

COWLES COMMISSION

FOR RESEARCH IN ECONOMICS

Report for Period

July 1, 1952—June 30, 1954

THE UNIVERSITY OF CHICAGO

IMPORTANT NOTICE

Effective July 1, 1955, the Cowles Commission for Research in Economics will transfer its headquarters and its research activities to Yale University, New Haven, Connecticut. Martin J. Beckmann, Gerard Debreu, Tjalling C. Koopmans, Jacob Marschak, and Roy Radner will accompany the Commission to New Haven and have received faculty appointments in the Department of Economics at Yale.

The new research group formed by these Commission members and other Yale faculty members, Harold W. Guthrie, Robert Summers, and James Tobin, is to be named the Cowles Foundation for Research in Economics at Yale University. Its Director of Research will be James Tobin; Harold W. Guthrie will serve as Assistant Director of Research.

The Cowles Foundation for Research in Economics at Yale, together with the Econometric Society, will be located at 30 Hillhouse Avenue in New Haven. The mailing address of the Cowles Foundation, to be used starting July 1, 1955 will be: Box 2125, Yale Station, New Haven, Connecticut.

**COWLES COMMISSION
BIENNIAL REPORT
1952-1954**

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COWLES COMMISSION FOR RESEARCH IN ECONOMICS

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PURPOSE

THE COWLES COMMISSION FOR RESEARCH IN ECONOMICS *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 and of society in general. Its approach is to encourage and extend the use of logical, mathematical, and statistical methods of analysis. It seeks to accomplish its purpose through research and instruction, through publication, and through other programs directed toward increasing the human resources devoted to such research.*

The Commission is a not-for-profit corporation, founded in Colorado in 1932 and, since 1939, chartered under the laws of the State of Illinois. Its governing bodies are its faculty, an executive committee, and a board of trustees.

Although it is an independent research organization with members of its staff in other research centers both in the United States and abroad, the Commission is affiliated in academic matters with the University of Chicago as a component of the Division of the Social Sciences. The Commission is also 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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* Acting Executive Director, July, 1952-August, 1953. Mr. William B. Simpson was on terminal leave of absence as Executive Director from September, 1952, to August, 1953.

† Left before October 1, 1952.

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INTRODUCTION

THE role of academic research in a free society is the creation and communication of new knowledge. The search for new truth is governed by the demands of free inquiry: free choice of topic, free choice of method, and free development of conclusions. Communication, to be effective, must relate new knowledge to old, must trace new implications for social means and ends, and must describe the new relations in terms understandable first to the specialist and ultimately to the interested layman. Both freedom of inquiry and effective communication are essential to the development and ultimate fulfilment of the free society.

The Cowles Commission for Research in Economics presents here an account of its research efforts for the two-year period, July 1, 1952—June 30, 1954. The work described is the product of a community of scholars pursuing their interrelated research interests in an academic environment which is both stimulating and free.

Cowles Commission staff members are chosen for their interest and competence in the rigorous development of economic theory and measurement. They have at their disposal the technical and general literature of the University of Chicago library system as well as the specialized resources of the Commission's own library. They have free access to the knowledge and critical judgment of colleagues through regular staff meetings and through the distribution of preliminary discussion papers which describe their work in its early stages. Final research results are carried to publication in the form of monographs or journal articles. Reprints of journal articles are frequently given wide distribution as Cowles Commission New Series Papers.

Thus through publication and broad circulation of research results an attempt is made to achieve effective communication with other researchers. However, the technical nature of the Commission's research methods and results has sometimes made it difficult for nonmathematical economists and interested lay-

men to appraise or follow what is being done and why. For this reason the character of Cowles Commission general research reports, such as this one, has been changed in recent years* toward a form of exposition which, it is hoped, will be understandable to a greater number of readers. For those with research backgrounds and interests, the listings of papers, publications, and addresses following the research report provide a key to the technical scope of the Cowles Commission's work.

The research described in the present report is financed through general support by Alfred Cowles and other members of the Cowles family, through time devoted to research by members of the faculty of the University of Chicago, and through grants or contracts for specific research projects. The study of futures markets has been supported by a grant from the Rockefeller Foundation. The studies of transportation systems have been made under a research contract with the RAND Corporation on the theory of resources allocation. The work on organization theory and the studies in the theory of competitive markets are conducted under a research contract, on decision-making under uncertainty, with the Office of Naval Research.

By developing financial support for the establishment and maintenance of a body of able scholars who are free to pursue their own research interests in their own way, the Cowles Commission promotes freedom of inquiry in the social sciences and thereby fulfils part of its responsibility as an academic research organization. By extensive dissemination of research results and by striving for simplicity and clarity in its annual or biennial research reports, it is attempting to broaden understanding of the economic problems with which it deals. Current readers and future years will determine whether or not this has been done effectively.

* See particularly *Economic Theory and Measurement: A Twenty Year Research Report, 1932-1952* (Chicago: Cowles Commission for Research in Economics, 1952). 180 pages.

REPORT ON RESEARCH ACTIVITIES

July 1, 1952—June 30, 1954

THE educated citizen looks upon economics as a rather complicated but probably dull subject. He is likely to admit that the development and the spread of economic knowledge are important for the welfare of society. He may even look with favor on the slow and halting process of accumulation of knowledge called economic research. But rarely does he take a personal interest in following the progress of economics. He is deterred equally by the abstruseness of theoretical writing—if he ever sees it—and by the use economists make of masses of unappealing statistical data on production, trade, consumption, inventories, and prices. If it is further intimated that mathematics—a subject he generally avoids—is used in economics to untie the knots and follow the threads of causation, then he is likely to leave the subject alone. For the satisfaction of his urge to know he may turn to history, or to psychology, or to any other field closely related to human experience. Or he may study the victories of mind over matter in technology, over nature in medicine.

It is not contested that the vindication of the effort that goes into research on such a practical subject as economics must lie in increased ability of mankind to make the best of its circumstances, resources, and endowment. However, the appraisal of what economists are contributing in this regard would be helped if their subject could be made to come to life more fully to the interested citizen. Somehow economists have so far not succeeded in putting across the fact that, back of every statistical series in the record of economic history, there is a whole category of human decisions. These may be decisions taken in the organization of production or trade, in the pursuit of gratification, as precaution for contingencies, or in bargaining for gain or advantage. There is a human decision around every corner in economic analysis. It is this aspect that makes economics a complicated, it is true, but an equally fascinating subject.

One source of fascination is that here, as in psychology, man studies an important part of himself. In addition, there is perhaps a fascination peculiar to economics in tracing the effects of interaction between different individuals, or groups of individuals, each with his own motivations or objectives. While the objectives of different individuals are partly conflicting, no one controls all the variables. One man may offer a commodity at a given price, but another will decide how much to buy at that price. One man may decide what level of inventory to aim for in setting the rate of production, but many other people by their purchases decide indirectly whether the inventory will actually be at that level or higher or lower. A union may call a strike or threaten to do so. An employer may decide to have it out or may forestall interruption of production by concessions. Since neither party to a contract can dictate the other party's behavior, the outcome reflects the bargaining power—that is, alternatives available—on the two sides. Generally, the outcome of interaction between economic decision-makers comes to less for each party than he would like. Sometimes, it is a best achievable compromise—in some all-around sense—that is permitted by the circumstances. But always it is a fascinating subject for analysis, full of surprises.

1. *Studies of Markets*

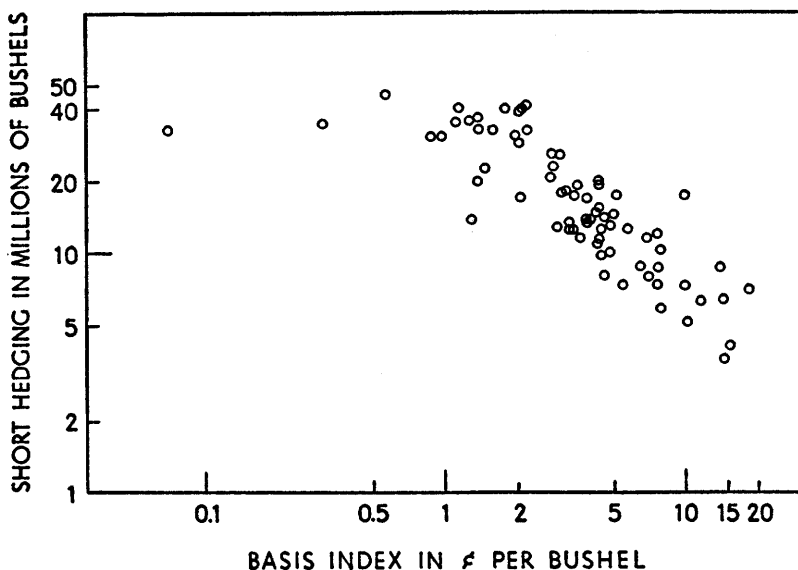
Markets are the stages on which the interplay of economic decision-makers is acted out. In the Cowles Commission's research program during the two-year period, July 1, 1952—June 30, 1954, a great deal of attention was given to the empirical and theoretical study of markets. Two empirical studies, one of the markets for future delivery and one of the market for livestock and livestock products, and one theoretical study of the action of competitive markets were mentioned in our previous ("Twenty Year") report and can now be described in greater detail.*

* At the end of this report (on p. 25) are listed titles and authors of Cowles Commission publications, discussion papers, and addresses by staff members, covering the two-year period of this report. The classification of this listing corresponds to the organization of this report.

