic growth course in place of a constant rate of growth in demand; and (b) a study of the economies and the penalties involved in accumulating backlogs of unsatisfied demand. Surprisingly, generalization (b) leads to considerably greater difficulties in analysis than (a). The use of probabilities to describe the growth process does little—if anything—to complicate matters. The probabilistic version of Chenery's model turns out to be closely related to the classical problem of gambler's ruin, and a powerful tool can be borrowed from that area—the generating function for the duration of the game. Thanks to this generating function, the (zero-backlog) probabilistic model becomes no more difficult to study than the corresponding deterministic one. A direct implication is that a probabilistic growth course makes it desirable to install plant capacity of a somewhat *larger* size than would be optimal if demand were growing at a steady rate equal to the expected value of the probabilistic increments. Uncertainty, in this sense, has a stimulating effect upon the magnitude of individual investments. If one goes beyond Chenery's model to include the possibility of backlogs as well as of uncertainty, it turns out that there is a curious ambiguity in the effects of an increase in the unpredictability of demand. Once the possibility of backlogs is admitted, an increase in variance can even lead to a decrease in the optimal size of individual installations [CFDP 54].

Beckmann has sought to treat systematically the classical speculative question of returns to scale in business administration. Entrepreneurial capacity is often regarded as the limiting factor in determining the size of the firm. The administrative hierarchy of a modern corporation is a device for overcoming this hurdle. It is often thought, however, that such hierarchies operate under diseconomies to scale owing to delays in decision-making and to increasing costs of administration per worker. Thus it is concluded that even where increasing returns prevail in production activities, at some level the diseconomies of administration will catch up with the economies of production. This level is then the optimal size of the firm. However, when the span of control (the number of subordinates per adminis-

\* H. B. CHENERY, "Overcapacity and the Acceleration Principle," *Econometrica*, January 1952.

trator) is constant, it can be shown that, while the size of the administrative staff tends to grow exponentially with the number of levels in a hierarchy, so does the working force. As a result the ratio of administrators to workers is bounded and very nearly constant for intermediate and large firms. Also nearly constant are the other measures of performance: total outlay of wage and salary per worker and average delay of decisions. The conclusion is that with a constant span of control there are no significant diseconomies to scale in the administration of a business, and that the limiting factors in a firm which would reverse any increasing returns to scale in production must be sought elsewhere [CFDP 51].

Koopmans has constructed a water storage policy for a hydroelectric reservoir with a variable but foreknown inflow of water. The policy indicates how to vary the supplementary thermal generation over a given planning period in order to meet a given, variable but foreknown, demand for power at minimum cost of supplementary generation over that period. Within its assumptions, the study also indicates how to calculate the marginal costs of temporary additions to power supply, or of temporary diversions of water to other purposes, and the incremental benefits for the entire planning period from additions to reservoir or turbine capacity. The method used is that of convex programming with a continuous time variable [CFP 115].

Most of the existing body of economic theory on resource allocation rests rather critically on the assumption of perfect divisibility of factors of production. Whenever the factors involved are indivisible and are to be combined in small numbers, the principles of marginal analysis offer no guidance and entirely new considerations seem to be called for. To obtain an idea of the peculiar difficulties that may then be faced, Beckmann and Laderman have studied a simple allocation problem where a given number of passengers is to be transported. Available are two types of planes of different capacity. What is the best combination of planes to be used? While an exact answer is not always known, definite bounds can be established for the largest number of the smaller and less efficient planes than should ever be used. This permits a substantial reduction in the number of alternatives to be tried [CFP 109].

Indivisibilities, this time in "set-up" costs, also characterize the

planning problem of a machine shop required to produce many different items so as to meet a rigid delivery schedule, remain within capacity limitations, and at the same time minimize the use of premium-cost overtime labor and subcontracting [Manne, CFP 116].

Inventory and lot size problems arise in endless variety. Beckmann has considered a model with continuous rather than discrete time. Orders can be placed at any time, but delivery times are random. It is interesting that the approximate value of the optimal lot size agrees with the lot size formula for the case of certainty (the Wilson formula) [CFDP 50]. Current work by Manne is aimed at a better understanding of the nature of multi-item inventory control processes. A good deal is now known about single-item models, but very little about the multi-item case where many products have to compete for the services of limited amounts of processing capacity. Given the present state of mathematical knowledge about such problems, it seems quite likely that Monte Carlo methods will have to be employed.

#### 4. *Portfolio Selection and Monetary Theory*

Harry Markowitz's monograph, described in the previous Report, will be published in April, 1959, under the title *Portfolio Selection*, as Cowles Foundation Monograph No. 16.

Following Markowitz's approach, Koopmans is considering the implications of diversification for the probability distribution of the anticipated return on an investment portfolio. The purpose of diversification in portfolio selection is to increase the predictability (reduce the variance) of the return to the dollar invested by taking advantage of a certain amount of mutual cancellation in the random fluctuations in the returns on individual assets. This suggests that, as an unintended by-product of efficient diversification, the distribution of the anticipated return on the portfolio may be close to the "normal distribution." If this conjecture is confirmed by further analysis, Markowitz's criterion of efficient portfolio selection—minimize anticipated variance for a given anticipated return—would find additional support in recent theories of choice under uncertainty.

While the major objective of Markowitz's monograph is prescriptive, to help portfolio managers make rational choices, other research projects in this area under way at Yale are primarily descriptive in focus. Recent developments in the theories of inventory holding and

of decision-making under uncertainty give promise of fruitful application in the theory of money and finance. Tobin has applied these tools to the question of the relationship of the demand for money to the rate of interest [CFP 106, 118]. A broader use of the same approach characterizes his book on monetary theory, currently under preparation. Richard Porter is continuing work on the subject of his doctoral dissertation (1957): a model of a commercial bank designed to explain the proportions of the major kinds of assets in the bank's portfolio in terms of the available rates of return together with the risks of deposit withdrawal and of losses from premature liquidation of earning assets. Leroy S. Wehrle's dissertation project is an empirical and theoretical study of life insurance company portfolios in relation to the timing of their future requirements for funds and the associated risks. In another current dissertation project, Susan Lepper is investigating the changes in portfolio composition that an investor following Markowitz's prescriptions would make as a result of certain taxes. Calculations of these tax effects are being made with the help of the IBM 650 of the Yale University Computing Center.

