REPORT *of*

RESEARCH ACTIVITIES

July 1, 1961–June 30, 1964

COWLES FOUNDATION
FOR RESEARCH IN ECONOMICS
AT YALE UNIVERSITY

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PURPOSE AND ORIGIN

THE 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.

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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:

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INTRODUCTION

OVER THE YEARS, the Cowles Foundation's research program has combined empirical and theoretical studies. The interpenetration and cross-fertilization of these two lines of inquiry constitutes an important objective of the Foundation. We believe that in the past three years we have made further progress in that direction. This has in part taken the form of theoretical and empirical work on related problems being done by the same investigator. In part it has consisted of spontaneous complementary choices of topics, in "purely theoretical" and in "preponderantly empirical" studies by different investigators.

It is somewhat difficult to find a proper substantive classification for the three years' work of a group of workers with a wide diversity of interests. However, the following areas of inquiry stand out:

Growth theory and the empirical study of growth.

Theory of competitive equilibrium.

Stability and fluctuations in national income.

Financial behavior and asset markets.

Decision-making by individuals, households, and firms.

Methods and tools of analysis.

With some forcing and pushing here and there, we shall arrange our report under those headings.

GROWTH THEORY

Like much of economic theory, the theory of growth ranges, through various gradations, from *normative* theory about "optimal" growth paths to *descriptive* theory about growth paths derived from given behavior assumptions, regardless of whether that behavior leads to optimality of some kind.

The studies of optimal growth made during the period of this report can be further classified according to the criterion of optimality used, the number of goods, industries, or production processes considered, and the assumed presence or absence of population growth and of technological progress of one kind or another.

In view of the mathematical difficulty of the subject of optimal economic growth, it is not surprising that optimality criteria have been selected in part on the basis of mathematical tractability. A substantial part of the literature applies one theoretically fruitful but practically somewhat unnatural criterion: that of maximizing a capital stock of specified composition at the end of a planning period of, say, twenty years. If consumption is treated merely as a necessary input to a "production" process that sustains the labor force at a subsistence level, this criterion prescribes maximal, forced, growth rather than optimal growth. If one considers a conventional rather than a subsistence level of consumption as "necessary" to sustain the labor force, the criterion still aims for maximal growth compatible with the specified per capita consumption level, held constant. In spite of this artificiality, the criterion has led to an interesting class of "turnpike theorems" following a conjecture put forward by Dorfman, Samuelson and Solow.* These theorems all refer to a model in which the outputs of each separate production process are proportional to its inputs. The results of the various production processes are strictly additive, and the outputs (including labor) of all production processes taken together become inputs to the processes of the next period. It is found that regardless of the composition of the given initial capital stock, and of that of the prescribed final capital stock, in long planning periods the maximal growth path runs for most of the time close to a "turnpike" path. In a constant technology, the turnpike is also a path of maximal *proportional* growth, in which total inputs as well as outputs of different commodities stand in such proportions, inherent in the technology, as are most conducive to fast growth in the long run.

Drandakis (CFDP 153) has examined such a closed production system with *n* commodities. The economy considered is composed of *n* production units, each possessing its own technology. Although joint production of commodities by each unit is possible, each unit can be identified with the production of just one of the commodities in which it is particularly productive. He examines the behavior of maximal growth paths of finite (or infinite) duration and he establishes their "turnpike property," using an approach first applied by McKenzie.**

Koopmans has written an expository survey (CFDP 152) of the literature on turnpike theorems for a constant technology, using a geometrical representation of the set of production possibilities for a two-commodity

Linear Programming and Economic Analysis, New York, 1958, Chapter 12.
**Econometrica,* Jan. 1963.

model. He finds that the analysis of maximal economic growth is simpler in a technology in which different production processes reinforce each other when engaged in simultaneously.

Drandakis has also studied (CFDP 165) the collection of all maximal paths that originate from the same given initial capital stock, each aiming for a different composition of the maximal terminal stock. He considers a two-commodity model in which each production process produces only one of the two goods, and in which technology may change from period to period. He then finds that, as the planning period becomes longer and longer, the form of the locus of all alternative maximal terminal stocks approaches more and more a straight line, of which the slope is again inherent in the technology. In addition he finds that, as the planning period becomes longer, the collection of all maximal growth paths which provide nonnegative terminal stocks narrows down rapidly.

The diagram on page 4 illustrates these findings for paths in a constant technology, all of which start at the initial stock point E. The terminal loci of all maximal growth paths for 1, 2 and 3 periods are given by the curves E^1, E^2, and E^3, respectively, showing the rapid flattening of these curves. Moreover, all maximal paths leading to nonnegative terminal stock at 5 and 10 periods are included between the dotted paths aaa and bbb, ccc and ddd, respectively, whereas maximal paths of 20 periods length are indistinguishable from eee for the first three years. One again sees that, if an economy with the assumed traits wishes to follow any long-run maximal growth path, then it is rather severely restricted in its selection of a proper combination of outputs in the earlier periods, regardless of its ultimate aim.