Both the empirical and the theoretical studies follow the method of "model construction": important variables are defined and, in the empirical studies, measured statistically. The behavior of the various parties in the market is described by a set of mathematical relationships between these variables, called a "model." In the theoretical studies the implications of such relationships are traced. In empirical studies the relationships are also estimated numerically or graphically to give greater quantitative precision to the conclusions.

The study of *futures markets in corn, cotton, and wheat* conducted by Houthakker, assisted by Telser, is nearing completion and is expected to be published in monograph form. A tentative table of contents is shown on page 46 of this report. One of the main purposes of this study is to throw light on the economics of behavior under uncertainty through the investigation of markets that have been developed to deal with that problem in practice. It is hoped, however, that the results will also be useful to those dealing in the markets in question or to those concerned with their organization or regulation. The importance in the economy of these commodities justifies the further hope that the study will enhance our understanding of economic fluctuations in general. A great deal of statistical material is available which relates to the markets in question, especially for recent periods.

The theory on which this study is based is mainly concerned with the interrelations between the prices in the cash and futures markets. Its cornerstone is the so-called theory of "normal backwardation," first enunciated by the late Lord Keynes in his *Treatise on Money*. According to this theory, futures prices are normally below the spot price expected to rule at the time of delivery. This doctrine has been reformulated so as to free it from certain theoretical objections and to make it applicable to the conditions in the major American commodity markets. It has been tested empirically in various ways, particularly by studying the complex of relations between the level of stocks and the difference between cash prices and futures prices. (This difference is known as the "basis.") In this connection the influence of the government's price support programs has also been analyzed and found to be considerable.



Of special importance among these relations is that between the volume of hedging and the basis. An empirical example is given in Figure 1, which shows, for each month during the period October, 1946—September, 1952, the average value of the basis index for corn (a measure of the basis with adjustment for storage cost and interest) and the volume of “short” hedging by large corn traders. “Short” hedging is the more common form of hedging in which the trader owns actual merchandise and is short in futures. It will be seen that as a rule a large volume of short hedging is accompanied by a low value of the basis index. The opposite has been found to be true for “long” hedging, in which the trader has sold merchandise forward and holds futures as a hedge.

The question of who gains and who loses in the futures market has always intrigued observers. One implication of the theory of normal backwardation is that in the long run the hedgers lose money on the futures side of their transactions. This “loss” can more properly be looked upon as a payment to the speculators in return for the risk-bearing service they provide. To test this implication, the gains and losses of three groups of futures traders—the large hedgers, the large speculators, and the small traders—

have been estimated. It was found that on the whole the large hedgers do lose in the futures market, though of course these losses have to be made up in the cash market. The large futures speculators in the grain markets appear to gain not only from the hedgers but also from the small traders. The latter are for the most part outside speculators, not professionally associated with the market. This lack of success has also been noted by previous investigators; in the cotton market, however, it does not seem to be true that small traders lose on the average.

The second empirical study concerns *the market in livestock and livestock products*. It was conducted by Clifford Hildreth, assisted by Frank Jarrett, as a co-operative project with the Agricultural Economics Research Unit of the University of Chicago, and will appear shortly as Cowles Commission Monograph No. 15 (Table of Contents reproduced on p. 46).

Livestock and livestock products—cattle, calves, hogs, chickens, turkeys, sheep, milk, and eggs—account for over half of the cash receipts from farming in the United States. In the form in which these products reach the consumer, they absorb over half of the consumer's expenditure for food. Fluctuations in prices and quantities of these commodities therefore have important effects on farm income and on the purchasing power of the consumer's dollar.

In throwing together several products into one category for purposes of analysis, there is always some loss of precision, in that one can no longer use one's knowledge with respect to demand or supply conditions for these individual commodities. Since the commodities in question are fairly good substitutes for each other both in production and in consumption, however, their prices retain fairly close relationships. For this reason the aggregation of these products is not so harmful as it otherwise might be, and it does bring the research task down to a level manageable within one project. The study may then be looked upon as a forerunner to more detailed analyses of individual types of livestock.

An economic model was drawn up containing the following relationships:

1. A relation explaining annual *production of livestock* (and products) on the basis of the quantities of feed grains, protein feeds, and roughage

- fed; inventory of livestock at beginning of the year; and a trend representing slow but sustained improvement in feeding efficiency
2. A relation explaining *demand for feed grain* on the basis of the prices of feed grain, of protein feeds, and of livestock (and products); the livestock inventory; and the amount of roughage fed
 3. A relation explaining *demand for protein feed* from the same set of variables
 4. A relation explaining *supply of livestock* (and products), that is, the quantity sold from farms, on the basis of the same three prices; the livestock inventory; and the price of farm labor
 5. A relation explaining the *demand for livestock* (and products), measured by the same quantity as the supply, on the basis of the price of livestock (and products); consumers' income; population; and a cost-of-living index (excluding livestock and product prices)

To estimate these relationships from annual data for the period 1920-1949, a statistical model was adopted representing these relationships by a particular form of algebraic equations ("linear in the logarithms"), with allowance for the random elements in economic behavior. Various methods of estimation were tried out, including the so-called "limited information" method developed by the Cowles Commission. The results were compared, and statistical and other evidence bearing on the assumptions underlying alternative methods was examined.

An interesting finding is that, in the fourth supply relation above, a rise in the price of livestock and products diminishes current marketings. This possibility has been the subject of much conjecture and is not hard to explain, since higher current prices are generally associated with more favorable expectations about future prices. For most livestock, raising planned future production requires withholding more of the animals currently on hand for breeding and sending fewer to market. Thus current and future marketings compete in two ways. What is sold now cannot be sold later, and what is sold now cannot be used to produce more to be sold later. While these considerations do not prove that current marketings decrease with an increase in current price, they make it seem entirely possible. Assumptions of such a short-run negative response have played an important part in theories of instability in livestock markets, particularly

for cattle, and it is interesting that they tend to be borne out by these results.

Application of the relationships to data for the year 1950 gave satisfactory "predictions" from all relationships except the fifth, the demand for livestock products. Increased competition between vegetable oils and animal fats was pinpointed as a likely contributing factor in the failure of the latter relation.

Ever since Adam Smith, economic theorists have been concerned with *appraising the effectiveness of competitive markets* as instruments for utilizing available resources for production and for distributing the product. It should not be thought that this is a closed subject. Recent advances in the introduction of new mathematical tools in economics have introduced greater clarity and rigor into this analysis. The Cowles Commission's work in this area during the period of this report was done largely by Gerard Debreu, partly in co-operation with Kenneth J. Arrow.*

The task of any productive and distributive system can be seen as follows. Let a typical consumer be presented with two or more alternative consumption programs, that is, two or more alternative statements specifying for each year in the present and in the future the flow of consumers' goods that will come to him in that year. Let it then be assumed that our consumer has a definite notion as to which consumption program would give him greater satisfaction. Let us further assume that each producer has a good knowledge of the alternative production programs, covering the present and the future, that are within the range of technical possibilities. (For the moment, let us rule out uncertainty in either future consumers' preferences or technological development.) There are, of course, limits to the amount of land that can be cultivated, to the rate at which minerals can be located and extracted, and to the amount of labor that can be rendered by a population increasing at a given rate. Finally, there is only a given amount of man-made equipment, buildings, and inventories available at the beginning of the period considered. The task of an economic system now is to utilize the available resources and the technological possibilities in such a

* Related work by Hurwicz is described in Section 4 of this report.

way that in some sense maximum satisfaction is obtained therefrom by consumers over an indefinite period.

However, this statement needs clarification. It is always possible to give some consumers a higher satisfaction level by increasing their consumption at the cost of that of others. In order to evaluate an economic system fully, therefore, we would need some criterion for the fairness or appropriateness of the distribution of income that it brings about. The search for such a criterion leads economists into the difficult realm of ethical philosophy. No generally accepted criterion has so far been developed. Owing to the ingenuity of the Italian economist Pareto, however, a second line of defense has been established in the problem of appraising an economic system. It is possible to formulate a criterion that concentrates on productive and distributive efficiency only, while skirting the problem of distributive *fairness*. Following Pareto, we say that an economic system utilizes its resources efficiently if it affords each consumer a level of satisfaction that could not possibly be raised, within the given limits of technology and resource availability, *except* at the cost of lowering someone else's satisfaction. In such a case, there is at least no slack anywhere in converting resources into satisfaction. Of course, one can visualize many different income distributions, with each of which resources are utilized efficiently.