### *5. Household Economic Behavior*

The Yale Workshop in Quantitative Economic Research, organized in 1954 with a grant from the Ford Foundation to facilitate empirical econometric research by faculty members and graduate students, focusing on the economic behavior of households, continued its operations during the period of this report. Although a separate organization, the Workshop overlaps the Cowles Foundation in personnel, location, and interests. The Workshop's activities are therefore part of the intellectual history of the Cowles Foundation. As before, these activities can be reported under three headings: (1) research training seminars, (2) doctoral dissertations, and (3) faculty research.

#### *Research training seminars*

The previous Report describes the survey of college students undertaken by the 1954-55 seminar, designed to study consumer interdependence. Further statistical analysis of these data has been undertaken by Donald Hester. Concentrating on the data concerning sport



coats, he has found that the principal vehicle for emulation is the price the student pays for a coat, which is of course related to its quality and to the establishment where it is bought. Interdependence shows less clearly with respect to the stock of coats owned or the number purchased per year [CFDP 56].

The third seminar, held in 1956-57, again under the direction of Tobin and Guthrie, designed an experimental survey concerning transfers of wealth between generations. Motives to save fall in three general categories: (1) to meet known or possible discrepancies between consumption needs and income from year to year, (2) to make provision for retirement, (3) to transfer wealth to the succeeding generation. Only the third kind of saving will contribute to any net accumulation over a lifetime. Consequently the strength of the drive to pass wealth along to heirs in the next generation is an important determinant of a society's capacity to accumulate capital. Little is known about saving on a lifetime basis, or even about prevalent social attitudes regarding the economic responsibilities of one generation for its successor, or for its predecessor. The seminar designed a questionnaire to collect information on this subject, and employed *National Analysts, Inc.* of Philadelphia to interview a sample of 90 households in the Philadelphia metropolitan area. The sample design was complex. The basic sample consisted of respondents 35-40 years of age with at least two children. If either husband or wife had living parents in the Philadelphia area, these were interviewed, in order to obtain a longer history of the same lineal family. The seminar students edited, coded, and tabulated the responses. In its primary purpose, to determine the feasibility of collecting information, at least qualitative information, of this kind, the survey was successful. But the number of respondents is of course too small to serve as the basis for substantive conclusions. At a later date, a larger survey may be undertaken building on the experience of this pilot study.

#### *Doctoral dissertations*

Watts completed, as a doctoral dissertation in 1957, the study of the determinants of consumer saving begun in the 1955-56 seminar, outlined in the previous Report. The techniques used for detecting the effects of long-run income expectations (which are not directly measured) on saving behavior were moderately successful. The re-

sults of the empirical work did suggest that long-run expectations exert a significant influence on saving behavior. To that extent the findings supported the consumption theories of Friedman\* and of Modigliani and Brumberg,† both of which use an extended income and consumption horizon as a frame of reference for explaining short-term household decisions. Some of the more specific features of these two theories were not so well substantiated by the data. In particular, some doubt is cast on the hypothesis that transitory or short-run variations of income and consumption will be completely uncorrelated. Moreover, the hypothesis that consumption is a constant proportion of income when both are considered over a long horizon does not accord with the findings of the study. A possible explanation for the failure of this hypothesis is the third kind of motive mentioned above, saving for another generation. The Friedman and Modigliani-Brumberg theories deal only with the first two categories of saving [CFP 123].

Watts and Tobin participated in a symposium commenting on Malcolm Fisher's statistical tests of the Friedman and Modigliani-Brumberg theories against British survey data [Tobin and Watts, A.]. Some of the same weaknesses in the theories that Watts found in U.S. data were also revealed in Fisher's calculations.

The plan of Thomas Dernburg's project on television ownership was also presented in the previous Report. The main results of the dissertation completed in 1957, are as follows: The spread of TV set ownership in an area where television has been introduced can be successfully described by the logistic law used to describe growth in many other contexts; the spread of television receivers was accelerated by the availability of plural broadcasting facilities; and there is little evidence of any saturation level short of 100 percent of households. The percentage of households owning sets in a given census tract depends not only on the number and age of existing broadcasting facilities but also, of course, on the economic and demographic characteristics of the population. Of these relationships, the most interesting are those involving income and level of educational attain-

\*MILTON FRIEDMAN, *A Theory of the Consumption Function*, Princeton, Princeton University Press, 1957.

†FRANCO MODIGLIANI and RICHARD BRUMBERG, "Utility Analysis and the Consumption Function—An Interpretation of Cross-Section Data," *Post-Keynesian Economics*, ed. K. K. Kurihara, New Brunswick, Rutgers University Press, 1954, pp. 388-436.

ment. In relation both to income and to educational level, Dernburg found that TV ownership rose up to a point and then fell off. The critical levels were about \$7,000 income and 11 years education [CFP 121].

Richard Rosett's analysis of the factors which determine a married woman's tendency to enter the labor force was also under way at the time of the last Report and was completed in 1957. Using Tobin's "limited variable" method of estimation, Rosett found that participation of a wife in the labor force is more likely the larger is the husband's wage rate, the larger is the wife's potential wage rate, the larger is their debt, the smaller is their property income, or the more extensive is her education. Participation is more likely for wives with no children or no young children and in the early years of marriage. It should be emphasized that each of these findings is a *net* effect associated with change in one variable while the others remain constant. Rosett had the assistance of computation facilities at the Watson Laboratory at Columbia University (IBM 650), at the Yale University Computing Center (IBM 650) and at the Massachusetts Institute of Technology Computation Center (IBM 704) [CFP 122].

These three studies were published together as *Studies in Household Economic Behavior*, Yale Studies in Economics, Vol. 9 (Yale University Press, 1958).

### *Faculty research*

Guthrie has continued his studies of liquid asset holdings and of consumer interdependence. Using data from four Surveys of Consumer Finances, he has computed lifetime relative income profiles for 25 social groups [CFDP 43]. The measure of relative income is the income decile in which a household falls in a ranking of an entire survey. The 25 sub-groups are determined by classification according to occupation, region, education, and race. The profiles show how, on the average, the relative income status of households in each of these groups changes with their age. These profiles are important tools in the two studies still in process.