Paths Maximizing a Sustainable Consumption Level

Optimality criteria that more fully recognize consumption as the purpose of economic activity have so far been applied mostly to models with a single consumption good. One simple criterion of this kind has been quite fruitful in models with a given exponential population growth. By this criterion one looks for the largest rate of consumption per head that is indefinitely sustainable. Phelps and a number of other authors independently discovered an interesting implication of this criterion. In Phelps' model (A) the stock of the single consumption good serves equally as the sole capital good, in such a way that output per worker increases, though at a decreasing rate, if the capital stock per worker increases. In the special case of a constant technology with constant returns to scale, his finding is that there stands out one particular "ideal"

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GOOD 1

GOOD 2

TURNPIKE

E^3

E^2

E^1

E^0

a

b

c

d

e

a

b

c

d

e

a

b
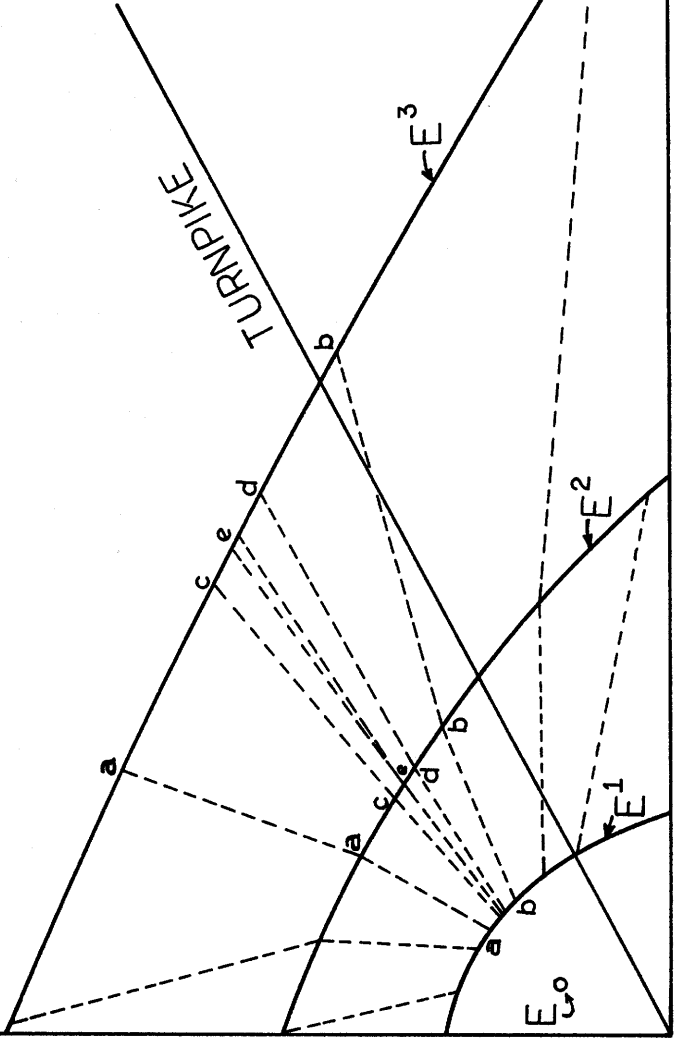
size of the initial capital stock which, if thereafter capital is made to grow forever in proportion to the population, will continually achieve the highest rate of consumption per worker that *can* be indefinitely maintained no matter how large the initial capital is. Starting from the "ideal" initial capital stock this rate of consumption can be maintained by the "golden rule of accumulation." This rule equates the proportion of output invested (i.e., of income saved) to the elasticity of output with respect to capital (the percentage increment in output made possible by a one percent increment in capital). In a competitive market economy, this rule also makes investment equal to total profits, consumption to total labor income. Srinivasan (CFDP 139) extended these results to an economy in which the single consumption good is different from the single capital good, with a family of production processes existing for either good.

The analytical significance of the golden rule path was further clarified in a discussion between Phelps (C) and I. F. Pearce.* In particular, in this discussion Phelps stated that a path in which the capital stock always exceeds that of the golden rule path by at least some given positive percentage yields at all times a smaller consumption than some other path feasible from the same initial capital stock. A proof for this statement was supplied by Koopmans, and both the statement and its proof were extended by Phelps to the cases of labor-augmenting as well as capital-augmenting technical progress.