In the competitive, private-enterprise economy, no economic agent is much concerned with protecting the consumption or income levels of other agents. Each commodity has a price in each period; each consumer seeks to maximize his satisfaction level by proper allocation of his expenditure in each period to the various commodities available at those prices; and each producer seeks to use his knowledge to maximize his profit, that is, the excess of the receipts from sale of products at those prices over the cost of the various inputs procured at those prices. Finally, prices are such as to equate supply and demand. Now the remarkable fact is that, if competition is perfect, that is, if everyone takes prices as given without attempting to influence them by the amounts offered or withheld from sale, then this competitive economy does use resources efficiently. This proposition, foreseen in Adam Smith's reference to the "invisible hand," and first

explicitly formulated by Pareto, is fully and rigorously proved in the work here reported on.

Pareto introduced also another and perhaps even more interesting idea, which leads to a second proposition of which the proof has been completed. Suppose there is an economy which does not use the idea of pricing all commodities and services. Instead, for instance, all production and distribution is carried out on orders from an all-powerful government. Suppose further that, by some unexplained miracle of planning, this economy does manage to use its resources efficiently, in the same sense indicated above. Then, so says our second proposition, whether the people involved know it or not, there is a system of prices such that, if each consumer maximized his satisfaction at those prices, and if each producer maximized his profit at those prices, the economy would be in precisely the same state. Somewhat oversimplified: the perfectly competitive market utilizes resources as well, insofar as productive and distributive efficiency is concerned, as the theoretical maximum of perfect planning can do. Since, in fact (and quite apart from any consideration of individual freedom), "perfect" planning without use of prices would require an accumulation of technical information and computation equipment that far surpasses the capacity even of modern electronic devices, competitive markets and the price system must be looked upon as invaluable instruments for the efficient utilization of resources, permitting allocative decisions to be decentralized and spread out over a great many enterprises.

The term "proof" has been used above. It should be said at once that any "proof" refers to a mathematical model of some reality. The reality itself is always more complicated. For instance, the model discussed disregards uncertainty, about which a few remarks below. The model also disregards the fact that some resources or products come in indivisible units, a fact which is at the root of the greater productivity of mass production. It also disregards production processes which involve harm (such as make pollution) or benefit (such as the combatting of insect pests) to others than those controlling the production decisions. But, if we grant all the simplifying assumptions made, the proofs are rigorous from there on. In fact, the hardest part of the mathe-

mathematical analysis is not immediately related to the propositions mentioned. It is concerned with proving the logical compatibility of the assumptions that make up the model of a competitive economy. It needs to be proved that there *exists* an equilibrium. That is, given the preferences of consumers, the technology of production and the resource availabilities, there *is* always a set of prices at which, if each consumer maximizes his satisfaction, and each producer his profits, equilibrium of supply and demand results in each market. By building upon work of Abraham Wald and of John von Neumann, such a proof has been supplied for the model of a competitive economy described above.

Extensions of these studies to take into account uncertainty concerning future technology, resource availability, and preferences have also been explored. It may be expected that some results carry over from the case of certainty to that of uncertainty. However, any efficiency properties of competitive markets in the case of uncertainty are likely to depend on whether the anticipations concerning the future held by the various decision-makers are the best that can be made and are mutually consistent.

2. *Study of Transportation Systems*

In earlier reports we have described studies of a model of transportation which was sufficiently simple to have some relevance for all transportation systems that depend on moving vehicles, ships, or other carriers. During the period of this report more detailed studies were made which related more specifically to two particular transportation systems: highway traffic and railroad transportation. Beckmann, Koopmans, McGuire, Winsten, and, during parts of the period, Nerlove and Goldman formed the team working on these problems, under Koopmans' direction.

Highway transportation has many features in common with markets. Traffic flows result from the interaction of many individual decisions with regard to whether or not to travel by road, which route to take, and at which speed. Apart from toll roads, however, no price is charged as a condition for the use of any particular road at any particular time. The "price" of road use is incurred indirectly, in the form of travel time, fuel cost, vehicle

depreciation, etc. Interaction between decisions arises particularly in the case of congested roads, where traffic is dense enough to cause the cost of travel to any one road user to be dependent on the number of other simultaneous road users.

As explained already, the kind of physical interaction where one man's decision places obstacles in another man's path was not considered in the general theory of competitive markets described above. Situations of this kind, however, have received considerable attention in economic literature. They are usually referred to as situations in which the social cost (the total cost to all individuals) of a decision exceeds the private cost borne by the deciding individual. With regard to highway traffic, the consequence of this circumstance is to increase congestion on the most traveled roads beyond the point of most efficient utilization of the highway network. Because normally only one's own cost is considered in choosing between a short congested road and a longer uncongested one, more drivers choose the congested road than would correspond to efficient use of the roads. Theoretically, a better utilization of the road network would be obtained if there were a way to collect from each user of a congested road a tax or toll which would act in some degree as a deterrent to the use of that road. If these toll rates were properly determined, the drivers that remained on a road would be those to whom the value of the use of that road was at least as great as the total cost (other than tolls) borne by all road users on their account. To prevent the tolls from becoming a net deterrent to all road use, the revenue collected could be applied to benefit all road users, for instance, by lowering gasoline taxes. Our studies have led us to set up equations from which such "efficiency toll rates" can be determined, but they have not led to practical suggestions as to how such tolls could be collected. However, they also indicate an answer to the more limited problem of how to set the rates on roads that are already toll roads in such a way as to promote better utilization of the highway network. They also give us a start on the problem of deciding when it is worth while to build or improve a certain road, even when tolls cannot be collected.

Best utilization of the road network is not the only preoccupation of our study of highway transportation. Methods for predicting highway traffic resulting from changes in capacity are also developed and discussed. In addition, the mathematical theory of waiting lines is applied to provide background to the analysis of congestion in various situations, such as at intersections or on two-lane two-way roads.

Compared with the wide dispersal of decision-making in highway traffic, a railroad company is a highly controlled entity, in theory subject to one policy determined by management and implemented all the way down the line of command. At the same time the technology of railroad operation is a good deal more complicated. To illustrate the difference, consider the fact that the engineer cannot in all circumstances with his own eyes ascertain that the track ahead is free at least for a distance within which his train can be stopped. This fact alone already necessitates a great deal of organization and central control to insure correct handling of the information on which safety depends. With the predominance of central control goes a slight shift in the purposes and uses of scientific analysis. In regard to highway traffic, the emphasis is on predicting what many independent drivers will do. In railroad transportation, greater emphasis falls on the type of analysis that can help management to make decisions resulting in greater efficiency of operation. Thus we enter an area of research, variously called "management science," "operations research," or "industrial engineering," concerned with the study of operational efficiency. The last few years have seen a considerable development in this field.

The Commission's exploratory studies of railroad operation were not performed for a railroad company or other railroad industry group.* Their original motivation was to contribute to the development of concepts and models that would help in defining and assessing the capacity of a railroad network. It soon became clear that this problem presupposes analysis of the main aspects of railroad operation, such as classification, or switching, policies at different freight yards, congestion delays

* Sources of support for the various studies in this report are enumerated in the Introduction, p. 2.

prior to classification, "accumulation delays" of cars waiting after classification until enough cars are available to form a train, scheduling of trains on connecting lines, etc. Besides an exploratory discussion of the main areas of railroad operation, this work has led to a few models for the discussion of a few specific operational problems, such as the assignment of classification work to successive yards down the line and the scheduling of trains on a single line. A report on the studies of highway and railroad transportation is being prepared for publication.

3. *Theory of Organization*

The comparison of highway and railroad transportation has shown how differences in technology between two systems serving quite similar purposes can lead to entirely different forms of organization. The need for a theory of organization is thereby suggested. How does the most suitable form of organization depend on the task to be performed and on the technological characteristics of the means to be used? How does interaction between decision-makers within an organization differ from interaction through a market or from interaction through sharing the use of facilities such as roads?

The theory of organization has comprised, since 1952, a major area of research at the Cowles Commission. This research is carried out by Jacob Marschak, Roy Radner, and recently Richard F. Muth and Donald Bratton, with Marschak as the project leader. The approach that is followed can perhaps best be illustrated by a model which is simple and admittedly unrealistic, yet which may be useful. Bodies falling in a vacuum, or bridge-frames conceived as webs of geometric lines, are also unrealistic models of real-world phenomena. Yet they proved essential for practical engineering by clarifying certain basic principles that could be applied to complicated reality. We hope to clarify in a similar way the essential principles for efficient organization forms, in private business as well as in the civilian or military agencies of the government.