In respect to liquid asset holdings, Guthrie finds that young households with low current incomes but belonging to groups that eventually achieve high relative income status show the lowest propensity to hold liquid assets, as measured by the ratio of liquid assets hold-

ings to income. Among groups that never achieve high relative income status, there seems to be a latent unsatisfied need for liquid reserves that can be satisfied only by households with no dependents or exceptionally high incomes. In general, the propensity to hold liquid assets increases with age (although holdings by older people in early postwar years were abnormally large), and declines with the size of the spending unit.

In the second study, Guthrie is comparing the power of absolute (dollar) income and relative income in explaining differences among households in saving and durable goods expenditure. Several variants of relative income can be tested: the status of a household can be measured relative to its entire social group, or relative only to its contemporaries within the social group.

Lifetime income profiles have proved a useful tool also in Summers' continuation and generalization of his investigation of household income dynamics, described in the previous Report (p. 27). In order to take account of the effects not only of age but of education, occupation, race, and region on household income and income change, Summers has used standard income profiles for different types of households. Summers' profiles concern dollar income, not Guthrie's measure of relative income position. His hypothesis is that the percentage deviation of a household's income from its profile income this year depends on the percentage deviation in the previous year. A single income dynamics relationship of this kind does not appear to describe satisfactorily all households. Summers has found it useful to divide households into two categories: "low status" and "high status," as defined by education, occupation, and race. The basic hypothesis and the division into two status categories were suggested by calculations on one reinterview sample of the Survey of Consumer Finances, and they are being tested against a second reinterview sample.

Tobin presented some of the findings of his analysis of the reinterview portion of the 1953 Survey of Consumer Finances at the Conference on consumer credit held by the National Bureau of Economic Research for the Federal Reserve Board [Tobin, C]. The general plan of this analysis has been described in the previous Report. In the conference paper, particular attention was devoted to analysis leading to the general conclusion that high outstanding debt deters further accumulation of debt and discourages expenditures on durable

goods. (Rosett's work adds the finding that debt encourages the wife to enter the labor market.) To the extent that expansion of consumer debt is self-limiting, the problem of preventing its inflationary consequences is less critical. The paper also examined the correlations between debt changes and liquid asset changes, concluding that in general households do not irrationally use debt to maintain high liquidity.

Tobin's paper on the predictive value of attitudinal data, with the conclusions indicated in the previous Report, was completed [CFDP 41].

Research on the structure of household assets and debts has been undertaken by Watts and Tobin for the Study of Consumer Expenditures, Incomes and Savings of the Wharton School of Finance and Commerce, University of Pennsylvania, which has provided the basic data and partial financial support. The data are from the 1950 Survey of Consumer Expenditures of the U.S. Bureau of Labor Statistics, covering 12,500 urban households. These data provide measures of some of the major items present in household portfolios: cash, mortgage debt, installment debt, household durable goods, automobiles, and owner-occupied real estate. Some important assets are conspicuously absent: securities, equities in unincorporated business, and real property held for rental or speculative purposes. Their absence is a definite handicap, rendering impossible analyses which would require an exhaustive, or nearly exhaustive, enumeration of household net worth. But it is felt that the data do permit study of the determinants and interrelations of levels and changes in levels of some important household assets and debts.

One part of the study will be a simple description of the variation in portfolio patterns over some 128 socio-economic groups. The statistical significance of the variation will be tested, and interpretation of significant patterns of variation will be attempted. A second part will be devoted to analyzing and comparing the effects of current income and housing level, a measure of more permanent economic status, on departures from "average" asset and debt positions. Correlations among portfolio components can also be examined for patterns of substitution and complementarity.

Finally, in addition to the "stock" variables mentioned above, the data include observations on corresponding changes in stocks or

“flows,” making it possible to estimate the effects of “stock” levels on each of the “flows.” The coefficients thus obtained can be interpreted as estimates of parameters of a system of difference equations describing the dynamics of portfolio adjustment. The stationary solution to that system, if it exists and is stable, can be interpreted as the “desired” pattern toward which households are moving. We can ask whether and how this “desired” portfolio pattern differs from the actual pattern observed at a given time.

The volume of data processing involved in this research has been enormous. The task has been made feasible only by the availability of electronic computing equipment. We are grateful to the Yale University Computing Center for the use of their IBM 650 and subsidiary machines and for bearing part of the costs of these services.

### *6. Research Tools and Methods*

Summers’ investigation of the small-sample properties of simultaneous equations estimators has proceeded with financial support from the National Science Foundation and free machine time on the IBM 704 machine of the Massachusetts Institute of Technology Computation Center. Using Monte Carlo techniques, Summers is appraising various proposed estimators in terms of relative bias and statistical efficiency. The model being considered initially consists of two stochastic equations in two jointly determined variables ( $y$ ’s) and four predetermined variables ( $z$ ’s):

$$\begin{aligned} y_1 + \beta_{12}y_2 + \gamma_{11}z_1 + \gamma_{12}z_2 + \gamma_{10} &= u_1 \\ y_1 + \beta_{22}y_2 + \gamma_{23}z_3 + \gamma_{24}z_4 + \gamma_{20} &= u_2 \end{aligned}$$

The parameters of interest are the  $\beta$ ’s, and  $\gamma$ ’s, the variance-covariance matrix of the  $u$ ’s, and certain combinations of these parameters. The methods of estimation used are: (a) Limited information single equation; (b) Theil’s Two-stage least squares method—(i)  $y_1$  dependent, (ii)  $y_2$  dependent; (c) Ordinary least squares—(i)  $y_1$  dependent, (ii)  $y_2$  dependent; (d) Full information maximum likelihood; (e) Full information maximum likelihood, diagonal variance-covariance matrix. Programming and “debugging” for the calculations involved are nearly completed. An important problem to be faced, once the program is running, is the investigation of the sensitivity of the empirical findings (i.e., the ranking of the different estimating tech-

niques) to changes in the parameters of the model. Experimental design, a technique not usually required by the econometrician, will be required here.

The "limited variable" technique of estimation from survey data, developed by Tobin (previous Report, pp. 25-26 and CFP 117), was used by Rosett in his study of working wives, discussed above. In the course of his work, Rosett developed programs for the iterative calculations required by the technique, for both the IBM 650 and the IBM 704. Rosett also generalized the method to apply to variables with concentrations of observations at any points, whether limiting values or not [CFDP 30].

It is increasingly true that economists wishing to estimate numerically a particular relationship among economic variables, or to test hypotheses concerning the relationship—e.g., household consumption in relation to income or business investment in relation to sales—have several kinds of data available to them. Some data are averages for large groupings of individual units: the whole nation, an industry, a region, a certain socio-economic grouping. Other data are the multitude of observations of individual units—households or firms—themselves. Some data are a cross-section "snapshot" at a given moment of time. Others are time series showing variation over time. How to combine these different kinds of data efficiently is a major unsolved problem involving both economic theory and statistical inference. A theory of "aggregation" is required, explaining how the economic process generates both the cross-sections of individual observations and the time series of aggregates and averages. During his visit to the Cowles Foundation as a Rockefeller Fellow, Holte contributed to the theory of aggregation [CFDP 21].

On May 3-4, 1957, the Cowles Foundation was host to an informal working conference of scholars particularly interested in these theoretical and statistical problems. The conference was stimulated in considerable measure by the interests of research workers at the U.S. Bureau of Agricultural Economics, who have need of econometric techniques for estimating supply and demand functions for agricultural commodities. Those present, other than regular staff members of the Cowles Foundation, were: William Cromarty, Michigan State University; R. J. Foote, U.S. Department of Agriculture; Clifford G. Hildreth, Michigan State University; Fritz C. Holte, The

Norwegian College of Agriculture, Oslo; Hendrik S. Houthakker, Stanford University; George G. Judge, Oklahoma Agricultural and Mechanical College; Lawrence R. Klein, Oxford University; Edwin Kuh, Massachusetts Institute of Technology; George Kuznets, University of California; James Morgan, University of Michigan; Guy H. Orcutt, Harvard University; Sten A. O. Thore, Konjunkturinstitutet, Stockholm.

### 7. *Economic Forecasting*

Prediction of fluctuations in overall business activity has long been one of the most intriguing and frustrating activities of economists. Forecasting techniques have been developed and modified in response to innovations in business cycle theory, refinements in statistical methods for testing and estimating economic relationships, and expanded collection of current economic data. The work at the Cowles Foundation led by Okun, under a grant from the Rockefeller Foundation, has as its objectives appraisal of the empirical success and economic logic of techniques of short-term forecasting and integration of various approaches.

An important addition has been made since the war to United States economic data through the inauguration of several "anticipations" series. These supply the economist with a continuing record of the level of intended spending by business firms on plant and equipment, the volume of household plans to buy automobiles and major durable appliances, the volume of intentions to buy homes and of home-building plans by construction firms, and the expected levels of business sales and inventories. Obviously, the intentions of firms and households are not uniformly fulfilled. Research efforts are therefore required to appraise the predictive value of the anticipations variables and to suggest efficient means for their utilization in forecasting. The Cowles Foundation contributed to statistical analysis of the predictive value both of consumer intentions [CFDP 41] and of business investment plans [CFDP 17]. Drawing on these and other studies, Okun reported that a number of the anticipations series appeared to have distinct predictive value, that they could be profitably utilized as complements to other economic data in prediction, and that they were amenable to econometric treatment through multiple regression analysis [CFDP 40].



Okun is currently engaged in a similar appraisal of another set of variables, which may be labelled *pre-flow* data. These statistical series measure, for particular types of economic transactions, the volume that has already been initiated but not yet completed. Among these variables are construction contract awards, housing starts, new and unfilled orders placed with manufacturers, and defense contracts awarded by the Federal Government.

The plans and orders recorded in anticipations and pre-flow series are not the causal forces that determine economic activity. They reflect the forces currently affecting the economy and determining its course over the near future. In that sense, the plans and orders are symptomatic (or barometric) predictors. Existing econometric models have excluded such data and have restricted themselves to causal relationships. Because of this practice, the models offer a causal explanation of past economic fluctuations as well as a method for predicting the national product of the future. However, it appears that a more eclectic choice of data can enhance the forecasting accuracy of economic models, at some expense in explanatory content. The research in short-term forecasting at the Cowles Foundation aims toward the development of a special-purpose predictive model, designed specifically to forecast national income and product by quarterly periods for several quarters in advance.

In recent years, encouraging marks for predictive accuracy have been earned both by econometric forecasts based on the Klein-Goldberger model\* and by the predictions of skilled business economists relying on their informed judgment. As Okun suggests in CFDP 45, there is ample room for improvement in accuracy. One can find no clear margin between econometric and noneconometric forecasts in the degree of predictive success. While econometric techniques have not surpassed intuitive methods in performance to date, there are a number of grounds for the conviction that the use of formal models can improve predictive accuracy. First, there are many unexplored potentialities of models, such as the use of symptomatic predictors. Second, a model is a valuable device for instruction and communication. The use and content of the model can be taught readily to persons with quantitative training in economics. Good judgment, on the other

\*L. R. KLEIN and A. S. GOLDBERGER, *An Econometric Model of the United States, 1929-1952*, Amsterdam, North-Holland Publishing Company, 1955.

hand, is hard to transmit to disciples. Third, the model is a tool for the verification and refinement of hypotheses. With predictions based on judgment, it is difficult to learn where intuition held up well and where it went awry. The econometric model, on the other hand, greatly facilitates the appraisal and analysis of past forecasting performance enabling the economist to eliminate discredited hypotheses and to subject new ones to test.

During four months of 1957, the forecasting project had the benefit of the advice and stimulation of Lawrence Klein, visiting the Cowles Foundation from Oxford. During his visit Klein sought to find measures of industrial capacity that could be used, individually or in aggregate, to strengthen the forecasting power of his econometric model of the United States economy. The inducement to business firms to invest can be expected to be greater when they are operating at or near capacity than when they have at hand excess capacity. In CFDP 49, Klein distinguished "pragmatic" concepts of capacity, which measure maximum attainable output in a technical sense, and more refined "theoretical" concepts, which allow for cost considerations. He concluded that, for many purposes, the pragmatic measures were satisfactory while, in certain instances, quantification of the theoretical concepts was desirable and feasible.

## RESEARCH CONSULTANTS

A RESEARCH CONSULTANT to the Cowles Foundation is a scholar at some other institution who maintains an active interest in the research program of the Foundation, manifested in exchanges of ideas and results with members of the Foundation's staff. Some Consultants are previous members of the staff, and some are completing research begun at the Cowles Commission or Foundation or pursuing further investigations stimulated by such research. Where a real relationship exists between the work of a Consultant and the program of the Cowles Foundation, the Foundation welcomes the opportunity to include the results in its publications.