Imagine a company engaged in shipping a product between two regions (call them North and South), buying where it is cheap and selling where it is dear. The company may hire mar-

ket specialists (observers) who can, we shall suppose, at the time purchase or sales orders are given, predict unfailingly the price in their respective markets; and it can hire personnel for shipping and trading operations. Suppose the firm's shipping facilities are limited, at each terminal point, to one trainload per week and let the cost of transporting one trainload be the unit of value in which all other costs or prices will be expressed. Suppose the firm knows (without the services of a market specialist) that the product price per trainload in the North is equally likely to be 6 or 10 or 14 units of value and that in the South the price is equally likely to be 7 or 8 or 9 units, independently of what the northern price is. What kind of organization will, in the long run, profit the company most? For example: Shall there be a specialist for each market, for one market, or for none? Shall all market information flow to one decision center or to two local branches? Shall these decide independently whether or not to ship (thus occasionally shipping in two opposite directions at the same time), or shall time and money be invested in consultations (periodic or occasional) between the branches? Or shall one branch take orders from the other?

The forms of organization can be grouped according to *which decision is based on what information*. In our example, the decision whether or not to ship from North to South can be based on either (1) the knowledge of both prices, or (2) the knowledge of the North price, or (3) the knowledge of the South price, or (4) the knowledge of price probabilities only. The decision whether or not to ship from the South to the North can be similarly based on any of the four different kinds of knowledge listed. Hence, in our example, all organization forms can be grouped into $4 \times 4 = 16$ classes. In particular, a *centralized* organization would belong to the class where each decision is based on the knowledge of both prices. Such an organization would reap, in the long-run average, a profit that could not be lower than that of any decentralized organization, *if the time of the central decision-maker were costless and the communication and processing of all the data were also free of cost*. If, for purposes of a step-wise analysis, the reader postpones the consideration of these "organization costs," he can compute, for each organization class, the "maxi-

imum expected gross profit" that will be obtained in the long-run average if each decision-maker always uses his information according to a "good" (i.e., on the average, most profitable) decision rule. This is used in the table on the following page, where selected organization charts are grouped into only 4 classes. The remaining $16 - 4 = 12$ classes are easily seen to be ineligible as they require more information, and hence presumably higher organization costs, without yielding a higher expected gross profit than the 4 listed classes. The reason for this lies in the relatively small range of variation of the southern price.

Note, in the lower right corner, a "routine" organization: one shipping agent performs the same operation every week, sometimes incurring a loss, but earning a modest gross profit on the average, against which are presumably debited only modest organization costs. The less routine there is and the more fresh information is used, the larger the expected gross profit, but also the more complicated the organization and the higher its cost. The latter depends on the number and kind of *positions* (essentially, salaries of executives); on the number and kind of *communication links* (telephone, traveling); and on the *cost of delays* in transmission through successive links, or, more important, through congestion at the nodes (i.e., on the executives' desks). To replace "routine" organization by one in which, for example, the decision to ship in either direction is based on the northern price—the case in the upper left corner—would only pay if the links, delays, and positions (other than that of the southern agent) involved in at least one organization chart of that class would cost less than $2\frac{1}{3} - 1 = 1\frac{1}{3}$ units. By thus taking organization costs into account and, in effect, comparing net rather than gross expected profits, the more efficient organization forms can be chosen.

In several respects the studies have gone beyond the features of the primitive example just given. For instance, the external events (such as, in our example, the two local prices) may include any number of variables, and these may be correlated instead of independent. The reader will guess the consequence: if two events are strongly correlated, knowledge of one of the two may be sufficient. Thought has also been given to the realistic case in which the probabilities of external events are not known

SOME ORGANIZATION CHARTS FOR SPECULATIVE TRADING

In each cell the first two lines give good decision rules; these yield the maximum expected gross profit, entered in the third line as the sum of profits contributed by each of the two decisions. In the alternative organization charts, O =observer (of prices); D =decider; A =shipping agent. The subscripts designate location: N =North; S =South. The arrows indicate the direction of communication.

	and the decision on whether to ship <i>northward</i> is based	
	on northern price p_N	on no current information
on northern price p_N	<p>Ship northward if $p_N = 10$ or 14 Ship southward if $p_N = 6$ Gross expected profit = $2 + \frac{1}{3}$</p>	<p>Ship northward always Ship southward if $p_N = 6$ Gross expected profit = $1 + \frac{1}{3}$</p>
on no current information	<p>Ship northward if $p_N = 10$ or 14 Ship southward never Gross expected profit = $2 + 0$</p>	<p>Ship northward always Ship southward never Gross expected profit = $1 + 0$</p>

beforehand: the team of executives has to make decisions while still learning about the relevant probabilities by accumulating and interchanging experience, thus gradually approaching the good decision rules and the maximum profit.

Another aspect is the assumption about how profit is determined by both the decisions and the external events. In the above example of purely speculative trading, each decision (to ship northward, southward) adds an independent contribution to the total profit. In reality, a company's profit can be seldom represented as a sum of the contributions of individual decision-makers, for example, of the production manager and the sales manager, or of the raw-materials purchaser and the personnel manager. Economists have been aware of this and have therefore usually represented a firm's output as some function (but usually not just a weighted sum) of its several inputs. In a sense, our objective is to extend the classical theory of the firm from the case of a single entrepreneur acting in full knowledge of all data to the case of a team of executives interchanging parts of their information and hence each acting under partial uncertainty.

In our example the decision-maker was ignorant of some variables (the price in a certain locality) while completely informed of others. In reality, all information the executive receives is incomplete. Before reaching him, the report is processed, reduced from details to essentials. Sometimes an executive transforms his information into a (presumably "good") decision; this he communicates to a "subordinate" executive in the form of an "order," or an "assignment"; the subordinate, in turn, with the help of additional, more special or local, information of his own, has then to choose a "good" decision on how to accomplish the assignment. Reports and orders are various forms of processed information and have obvious advantages over unprocessed masses of data. The concept of organization form (which, as we have seen, determines the maximum expected gross profit as well as the organization cost) must therefore include not only the network of executive positions and communications but also the way in which information is processed, "coded."

Perhaps one is permitted to assume that, in the course of decades of competitive struggle, business firms, or at least the more successful business firms, have already evolved reasonably efficient communication networks and codes, appropriate to the particular branch of industry or commerce and to other individual circumstances. If so, theory can be checked against facts.

Accordingly, the Cowles Commission's staff is having discussions with management consultant firms to draw on their experience; in addition, one large manufacturing company has kindly offered a desk to a Commission staff member, in exchange for some work on their problems of production scheduling and inventory control. Our staff member will seek to answer these questions: What information does each executive receive and give during a typical day, from whom and to whom? What decisions does he make? What time elapses between various communications and decisions? We hope this will help to put some flesh on the bare bones of the theory.

So far, we have spoken of teams of decision-makers. But the analysis of teams presupposes a study of a simpler and more basic problem: decisions of single persons. Such study does, in fact, form another part of the project on "Decision-making under Uncertainty." It has been pursued by Chernoff, Debreu, Herstein (in co-operation with John Milnor of Princeton), Marschak, Radner, and Törnqvist.

It may be questioned whether maximum expected profit (in dollars) is properly considered a decision-maker's goal. A more general criterion has been analyzed, that of "maximum expected utility," as is possibly exemplified by the strategist's concepts of "average military worth" and "calculated risk." With the help of the concept of maximum expected utility, one can again define "good rules" for the decision-maker. Such rules have been extended to the realistic case when one does not know in advance the probabilities of relevant events but can gradually improve his decisions helped by the inflow of successive observations. Measurable concepts such as value of information and value of precision have been developed.

Furthermore, members of the research group are interested in how ideally "good" decision-making, based on consistent goals

and quiet deliberation, compares with habits of actual decisions by men in our society—decisions that are often made under pressure of time and are sometimes contradictory—and how the practice of good decision-making could be developed by training. For such studies there has been occasional co-operation with psychologists. One effect of this co-operation may be mentioned here: in line with the results of psychological experiments, we relax the assumption of consistent decision-making and assume that a man's choices are subject to variations; we continue to assume, however, that these choices obey definite probability laws and can therefore be studied statistically.

While the theory of organization and decision-making is still in its beginnings, it is believed that continued work in this field will ultimately find practical use in business as well as in governmental administration.

4. *Other Substantive Research Topics*

The research of the Cowles Commission in the period of this report has included, besides the major projects described, a number of additional investigations on a variety of problems. Some of these continue with ideas developed in earlier periods, and some of these are likely to be extended beyond the present period. We shall now indicate a few of these by brief comments, which of necessity will involve here and there some technical terminology. We shall in some cases refer to studies made by research consultants of the Commission in other universities, sometimes as a part of the research program of another institution. We shall first comment on substantive research topics not yet covered, and thereafter on studies aimed at the development of statistical or mathematical tools of analysis. In neither category will complete coverage be attempted. The list of titles of papers or addresses following this report may serve as supplementary information.

In our preceding report we mentioned a study by Klein, published during the present report period, relating to the input-output analysis of Professor Leontief of Harvard University. This analysis is designed to represent the effects upon output in each industry of given changes in final demand. Arrow has considered

a problem suggested by an input-output analysis of the Italian economy by H. B. Chenery. The problem is to meet a given domestic demand from domestic production, limited by given industrial capacities, and from imports, in such a way as to minimize foreign exchange requirements. Surprisingly, he finds that, within wide limits, the best balance of imports and domestic production is independent of import prices.