The following were Research Consultants June 30, 1958:

THEODORE W. ANDERSON  
Dept. of Mathematical Statistics  
Columbia University  
New York, New York

KENNETH J. ARROW  
Dept. of Economics  
Stanford University  
Stanford, California

H. DAVID BLOCK  
Dept. of Eng. Mechs. and Materials  
Cornell University  
Ithaca, New York

CARL F. CHRIST  
Department of Economics  
University of Chicago  
Chicago, Illinois

H. T. DAVIS  
Department of Mathematics  
Northwestern University  
Evanston, Illinois

TRYGVE HAAVELMO  
University Institute of Economics  
Oslo, Norway

CLIFFORD G. HILDRETH  
Dept. of Agricultural Economics  
Michigan State University  
East Lansing, Michigan

WILLIAM C. HOOD  
Dept. of Political Economy  
University of Toronto  
Toronto, Canada

HENDRIK S. HOUTHAKKER  
Dept. of Economics and Soc. Sciences  
Mass. Institute of Technology  
Cambridge, Massachusetts

LEONID HURWICZ  
School of Business Administration  
University of Minnesota  
Minneapolis, Minnesota

LAWRENCE R. KLEIN  
Institute of Statistics  
Oxford University  
Oxford, England

LIONEL W. MCKENZIE  
Dept. of Economics  
University of Rochester  
Rochester, New York

HARRY MARKOWITZ  
Computer Dept., General Electric Co.  
Arizona State College  
Tempe, Arizona

ROY RADNER  
Department of Economics  
University of California  
Berkeley, California

THOMAS C. SHELLING  
Department of Economics  
Yale University  
New Haven, Connecticut

HERBERT A. SIMON  
Graduate School of Industrial Adm.  
Carnegie Institute of Technology  
Pittsburgh, Pennsylvania

## GUESTS

**F**OLLOWING the tradition of the Cowles Commission, the Cowles Foundation is pleased to have as guests advanced students and scholars from other research centers in this country and abroad. Their presence both stimulates the work of the staff and aids in spreading the results of its research. To the extent that its resources permit, the Foundation has accorded office, library, and other research facilities to guests who are in residence for an extended period. The following were associated with the organization in this manner during the past two years.

**FRITZ CHRISTIAN HOLTE** (Norway). August 1956—May 1957. Sponsored by the United States Educational Foundation in Norway. Returned to The Norwegian College of Agriculture, Oslo, Norway.

**THOMAS PETER HILL** (England). September 1957—January 1958. Sponsored by the Rockefeller Foundation. Returned to the Institute of Statistics, University of Oxford, England.

**EVA BOESSMANN** (Germany). September 1957—May 1958. Sponsored by the Rockefeller Foundation. Returned to the University of Frankfurt, Germany.

**DAVID A. CLARKE, JR.** (U.S.A.). September 1957—May 1958. Sabbatical leave from The Giannini Foundation of Agricultural Economics, College of Agriculture, University of California.

**MICHIO MORISHIMA** (Japan). November 1957—January 1958. Sponsored by the Rockefeller Foundation. Returned to the Institute of Social and Economic Research, Osaka University, Japan.

**WIESLAW SADOWSKI** (Poland). January 1958—July 1958. Sponsored by the Ford Foundation (through the Institute of International Education). Returned to Central School of Planning and Statistics, Warsaw, Poland.

## COWLES FOUNDATION SEMINARS

*July 1, 1956—June 30, 1958*

1956

- October 16.* WILLIAM J. VICKREY, Columbia University, "The Optimum Trend of the General Price Level."  
*October 30.* ROBERT DORFMAN, Harvard University, "A Model of Alternative Means for Meeting Fluctuating Demands."  
*November 20.* HERMAN WOLD, Institute of Statistics, University of Uppsala, "Demand Analysis: A Survey of Problems and Methods."

1957

- January 8.* PAUL A. SAMUELSON, Massachusetts Institute of Technology, "An Economic 'Brownian Movement.'"  
*February 5.* DUNCAN LUCE, Columbia University, "Utility and Subjective Probability."  
*March 12.* MAURICE McMANUS, Massachusetts Institute of Technology, "The Existence of a Competitive Equilibrium in a Money Economy."  
*April 2.* FRANK HAHN, Massachusetts Institute of Technology, "Money Dynamic Stability and Growth."  
*April 16.* JOHN MEYER, Harvard University, "Econometric Studies of Investment Decisions."  
*October 8.* PIERRE MASSÉ, Electricité de France, "Investment Problems at Electricité de France."  
*October 18.* FRANCO MODIGLIANI, Carnegie Institute of Technology, "The Cost of Capital, Corporation Finance and the Theory of Investment."  
*November 22.* HORST MENDERSHAUSEN, The RAND Corporation, "Economic Problems in Air Force Logistics."  
*December 3.* G. L. S. SHACKLE, Columbia University, "Expectation: Some Difficulties."  
*December 10.* H. S. HOUTHAKKER, Stanford University, "Theory of Normal Backwardation."

1958

- January 28.* JACQUES DRÈZE, Carnegie Institute of Technology, "Decision Making under Uncertainty and the Identification Problem."  
*February 13.* SIDNEY S. ALEXANDER, Massachusetts Institute of Technology, "Rates of Change as Forecasters."  
*March 4.* TRYGVE HAAVELMO, University of Oslo, "On the Formal Theory of Investment Behavior."  
*March 14.* FRANKLIN M. FISHER, Society of Fellows, Harvard University, "The Demand for Aluminum Ingot in the United States in the Interwar Period." Also some remarks on "A Theorem on *A Priori* Restrictions and Identification."

## COWLES FOUNDATION MANAGEMENT SEMINARS

THESE seminars, initiated in 1956, are aimed at promoting knowledge in the management sciences. The meetings serve as a medium for the two-way exchange of ideas between members of the Yale academic community and management people in Connecticut industries. To date, the following sessions have been held:

1956

*June 19.* MELVIN SALVESON, General Electric Company, "The Role of Entrepreneurship in a Large Decentralized Corporation."

*July 24.* ROBERT SUMMERS, Yale University, "Inventory Policies and Queuing Theory."

*August 28.* O. WENDELL HAMILTON, Stevenson, Jordan, and Harrison, Inc., "Inventory Management in a Corporate Firm Manufacturing to a Stock Position."

*September 27.* GERSHON COOPER, Dunlap and Associates, "Acquisition of Capital Assets by a Business Firm: A Case Study."

*November 9.* ALBERT O. HIRSCHMAN, Yale University, "Demand Analysis in Underdeveloped Countries: Two Case Studies from Colombia."

*December 5.* TJALLING C. KOOPMANS, Yale University, "Water Storage Policy in a Simplified Hydroelectric System."

1957

*January 17.* ALAN S. MANNE, Yale University, "Programming of Economic Lot Sizes."

*March 5.* ROYAL CRYSTAL, Connecticut Medical Service, "Cost Analysis at C. M. S."

*April 16.* ALAN GOLDMAN, Norden-Ketay, Inc., "Information Flow and Worker Productivity."

*April 23.* LEO SCHNITZER, Burndy Corporation, "Some Experiences in Applying Inventory Control Models."

*May 7.* DAVID VOTAW, Yale University, "Industrial Quality Control."

*May 22.* MARTIN J. BECKMANN, Yale University, "An Economist Looks at the Theory of Inventory Control."

1958

*February 5.* MARTIN SHUBIK, General Electric Company, "Maximization Aims in Business Enterprises."

*April 22.* GEORGE DANTZIG, The RAND Corporation, "Linear Programming."

*May 28.* JACOB MARSCHAK, Yale University, "The Theory of Organization."

## LIBRARY OF THE COWLES FOUNDATION

NATALIE SIRKIN, *Librarian*

THE library of the Cowles Foundation is designed primarily as a convenience to its staff members, providing in one place most of the books and journals they need in their research. The library is also heavily used by other members of the Department of Economics and graduate students.

The library consists of some 3,650 books, 160 journals, thousands of pamphlets, and much recent unpublished material. Of the total number of books, just under 700 were acquired during the two-year period covered by this report. Broken down by subject, these were: economics, 55%; collections of statistical data, 14%; mathematics, 10%; statistics (theory), 9%; reference books, 4%; social sciences other than economics, 3%; all others, 5%. Current books—books acquired within days or weeks of their publication—accounted for three-fourths of the new acquisitions.

Books circulate for as much as a month and journals for two days; they are not renewable. A reserve shelf is kept for some 300 books which are in demand for economic courses, and these circulate overnight.

## THE ECONOMETRIC SOCIETY

THE Econometric Society is an international society for the advancement of economic theory in its relation to statistics and mathematics. Its main object is the promotion of studies directed toward unification of the theoretical quantitative and the empirical quantitative approaches to economic problems and penetrated by the kind of constructive and rigorous thinking that has come to dominate the natural sciences. Any activity which promises ultimately to further such a unification of theoretical and factual studies in economics is considered to be within the sphere of interest of the Society.

At the present time the Econometric Society publishes a quarterly journal, *Econometrica*. It holds one European and one or two North American meetings each year. As an international organization, the officers of the Econometric Society represent many different countries. The major governing body of the Society is its Fellows. At the present time these number 122, and a maximum of six additional fellows are elected each year. Membership in the Society is open to anyone seriously interested in the objectives of the Society. Institutional memberships are also available in order to solicit the support of interested business firms and research organizations. In addition to the 1,650 members, there are 1,400 non-member subscribers to the journal, mainly libraries, business firms, and research organizations.

Three individuals, Irving Fisher, Professor of Economics at Yale, Ragnar Frisch, Professor of Economics at the University of Oslo, and Charles Roos, a research fellow at Princeton, were instrumental in the founding of the Society in 1930, two years prior to the establishment of the Cowles Commission. Initially the Society had less than 200 members, and its activities were restricted to the arrangement of small meetings at which papers were read and discussed. Because of the small membership and the minimal dues, it was not possible to publish a journal. With the founding of the Cowles Commission in 1932, a proposal was made that the Commission support the activities of the Econometric Society, and enable it, among other things, to publish a journal. After due consideration this proposal was adopted, and the first issue of the journal *Econometrica* was published in 1933. In the following years the Society grew, and with the increase in membership and subscriptions it became somewhat more