Harberger made a study of the elasticity of United States demand for imports, using short-cut estimation methods, which are described in Section 5. His estimates of these elasticities are higher than those reached in previous studies, to an extent significant for policy conclusions. The discrepancy appears to be the result of the choice of a method of estimation that recognizes the existence of simultaneous economic relations between the variables involved.

Related to the theoretical analysis of competitive markets, described above, is work by Hurwicz on the possibilities of attaining efficiency in the use of resources by decentralized decisions guided by a price system. This study is an attempt to go beyond the assumption of perfect divisibility of resources and thus, for instance, to recognize the superior productivity of large units or complexes of machinery.

Another attempt to deal with allocation problems of indivisible resources is a study of the so-called "assignment problem," to which Beckmann, Koopmans, Motzkin, and Törnqvist have contributed and in which two visits from Professor Harold Kuhn of Bryn Mawr College have been a stimulating factor. The problem concerns assignment of personnel to jobs, or plants to locations, or any other x 's to y 's, in such a way as to maximize the economic benefit from the assignment. A price system which sustains an optimal assignment has been found for the case in which the benefit from each x - y -combination is independent of how other x 's and y 's are matched. Since this condition is not generally met in the assignment of plants to locations, the efficiency of locational choices guided by the price system is as yet in question.

Hildreth and Houthakker both made studies in which the concepts of activity analysis were used or extended to analyze

alternative production possibilities in one industry. The former discussed the choice of a fertilizer treatment in cotton-growing in response to market prices of the product and of factors of production. The latter laid a connection between the variability of input-output ratios as between establishments in an industry and the aggregate production function of that industry.

5. *Statistical and Mathematical Tools*

During the period of this report Cowles Commission monograph 14, *Studies in Econometric Method*, was published. It summarizes the main results of the Commission's work in the statistical methodology of the measurement of economic relations, published earlier in more technical presentation. In addition, it contains new work on methodological problems, described in our preceding report. The table of contents is reproduced on page 46.

Monograph 14 is addressed in the main to statisticians interested in econometrics. Another book, in preparation by Carl Christ, addresses the general economist in expository language. It deals with economical model construction in general as well as with the associated statistical estimation problems.

Studies in statistical methods for econometrics during the period of this report have been in the nature of explorations and new departures. Hildreth has dealt with the problem of estimating a production function when it is known that successive equal increases in input produce successively smaller (or equal) increases in output. Harberger has demonstrated the feasibility of computationally very simple estimating procedures. On the basis of explicitly stated assumptions about the possible extent of year-to-year shifts in demand or supply functions, he arrives at surprisingly narrow limits on the elasticities of demand or supply in question. Houthakker has discussed how the specification of the variables that one can afford to include in estimating a behavior relationship depends on the number and kind of observations available.

Winsten and Prais studied the estimation of trends in the case where the "deviations from trend" in a time series are serially correlated. Both Radner and T. W. Anderson, independently,

studied the possibility of basing the analysis of time series and relations between time series on a continuous time variable rather than a discrete one.

With regard to mathematical tools used in economics, horizons are expanding. An expository article by Herstein, addressed to the applied mathematician, gives a variety of examples of mathematical techniques which economists have found useful. Debreu has given a summary of separation theorems of convex sets, which are crucial to the understanding of the role of prices as guides to the allocation of resources. Beckmann has discussed inequalities that indicate how simultaneous changes in technology, in resource availability, and in valuations of end-products affect rates of output and prices in various industries. These extend earlier results by Samuelson known as the "le Chatelier principle of linear programming." Davis has continued his systematic studies of nonlinear operators and differential equations.

6. *Concluding Remarks*

At the beginning of this report we have emphasized the fascination which economic research holds for those engaged in it. We do not know whether the description of specific pieces of research has conveyed a feeling for the challenge of the problems concerned. However, we do not wish to leave the impression that intellectual delight in the subject matter is regarded as the ultimate motivation for engaging in economic research. The relation of ends and means is just the other way around. There is ample precedent, in the natural and social sciences alike, for the belief that a free reign to intellectual curiosity may open up the pathways to useful and applicable knowledge more readily than a carefully charted plan of approach. In the selection of problems for investigation and of methods of study, the criterion of intellectual stimulation to open minds takes at least an equal place with any other relevant criteria.

SELECTED LIST OF STAFF PUBLICATIONS, PAPERS, AND ADDRESSES*

July 1, 1952—June 30, 1954

1. *Studies of Markets*

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- . "Une économie de l'incertain," presented December 9, 1953, at the École Nationale Supérieure des Mines, Paris, France.
- . "Valuation Equilibrium and Pareto Optimum," *Proceedings of the National Academy of Sciences of the U.S.A.*, Vol. 40, July, 1954, pp. 588-592. (Reprinted as CCNS, No. 84.)
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- . "Commodity Futures" (with L. G. TELSER), presented December 28, 1953, before the Econometric Society and the American Farm Economic Association, Washington, D.C.
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* In this listing Cowles Commission New Series Papers are designated by CCNS and Discussion Papers by CCDP.

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BECKMANN, MARTIN J., MCGUIRE, C. BARTLETT, and WINSTEN, CHRISTOPHER B. *Studies in the Economics of Transportation*, with an introduction by TJALLING C. KOOPMANS (forthcoming).

FOX, KIRK. "Economical Routing of Empty Railroad Freight Cars." CCDP, Economics 2047.

MCGUIRE, C. BARTLETT. "The Allocation of Switching Work in a System of Classification Yards" (with M. BECKMANN, T. C. KOOPMANS, and C. B. WINSTEN), *Proceedings of the Railway Systems and Procedures Association, Winter Meeting, Chicago, Illinois, November 4, 5, 6, 1953*, published by the Railway Systems and Procedures Association, December, 1953.

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NERLOVE, MARC. "Optimal Routings of Empty Boxcars, 1940-1950," CCDP, Economics 2086.

3. *Theory of Organization*

BECKMANN, MARTIN J. "On Marschak's Model of an Arbitrage Firm" (with DANIEL WATERMAN), presented September 4, 1952, before the Econometric Society, East Lansing, Michigan. Also CCDP, Economics 2058.

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5. *Statistical and Mathematical Tools*

- ANDERSON, T. W. "On Estimation of Parameters in Latent Structure Analysis," *Psychometrika*, Vol. 19, March, 1954, pp. 1-10.
- BECKMANN, MARTIN J. "A Lagrangean Multiplier Rule in Linear Activity Analysis and Some of Its Applications." CCDP, Economics 2054.
- . "The Generalized (Weak) Le Chatelier Principle in Linear Activity Analysis." CCDP, Economics 2092.
- . "On a Variational Problem in Nonstatic Linear Activity Analysis." CCDP, Economics 2095.
- CHRIST, CARL F. "What Kind of Data for Econometrics" (abstract), *Econometrica*, Vol. 21, April, 1953, pp. 338-339.
- . "Pitfalls in Econometrics," presented December 28, 1953, before the Econometric Society and the American Economic Association, Washington, D.C.
- . An expository monograph on econometric models and methods, to be published as a Cowles Commission monograph.
- DEBREU, GERARD. "The Continuity of Multivalued Functions in Economics. CCDP, Economics 2079.

- . "Separation Theorems for Convex Sets." CCDP, Mathematics 423.
- DEBREU, GERARD, and HERSTEIN, I. N. "Nonnegative Square Matrices," *Econometrica*, Vol. 21, October, 1953, pp. 597-607. (Reprinted as CCNS, No. 76.)
- GURLAND, JOHN. "An Example of Autocorrelated Disturbances in Linear Regression," *Econometrica*, Vol. 22, April, 1954, pp. 218-227. (Reprinted as CCNS, No. 85.)
- . "Distribution of Semidefinite and of Indefinite Quadratic Forms" (abstract), *Annals of Mathematical Statistics*, Vol. 24, March, 1953, p. 138.
- . "Distribution of Quadratic Forms and Ratios of Quadratic Forms," *Annals of Mathematical Statistics*, Vol. 24, September, 1953, pp. 416-427. (Reprinted as CCNS, No. 79.)
- HARBERGER, ARNOLD C. "On the Estimation of Economic Parameters." CCDP, Economics 2088.
- HERSTEIN, I. N. "Comments on Solow's 'Structure of Linear Models,'" *Econometrica*, Vol. 20, October, 1952, pp. 685-686.
- . "Some Mathematical Methods and Techniques in Economics," *Quarterly of Applied Mathematics*, Vol. 11, October, 1953, pp. 249-262. (Reprinted as CCNS, No. 78.)
- HILDRETH, CLIFFORD. "Point Estimates of Ordinates of Concave Functions," *Journal of the American Statistical Association*, Vol. 49, September, 1954, pp. 598-619. (To be reprinted as CCNS, No. 88.)
- HOOD, WILLIAM C., and KOOPMANS, TJALLING C. (eds.). *Studies in Econometric Method*, by COWLES COMMISSION RESEARCH STAFF. Cowles Commission Monograph No. 14. New York: John Wiley & Sons, 1953. 324 pp.
- HOUTHAKKER, H. S. "The Specification Problem in Regression Analysis" (abstract), *Econometrica*, Vol. 21, July, 1953.
- . "Electronic Computation in Economic Statistics" (with J. A. C. BROWN and S. J. PRAIS), *Journal of the American Statistical Association*, Vol. 48, September, 1953, pp. 414-428.
- HURWICZ, LEONID. "Aggregation in Macroeconomic Models" (abstract), *Econometrica*, Vol. 20, July, 1952, pp. 489-490.
- . "Problems of Identifiability" (abstract of discussion), *Econometrica*, Vol. 20, July, 1952, p. 481.
- SIMON, HERBERT A. "On the Definition of the Causal Relation," *Journal of Philosophy*, Vol. 49, July, 1952, pp. 517-528. (Reprinted as CCNS, No. 70.)