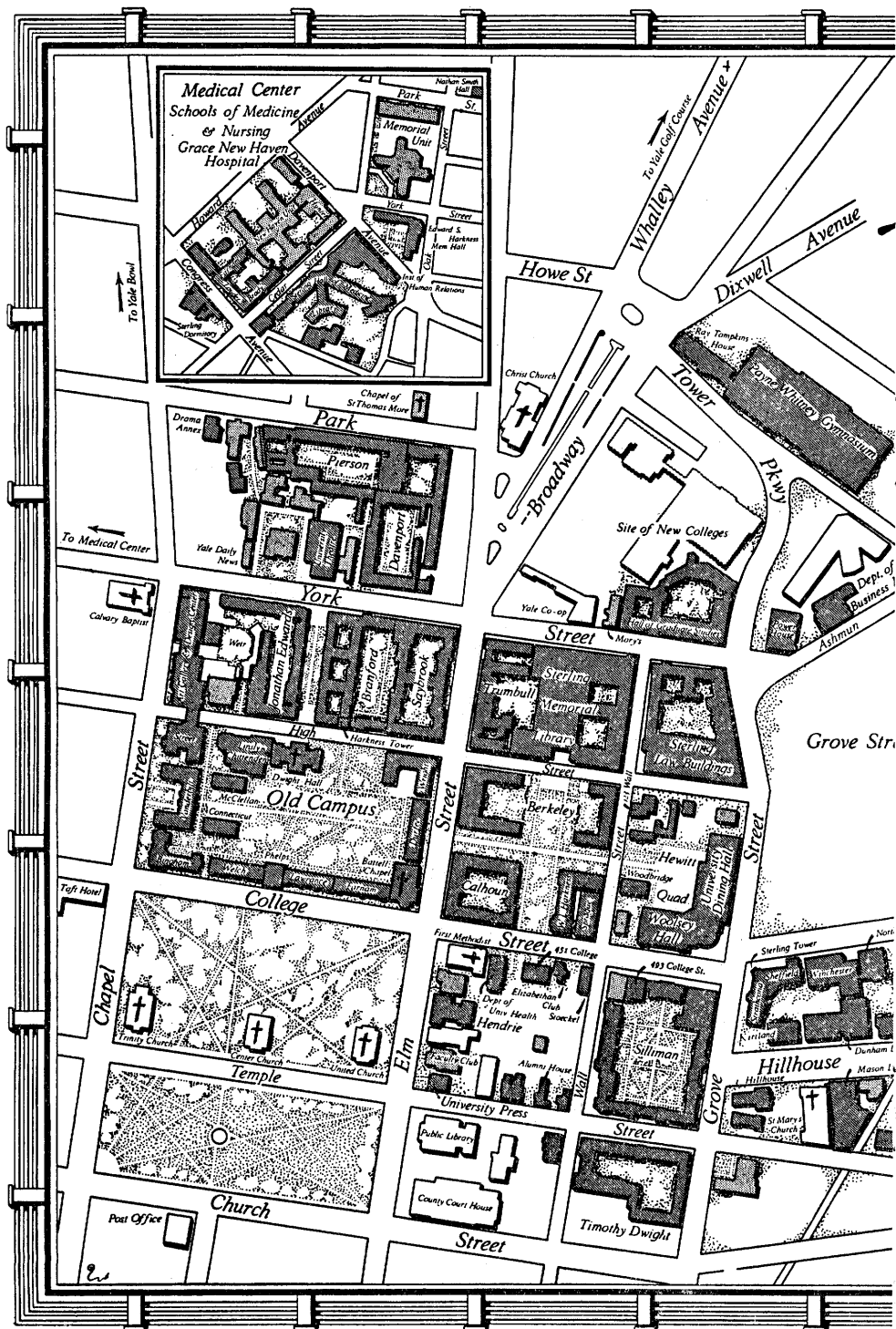


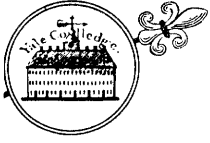
self-supporting. But costs were also rising, and the Cowles Commission continued to bear a considerable portion of the administrative expenses of the Society. The two organizations were administered jointly.

With the establishment of the Cowles Foundation at Yale University, it was decided to separate the administrative functions of the Econometric Society from those of the Cowles Foundation, and if possible to draw the financial support of the Society more fully from its membership than had been done to date. A gradual reduction in the financial contribution of the Cowles Commission, begun while the Society was still located in Chicago, has been continued. At present the Society receives a contribution of \$2,000 a year from the Cowles Foundation; and it is expected that this level will be maintained in the future. In 1958 the Cowles Foundation gave an additional \$2,000 to the Society to help cover the cost of publishing a bibliographical directory of Econometric Society members. Efforts are being made to replace the reduction in the Cowles Foundation contribution from such sources as institutional memberships and an increase in individual memberships.

RICHARD RUGGLES

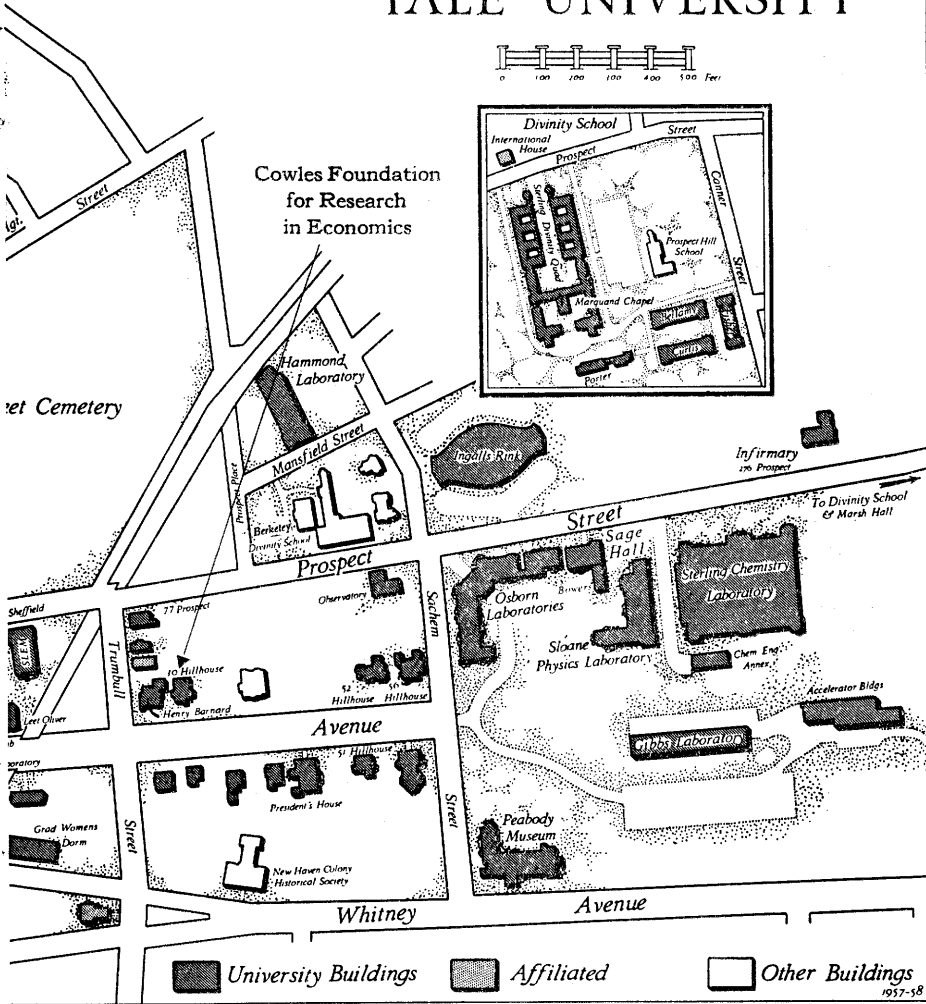
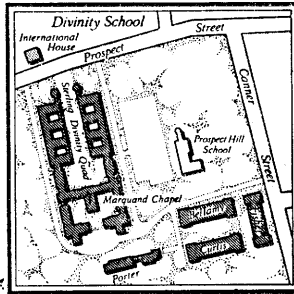
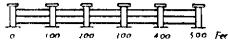
*Professor of Economics, Yale University*  
*Secretary*





R. Galvin

# YALE UNIVERSITY



## COWLES COMMISSION MONOGRAPHS

1934-1958\*

No. 1. *Dynamic Economics*, by CHARLES F. ROOS. 1934. Evanston, Ill.: Principia Press. 275 pages. (Out of print.)

No. 2. *NRA Economic Planning*, by CHARLES F. ROOS. 1937. Evanston, Ill.: Principia Press. 596 pages. (Out of print.)