- . "Spurious Correlation: A Causal Interpretation," *Journal of the American Statistical Association*, Vol. 49, September, 1954, pp. 467-479. (To be reprinted as CCNS, No. 89.)
- TELSEER, LESTER G. "Analysis of Variance with a Certain Linear Restriction" (with F. A. BOBKOSKI). CCDP, Statistics 384.

STAFF CHANGES

July 1, 1952—June 30, 1954

EFFECTIVE July 1, 1952, ROSSON L. CARDWELL assumed the executive directorship of the Cowles Commission, succeeding WILLIAM B. SIMPSON. Simpson continued as secretary of the Econometric Society through September, 1952, and as coeditor of *Econometrica* until March, 1953, at which time he embarked on a year's tour of the world. Cardwell has had administrative responsibility for the Econometric Society since October, 1952, first as assistant secretary-treasurer and more recently as secretary.

JOHN GURLAND gave up his joint appointment in the Cowles Commission and the University's Committee on Statistics at the end of July, 1952, in order to accept an appointment as Associate Professor of Statistics at Iowa State College.

On August 1, 1952, LEO TÖRNQVIST, Professor of Statistics at the University of Helsinki, Finland, began a year's appointment as Visiting Professor in the Cowles Commission. His year of research and study was made possible, in part, by a grant provided by the United States Department of State under its educational exchange program. He also received salary support under the ONR contract of the Cowles Commission for his work on the project "Decision-making under Uncertainty."

September, 1952, saw the departure of both WM. L. DUNAWAY and DANIEL WATERMAN. LESTER TELSER, a graduate student in the Department of Economics, replaced Dunaway as a research assistant. Waterman was succeeded as computation leader by EDWIN GOLDSTEIN, who held this position until July, 1953, when he returned to his graduate studies in mathematics at Northwestern University.

STEPHEN G. ALLEN spent the fall quarter, 1952, at the Cowles Commission, on leave from the Applied Mathematics and Statistics Laboratory at Stanford University, to complete his study of linseed oil inventories. He later accepted an appoint-

ment as Assistant Professor of Business Administration at the University of Minnesota.

GARY BECKER worked as a research assistant on the Commission's ONR project, starting in October, 1952. He left the Commission the following spring in order to devote full time to his doctoral dissertation in the Department of Economics.

The Commission's RAND project staff, working on "Theory of Resources Allocation," was augmented in mid-October, 1952, by the appointment of CHRISTOPHER B. WINSTEN from Oxford as a research associate. He continued with this project through 1953-54 before returning to the Institute of Statistics, Oxford, England.

At the end of June, 1953, I. N. HERSTEIN moved to Philadelphia to become Assistant Professor of Mathematics at the University of Pennsylvania.

MARC NERLOVE, a graduate student in economics at Johns Hopkins University, joined the Cowles Commission staff as a research assistant for the summer quarter, 1953. When he left in the fall, the portion of his work dealing with transportation was taken over by THOMAS A. GOLDMAN, who continued as research assistant for the balance of the year.

After four and a half years with the Commission, CLIFFORD HILDRETH resigned in September, 1953, to accept an appointment as Professor of Agricultural Economics at North Carolina State College in Raleigh, North Carolina.

JAGNA ZAHL, who succeeded Goldstein as computation leader, left the Commission in early fall, 1953, and was herself succeeded by FRANCIS BOBKOSKI, a graduate student in statistics and a former member of the Commission's computing staff.

ARNOLD C. HARBERGER returned from Johns Hopkins University to the University of Chicago as an Associate Professor of Economics in October, 1953. He later joined the Cowles Commission's staff as a Research Associate, re-establishing a research relationship which began in 1949, when he was a research assistant of the Commission.

In January, 1954, HENDRIK S. HOUTHAKKER began an appointment as Acting Associate Professor of Economics at Stanford University. However, he has continued to direct the Commis-

sion's study of markets for future delivery, from Stanford, as a consultant.

RICHARD F. MUTH was appointed Research Associate in the Cowles Commission beginning April 1, 1954, and was assigned to the ONR project "Decision-making under Uncertainty." His appointment succeeded that of ALAN L. TRITTER, whose four-month research assistantship had ended in February.

TJALLING C. KOOPMANS resigned from his position as Director of Research of the Cowles Commission on June 30, 1954, in order to be able to devote more time to research. He has been given a leave of absence for 1954-55 so that he may pursue a program of study and research at Yale University under a grant from the Rockefeller Foundation. ROSSON L. CARDWELL, Executive Director of the Commission, has been appointed Acting Director of Research for 1954-55.

GUESTS AT THE COWLES COMMISSION

July 1, 1952—June 30, 1954

- PIERRE F. J. BAICHÈRE (France). September, 1952—February, 1953. Sponsored by the Rockefeller Foundation.
- KARL HENRIK BORCH (Norway). March—August, 1953. Returned to position with United Nations.
- JACQUES DRÈZE (Belgium). May—June, 1954. Sponsored by the Belgian American Educational Foundation.
- ATLE HARALD ELSAS (Norway). June—November, 1953. On scholarship from Norges Almenvitenskapelige Forskningsraad, Norway. Returned to position as Chief of Monetary Policy Office, Ministry of Finance, Norway.
- MASAO FUKUOKA (Japan). June—August, 1954. Sponsored by the Rockefeller Foundation. Returned to Keio University, Japan.
- JOSE GIL-PELAEZ (Spain). October, 1952—July, 1953. Sponsored by the Institute of International Education. Returned to the University of Madrid and the Research Center C.S.D.I., Spain.
- WILLIAM HAMBURGER (U.S.A.). August—September, 1953. Returned to Stanford University, California.
- HERMAN F. KARREMAN (Netherlands). September, 1952—June, 1953. Scholarship from University of Chicago. Returned to employment with the Central Planning Bureau, The Netherlands.
- WILLIAM E. KRELLE (Germany). June, 1954. Sponsored by the Rockefeller Foundation. Returned to Heidelberg University, Germany.
- GIOVANNI MANCINI (Italy). March, 1954—present. Scholarship from Bank of Italy.
- RENÉ F. MONTJOIE (France). September, 1953—June, 1954. Rockefeller Foundation Fellow. Returned to the French Corps of Mining Engineers.
- SIGBERT J. PRAIS (England). September, 1953—April, 1954. University of Chicago Postdoctoral Fellow. Returned to the University of Cambridge, England.
- BERTRAM E. RIFAS (U.S.A.). June, 1952—September, 1953. Accepted position as Research Associate, Operations Research Group, Department of Engineering Administration, Case Institute of Technology, Cleveland, Ohio.
- CIRO TOGNETTI (Italy). June—July, 1953. Scholarship from Bank of Italy. Returned to University of Pisa, Italy.

COWLES COMMISSION SEMINARS, 1952-1954

Fall, 1952

October 9. ABBA P. LERNER, Roosevelt College, "Social Welfare Functions."

October 23. LEO TÖRNQVIST, "Some Remarks about the Decision Concept."

November 6. COLIN CLARK, University of Oxford, "A New Theory of Industrial Location."

November 20. MILTON FRIEDMAN, University of Chicago, "The Effect of Individual Choice on the Income Distribution."

December 4. JACOB MARSCHAK, "Some Building Stones for a Theory of Organizations."

December 18. TJALLING C. KOOPMANS, "Activity Analysis and Its Applications."

Winter, Spring, Fall, 1953

January 15. H. S. HOUTHAKKER, "Theory of Futures Markets."

January 29. O. H. BROWNLEE, University of Minnesota, "The Effects of Taxation on the Price Level in the Short Run."

February 12. MARTIN BECKMANN, "Some Implications of Activity Analysis for Price Theory."

February 26. T. A. HIERONYMUS, University of Illinois, "An Empirical Study of Price Expectations and Marketing Decisions."

March 12. LAWRENCE R. KLEIN, "Some Preliminary Estimates of a New Econometric Model for the United States."

April 9. CLIFFORD HILDRETH, "Relations Affecting Livestock Production and Price."

April 23. ANATOL RAPOPORT, University of Chicago, "Theory of Communication Nets."

May 7. ROBERT L. GUSTAFSON, University of Chicago, "Optimum Storage Rules for Grains."

May 21. J. R. N. STONE, University of Cambridge, "A Cambridge View on Economic Research."

October 8. ARNOLD C. HARBERGER, "Estimating Economic Parameters."

October 22. D. GALE JOHNSON, University of Chicago, "Regional and Occupational Differences in Income in the United States."

November 5. ROBERT H. STROTZ, Northwestern University, "The Optimal Rate of Plant Expansion."

November 19. ROY RADNER, "The Firm as a Team."

December 3. ANDREW VAZSONYI, Hughes Aircraft Company, "The Use of Mathematics in Production and Inventory Control."

Winter, Spring, 1954

January 28. SIGBERT J. PRAIS, "Equivalent Adults, Economies of Scale, and Standard of Living."

February 11. LLOYD A. METZLER, University of Chicago, "A Second Look at the Transfer Problem."

February 25. GEORGE KATONA, University of Michigan, "On the Prediction Value of Economic Attitudes."

March 11. G. W. PLATZMAN, University of Chicago, "The Use of High-Speed Computers in Meteorology."

April 8. ARNOLD TUSTIN, Massachusetts Institute of Technology, "Problems of System Analysis in Engineering and Economics."

April 22. THOMAS E. CAYWOOD, Caywood-Schiller Associates, "A Problem in Applied Game Theory."

May 11. ROBERT R. BUSH, Harvard University, "The Analysis of Latency Data."

May 13. FRANCO MODIGLIANI, Carnegie Institute of Technology, "The Consumption Function."

May 27. ALFRED KRAESSEL, University of Chicago, "Some Economic Aspects of Latin America."

June 10. RICHARD L. MEIER, University of Chicago, "On Creativity."

COWLES COMMISSION PAPERS, 1944-1954

NEW SERIES*

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

ALFRED COWLES, "Can Stock Market Forecasters Forecast?" *Econometrica*, Vol. 1, July, 1933, pp. 309-324.

ALFRED COWLES and HERBERT E. JONES, "Some A Posteriori Probabilities in Stock Market Action," *Econometrica*, Vol. 5, July, 1937, pp. 280-294.

No. 33. EVSEY D. DOMAR, "Capital Accumulation and the End of Prosperity," *Proceedings of the International Statistical Conference Held in Washington, D.C., September 6-18, 1947*, Vol. 5, 1949 (reprinted as a Supplement to *Econometrica*, Vol. 17, July, 1949, pp. 307-314).

No. 35. Approaches to Business Cycle Analysis: ROBERT A. GORDON, "Business Cycles in the Interwar Period: 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, *Papers and Proceedings of the American Economic Review*, Vol. 39, May, 1949, pp. 47-88.

No. 45. GERARD DEBREU, "The Coefficient of Resource Utilization," *Econometrica*, Vol. 19, July, 1951, pp. 273-292.

No. 47. HERBERT A. SIMON, Two Papers on Organization Problems and Economic Theory: "A Formal Theory of the Employment Relationship," *Econometrica*, Vol. 19, July, 1951, pp. 293-305; "A Comparison of Organisation Theories," *Review of Economic Studies*, Vol. 20, No. 51, 1952-53, pp. 40-48.

No. 50. T. W. ANDERSON, "Estimating Linear Restrictions on Regression Coefficients for Multivariate Normal Distributions," *Annals of Mathematical Statistics*, Vol. 22, September, 1951, pp. 327-351.

No. 52. TJALLING C. KOOPMANS, "Efficient Allocation of Resources," *Econometrica*, Vol. 19, October, 1951, pp. 455-465.

No. 53. JACOB MARSCHAK, "Why 'Should' Statisticians and Businessmen Maximize Moral Expectation?" *Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability*, 1951, p. 493-506.

* Listing includes all papers which are available and may be obtained upon request. (For a complete listing of New Series Papers prior to No. 60, see *Economic Theory and Measurement: A Twenty Year Research Report, 1932-1952* [Chicago: Cowles Commission for Research in Economics, 1952].)

- No. 54. KENNETH J. ARROW, "An Extension of the Basic Theorems of Classical Welfare Economics," *Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability*, 1951, pp. 507-532.
- No. 55. LAWRENCE R. KLEIN, "Estimating Patterns of Savings Behavior from Sample Survey Data," *Econometrica*, Vol. 19, October, 1951, pp. 438-454.
- No. 56. GEORGE H. BORTS, "Production Relations in the Railway Industry," *Econometrica*, Vol. 20, January, 1952, pp. 71-79.
- No. 57. HARRY MARKOWITZ, "The Utility of Wealth," *Journal of Political Economy*, Vol. 60, April, 1952, pp. 151-158.
- No. 58. GERARD DEBREU, "Definite and Semi-definite Quadratic Forms," *Econometrica*, Vol. 20, April, 1952, pp. 295-300.
- No. 59. HERBERT A. SIMON, "On the Application of Servomechanism Theory in the Study of Production Control," *Econometrica*, Vol. 20, April, 1952, pp. 247-268.
- No. 60. HARRY MARKOWITZ, "Portfolio Selection," *Journal of Finance*, Vol. 7, March, 1952, pp. 77-91.
- No. 61. PAUL A. SAMUELSON, "Economic Theory and Mathematics—an Appraisal," *Papers and Proceedings of the American Economic Review*, Vol. 42, May, 1952, pp. 56-69.
- No. 62. KENNETH J. ARROW, "The Determination of Many-Commodity Preference Scales by Two-Commodity Comparisons," *Metroeconomica*, Vol. 4, December, 1952, pp. 105-115.
- No. 63. ERLING SVERDRUP, "Weight Functions and Minimax Procedures in the Theory of Statistical Inference," *Archiv for Matematik og Naturvidenskab*, Vol. 51, No. 7, 1952, pp. 1-76.
- No. 64. GERARD DEBREU, "A Social Equilibrium Existence Theorem," *Proceedings of the National Academy of Sciences*, Vol. 38, October, 1952, pp. 886-893.
- No. 65. I. N. HERSTEIN and JOHN MILNOR, "An Axiomatic Approach to Measurable Utility," *Econometrica*, Vol. 21, April, 1953, pp. 291-297.
- No. 66. MARTIN BECKMANN, "A Continuous Model of Transportation," *Econometrica*, Vol. 20, October, 1952, pp. 643-660.
- No. 67. LEO A. GOODMAN and HARRY MARKOWITZ, "Social Welfare Functions Based on Individual Rankings," *American Journal of Sociology*, Vol. 58, November, 1952, pp. 257-262.
- No. 68. CLIFFORD HILDRETH, "Alternative Conditions for Social Orderings," *Econometrica*, Vol. 21, January, 1953, pp. 81-94.
- No. 69. LAWRENCE R. KLEIN, "On the Interpretation of Professor Leontief's System," *Review of Economic Studies*, Vol. 20, No. 52, 1952-53, pp. 131-136.

No. 70. HERBERT A. SIMON, "On the Definition of the Causal Relation," *Journal of Philosophy*, Vol. 49, July, 1952, pp. 517-528.

No. 71. EDMOND MALINVAUD, "Capital Accumulation and Efficient Allocation of Resources," *Econometrica*, Vol. 21, April, 1953, pp. 233-268.

No. 72. Two Papers on the Application of Activity Analysis to the Theory of International Trade: STANLEY REITER, "Trade Barriers in Activity Analysis," *Review of Economic Studies*, Vol. 20, No. 53, 1952-53, pp. 174-180; LIONEL W. MCKENZIE, "Specialisation and Efficiency in World Production," *Review of Economic Studies*, Vol. 21, No. 56, 1953-54, pp. 165-180.

No. 73. ARNOLD C. HARBERGER, "A Structural Approach to the Problem of Import Demand," *Papers and Proceedings of the American Economic Review*, Vol. 43, May, 1953, pp. 148-159.

No. 74. R. H. STROTZ, J. C. McANULTY, and J. B. NAINES, JR., "Goodwin's Nonlinear Theory of the Business Cycle: An Electro-Analog Solution," *Econometrica*, Vol. 21, July, 1953, pp. 390-411.

No. 75. Three Papers on Recent Developments in Mathematical Economics and Econometrics: ROBERT H. STROTZ, "Cardinal Utility"; LEONID HURWICZ, "What Has Happened to the Theory of Games"; TJALLING C. KOOPMANS, "Activity Analysis and Its Applications"; and discussion by WILLIAM J. BAUMOL, *Papers and Proceedings of the American Economic Review*, Vol. 43, May, 1953, pp. 384-416.

No. 76. GERARD DEBREU and I. N. HERSTEIN, "Nonnegative Square Matrices," *Econometrica*, Vol. 21, October, 1953, pp. 597-607.

No. 77. KENNETH J. ARROW, "Le Rôle des valeurs boursières pour la répartition la meilleure des risques," *International Colloquium on Econometrics, 1952*, pp. 41-47. Paris: Centre National de la Recherche Scientifique, 1953.