No. 3. *Common-Stock Indexes*, by ALFRED COWLES and ASSOCIATES. Second Edition, 1939. Evanston, Ill.: Principia Press. 499 pages. Price \$6.00. New monthly indexes of stock prices, stock prices adjusted for reinvestment of cash dividends, and yield expectations; and annual indexes of yields, dividend payments, earnings-price ratios, and earnings for 69 industry groups, 1871-1938.

No. 4. *Silver Money*, by DICKSON H. LEAVENS. 1939. Evanston, Ill.: Principia Press. 439 pages. A sketch of the history of the monetary use of silver, followed by more detailed consideration of recent developments. (Out of print.)

No. 5. *The Variate Difference Method*, by GERHARD TINTNER. 1940. Evanston, Ill.: Principia Press. 175 pages. The history and use of this method for the analysis of time series, with new devices of treatment and extensive tables to aid calculations. (Out of print.)

No. 6. *The Analysis of Economic Time Series*, by HAROLD T. DAVIS. 1941. Evanston, Ill.: Principia Press. 620 pages. The historical development of the subject is reviewed, methods are described, and applications made to economic phenomena. (Out of print.)

No. 7. *General-Equilibrium Theory in International Trade*, by JACOB L. MOSAK. 1944. Evanston, Ill.: Principia Press. 187 pages. Price \$2.50. The modern theory of economic equilibrium (as stated by J. R. Hicks and others) applied to an important field.

No. 8. *Price Flexibility and Employment*, by OSCAR LANGE. 1944. Evanston, Ill.: Principia Press. 114 pages. Price \$2.75. A clarification of important concepts that have had much currency in the practical discussion of depressions and wars but remained too vague to allow useful treatment.

No. 9. *Price Control and Business*, by GEORGE KATONA. 1945. Evanston, Ill.: Principia Press. 246 pages. A study of the working of price control based on field studies among producers and distributors of consumers' goods in the Chicago area, 1942-1944. (Out of print.)

No. 10. *Statistical Inference in Dynamic Economic Models*, edited by TJALING C. KOOPMANS, with Introduction by JACOB MARSCHAK. 1950. New York: John Wiley and Sons. 438 pages. Price \$7.50. Original contributions from many authors concerning statistical problems encountered in economic model construction.

No. 11. *Economic Fluctuations in the United States, 1921-1941*, by LAWRENCE R. KLEIN. 1950. New York: John Wiley and Sons. 174 pages. Price \$4.50. The methodology of econometric model construction is applied to business cycle analysis with possible implications for prediction and policy making.

\*Orders for Monographs 3, 7, and 8 should be sent to the Principia Press, Inc., 2019 Orrington Avenue, Evanston, Illinois. Orders for subsequent monographs should be sent to John Wiley and Sons, 440 Fourth Avenue, New York City. Prices are subject to change.

No. 12. *Social Choice and Individual Values*, by KENNETH J. ARROW. 1951. New York: John Wiley and Sons. 99 pages. Price \$3.25. Methods of symbolic logic are applied to the question whether a social valuation of alternatives can be consistently derived from given, partly conflicting, individual valuations.

No. 13. *Activity Analysis of Production and Allocation*, edited by TJALLING C. KOOPMANS. 1951. New York: John Wiley and Sons. 404 pages. Price \$5.50. Contributions from economists and mathematicians on the theory and techniques of efficient allocation of resources and programming of activities.

No. 14. *Studies in Econometric Method*, by COWLES COMMISSION RESEARCH STAFF, edited by WM. C. HOOD and T. C. KOOPMANS. 1953. New York: John Wiley and Sons. 324 pages. Price \$6.00. Presents and extends methods developed in Monograph 10 in an expository style addressed primarily to the user of methodology.

No. 15. *A Statistical Study of Livestock Production and Marketing*, by CLIFFORD HILDRETH and F. G. JARRETT. 1955. New York: John Wiley and Sons. 156 pages. Price \$5.50. Economic relations underlying the operation of livestock markets in the United States are estimated and tested by several alternative procedures.

#### SPECIAL PUBLICATIONS

*Economic Aspects of Atomic Power*, an exploratory study under the direction of SAM H. SCHURR and JACOB MARSCHAK. 1950. 289 pages. Price \$6.00. An analysis of the potential applicability of atomic power in selected industries and its economic effects in both industrialized and underdeveloped areas. Orders should be sent to Princeton University Press, Princeton, New Jersey.

*Income, Employment, and the Price Level*, notes on class lectures by JACOB MARSCHAK. Autumn 1948 and 1949. 95 pages. Price \$1.00. Orders should be sent to Kelley and Millman, 80 East Eleventh Street, New York City.

*Studies in the Economics of Transportation*, by MARTIN J. BECKMANN, C. B. MCGUIRE, and CHRISTOPHER B. WINSTEN, introduction by TJALLING C. KOOPMANS. 1956. 232 pages. Price \$4.00. This exploratory study of highway and railroad systems examines their theoretical aspects and develops concepts and methods for assessing the capabilities and efficiency of existing and projected traffic systems. Orders should be sent to Yale University Press, New Haven, Connecticut.

## COWLES COMMISSION NEW SERIES PAPERS AND COWLES FOUNDATION PAPERS

This series includes selected articles published by members of the research staff or by others working in close association with them.

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

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

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

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

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

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- 57 GERARD DEBREU, *Cardinal Utility for Even-chance Mixtures of Pairs of Sure Prospects.*
- 58 BENTON F. MASSELL, *Capital Formation and Technological Change.*
- 59 JACOB MARSCHAK and ROY RADNER, *Economic Theory of Teams.*
- 60 LEROY S. WEHRLE, *A Theory of Life Insurance Company Portfolio Selection.*
- 61 SIDNEY G. WINTER, JR., *Testing for Neutrality of Technological Change.*

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BY STAFF MEMBERS SINCE JULY 1, 1956

MARTIN J. BECKMANN

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GERARD DEBREU

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- JOHN HARSANYI  
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- LAWRENCE KLEIN  
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- TJALLING C. KOOPMANS  
Papers: CFP 108, 115  
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A. *Three Essays on the State of Economic Science*, published August 1957 by McGraw-Hill, 231 pp.
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CHARLES B. MCGUIRE

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ARTHUR M. OKUN

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ROY RADNER

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RICHARD ROSETT

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ROBERT SUMMERS

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JAMES TOBIN

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HAROLD WATTS

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