No. 78. I. N. HERSTEIN, "Some Mathematical Methods and Techniques in Economics," *Quarterly of Applied Mathematics*, Vol. 11, October, 1953, pp. 249-262.

No. 79. JOHN GURLAND, "Distribution of Quadratic Forms and Ratios of Quadratic Forms," *Annals of Mathematical Statistics*, Vol. 24, September, 1953, pp. 416-427.

No. 80. GERARD DEBREU, "A Classical Tax-Subsidy Problem," *Econometrica*, Vol. 22, January, 1954, pp. 14-22.

No. 82. JACOB MARSCHAK, "Three Lectures on Probability in the Social Sciences," in *Mathematical Thinking in the Social Sciences*, ed. PAUL F. LAZARSFELD, pp. 166-215. Glencoe, Ill.: Free Press, 1954.

No. 84. GERARD DEBREU, "Valuation Equilibrium and Pareto Optimum," *Proceedings of the National Academy of Sciences*, Vol. 40, July, 1954, pp. 588-592.

No. 85. JOHN GURLAND, "An Example of Autocorrelated Disturbances in Linear Regression," *Econometrica*, Vol. 22, April, 1954, pp. 218-227.

No. 86. S. G. ALLEN, "Inventory Fluctuations in Flaxseed and Linseed Oil, 1926-1939," *Econometrica*, Vol. 22, July, 1954, pp. 310-327.

No. 87. KENNETH J. ARROW and GERARD DEBREU, "Existence of an Equilibrium for a Competitive Economy," *Econometrica*, Vol. 22, July, 1954, pp. 265-290.

SPECIAL PAPERS

No. 1. JOHN R. MENKE, "Nuclear Fission as a Source of Power," *Econometrica*, Vol. 15, October, 1947, pp. 314-334.

No. 3. TJALLING C. KOOPMANS, "Uses of Prices," *Proceedings of the Conference on Operations Research in Production and Inventory Control*, pp. 1-7. Cleveland: Case Institute of Technology, 1954.

COWLES COMMISSION MONOGRAPHS 1934-1954*

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

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

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

No. 4. *Silver Money*, by DICKSON H. LEAVENS. Evanston, Ill.: Principia Press, 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. Evanston, Ill.: Principia Press, 1940. 175 pages. Price \$2.50. The history and use of this method for the analysis of time series, with new devices of treatment and extensive tables to aid calculations.

No. 6. *The Analysis of Economic Time Series*, by HAROLD T. DAVIS. Evanston, Ill.: Principia Press, 1941. 620 pages. Price \$5.00. The historical development of the subject is reviewed, methods are described, and applications made to economic phenomena.

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

No. 8. *Price Flexibility and Employment*, by OSCAR LANGE. Evanston, Ill.: Principia Press, 1944. 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.

* Orders for Monographs 3-9 (1 and 2 are out of print) should be sent to The Principia Press, Evanston, Illinois. Orders for subsequent monographs should be sent to John Wiley and Sons, 440 Fourth Avenue, New York. Orders for *Economic Aspects of Atomic Power* should be sent to Princeton University Press, Princeton, New Jersey.

No. 9. *Price Control and Business*, by GEORGE KATONA. Evanston, Ill.: Principia Press, 1945. 246 pages. Price \$3.00. A study of the working of price control based on field studies among producers and distributors of consumers' goods in the Chicago area, 1942-1944.

No. 10. *Statistical Inference in Dynamic Economic Models*, edited by Tjalling C. KOOPMANS, with Introduction by JACOB MARSCHAK. New York: John Wiley & Sons, 1950. 438 pages. Price \$6.00. Original contributions from many authors concerning statistical problems encountered in economic model construction. *Contents:*

Introduction; PART ONE. SIMULTANEOUS EQUATION SYSTEMS: *Problems of Identification; Problems of Structural and Predictive Estimation; Problems of Computation*; PART TWO. PROBLEMS SPECIFIC TO TIME SERIES: *Trend and Seasonality; Estimation Problems; Continuous Stochastic Processes*; PART THREE. SPECIFICATION OF HYPOTHESES.

No. 11. *Economic Fluctuations in the United States, 1921-1941*, by LAWRENCE R. KLEIN. New York: John Wiley & Sons, 1950. 174 pages. Price \$4.00. The methodology of econometric model construction is applied to business cycle analysis with possible implications for prediction and policy making. *Contents:*

I. Model Building—General Principles; II. Economic Theory; III. Statistical Model; IV. Adequacy of the Available Data.

No. 12. *Social Choice and Individual Values*, by KENNETH J. ARROW. New York: John Wiley & Sons, 1951. 99 pages. Price \$2.50. 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. *Contents:*

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

No. 13. *Activity Analysis of Production and Allocation*, edited by Tjalling C. KOOPMANS. New York: John Wiley & Sons, 1951. 404 pages. Price \$4.50. Contributions from economists and mathematicians on the theory and techniques of efficient allocation of resources and programming of activities. *Contents:*

Introduction; PART ONE. THEORY OF PROGRAMMING AND ALLOCATION; PART TWO. APPLICATIONS OF ALLOCATION MODELS; PART THREE. MATHEMATICAL PROPERTIES OF CONVEX SETS; PART FOUR. PROBLEMS OF COMPUTATION.

No. 14. *Studies in Econometric Method*, by COWLES COMMISSION RESEARCH STAFF, edited by Wm. C. HOOD and T. C. KOOPMANS. New York: John Wiley & Sons, 1953. 323 pages. Price \$5.50. Presents and extends

methods developed in Monograph 10 in an expository style addressed primarily to the user of methodology. *Contents:*

I. Economic Measurements for Policy and Prediction, *Jacob Marschak*; II. Identification Problems in Economic Model Construction, *Tjalling C. Koopmans*; III. Causal Ordering and Identifiability, *Herbert A. Simon*; IV. Methods of Measuring the Marginal Propensity to Consume, *Trygve Haavelmo*; V. Statistical Analysis of the Demand for Food: Examples of Simultaneous Estimation of Structural Equations, *M. A. Girshick and Trygve Haavelmo*; VI. The Estimation of Simultaneous Linear Economic Relationships, *Tjalling C. Koopmans and Wm. C. Hood*; VII. Asymptotic Properties of Limited-Information Estimates under Generalized Conditions, *Herman Chernoff and Herman Rubin*; VIII. An Example of Loss of Efficiency in Structural Estimation, *S. G. Allen, Jr.*; IX. Sources and Size of Least-Squares Bias in a Two-Equation Model, *Jean Bronfenbrenner*; X. The Computation of Maximum-Likelihood Estimates of Linear Structural Equations, *Herman Chernoff and Nathan Divinsky*.

No. 15. *A Statistical Study of Livestock Production and Marketing*, by CLIFFORD HILDRETH and F. G. JARRETT. New York: John Wiley & Sons. (In press.) A comprehensive study of the economic factors determining quantities and prices of livestock and livestock products produced and sold in the United States; it combines extensive theoretical discussion and careful statistical analysis of the operation of the livestock sector. *Contents:*

I. Introduction; II. The Economic Model; III. The Observations; IV. Some Estimated Relations; V. The Production Relation; VI. The Farm Decision Relations; VII. The Demand Relation; VIII. Prediction Tests.

Commodity Futures: A Study in the Economics of Uncertainty, by H. S. HOUTHAKKER (assisted by LESTER G. TELSER). (Forthcoming.) A study of commodity futures markets which investigates the reaction of groups concerned with these markets to uncertainty about future developments. *Contents:*

I. Commodity Futures and the Economics of Uncertainty; II. The Futures Contract and Its Uses; III. Theory of Cash and Futures Prices; IV. Interrelations of Stocks, Hedging, and the Basis; V. Gains and Losses of Various Groups of Traders; VI. Concluding Remarks.

Economic Aspects of Atomic Power, An Exploratory Study under the direction of SAM H. SCHURR and JACOB MARSCHAK. Princeton: Princeton University Press, 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. *Contents:*

Preface.

PART ONE. ECONOMIC COMPARISONS OF ATOMIC AND CONVENTIONAL POWER: I. Economic Characteristics of Atomic Power; II. The Cost of Electricity from Conventional Energy Sources.

PART TWO. ATOMIC POWER IN SELECTED INDUSTRIES: III. The Industry Analyses: A Summary View; IV. Aluminum; V. Chlorine and Caustic Soda; VI. Phosphate Fertilizers; VII. Cement; VIII. Brick; IX. Flat Glass; X. Iron and Steel; XI. Railroad Transportation; XII. Residential Heating.

PART THREE. ATOMIC POWER AND ECONOMIC DEVELOPMENT: XII. The Effects of Atomic Power on National or Regional Economies; XIV. Atomic Power and the Industrialization of Backward Areas.

Income, Employment, and the Price Level, notes on class lectures by JACOB MARSCHAK. Autumn, 1948 and 1949. Inquiries should be addressed to the Cowles Commission.