Paths Maximizing a Discounted Sum of Future Consumption Flows

If the initial capital stock falls short of the "ideal"—as is likely in most actual economies—an objective of constant consumption per worker does not do justice to the growth potential of the economy. In his two-goods model (CFDP 139) Srinivasan experimented with maximization of the sum of future per capita consumption flows, discounted by a positive discount rate so as to reduce the weight of the consumption levels in a more distant future. It was found that, given the discount rate, the ratio of investment to output (both evaluated at competitive market prices implicit in the optimal path) is *not*, in general, a constant over time, but approaches a constant as time proceeds indefinitely. Further, the optimal paths corresponding to different initial stocks of capital (but to the same discount rate) approach the *same* proportional growth path as time proceeds. As the discount rate itself is made to approach zero from above,

*American Economic Review, Dec. 1962.

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this limiting proportional growth path itself approaches the equivalent of the golden rule path described above, which maximizes the indefinitely sustainable per capita consumption level. The ultimate share of rents in income corresponding to the optimal path for any positive discount rate was found to exceed the ultimate investment ratio.

Paths Maximizing a Sum of Future Utilities

Going back to a one-good model, Koopmans carried this analysis a step further (CFDP 163) by maximizing a (possibly discounted) sum of future per capita utilities derived from consumption, rather than of the consumption levels themselves. Assuming a diminishing marginal utility for higher levels of consumption this criterion gives greater relative weight to the needs of consumers in years of low per capita consumption. Results similar to those of Srinivasan were obtained. The case where both a zero discount rate and an infinite future are assumed could not be re-solved by maximizing the (infinite) sum of future per capita utilities. A solution could be found, however, by minimizing the sum of utility differences between Phelps' golden rule path (optimal for the "ideal" initial capital stock) and the path to be selected optimally for the given initial stock. It was found to be logically impossible to go further and give equal weight to the utilities of all future individuals, rather than of all future generations on a per capita basis. Even the latter becomes impossible if one assumes continual technological progress for an unlimited future.

Time Perspective

If one uses the criterion of the discounted sum of future utilities, the same discount rate of necessity applies equally to the poorer and wealthier phases of a growth path. In the previous report we described a stationary utility function, defined for an entire consumption path, in which this need not be the case. In CFDP 142, Peter A. Diamond, Koopmans and Richard E. Williamson found a new property of a stationary utility function (as given, or after a suitable recalibration of the utility scale). Referred to as "time perspective," this property says that if two consumption paths are postponed by the same time span, and if the gap thereby created is filled by the same consumption stream for the two paths, the utility difference between the paths diminishes. This property implies the property of impatience, discussed in our previous report, in a wider class of cases than previously known. Work toward maximizing this utility function in a simple constant technology is in progress.

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Models With a Constant Savings Ratio

One takes a step away from normative toward descriptive theory if, instead of maximizing or optimizing with respect to consumption levels or their utilities, one assumes that consumption, and hence investment, are constant fractions of output. The simplification so obtained can be exploited to obtain greater insight in other aspects of economic growth one may wish to study.

In CFDP 164, Srinivasan has studied growth paths of income, prices and terms of trade for a two-country three-goods model, where each country devotes a constant fraction of its income to consumption. Alternative assumptions about capital flow between the two countries include a case of international aid, and a competitive case where capital is attracted by the higher return.

Vintage Models

The same constant ratio of savings to income (or of investment to output) underlies work by Phelps on "vintage" models of capital. These have their origin in a paper by Robert M. Solow,* in which a "Cobb-Douglas" production function is employed in such a way that advances in technology can be embodied only in currently-produced capital goods, leaving the efficiency of old investments unchanged. Phelps found that the presence of such embodied technical progress can increase or decrease the estimated rate of return to investment. To the degree that old capital does not embody the latest technology, such old capital should be assigned relatively less labor, and this tends to raise the social rate of return to new investment. On the other hand, the faster the rate of embodied technical progress that is expected to occur currently, the more costly it is to meet plans to increase future output capacity by means of present investment instead of by later investment; there is a cost associated with investing now rather than later, which might be called "anticipated obsolescence," and this factor operates to reduce the rate of return to investment. For the United States economy, the former factor predominates over the latter: Phelps shows that if a steady 3 percent annual rate of improvement of new capital goods is assumed then the estimated rate of return to U.S. aggregate business investment in 1954 is about 14 percent; while if no embodied technical progress is assumed, the estimated rate of return is in the neighborhood of 8 percent. Tobin (E) arrived at about the same esti-

*In *Mathematical Models in the Social Sciences,* Arrow, Karlin and Suppes, eds., Stanford University Press, 1960.

mate of the rate of return to investment by a simple, approximative method.

Another result presented in CFP 188—discussed in the previous report in connection with CFDP 110—is the proposition that, in the long run, the responsiveness (elasticity) of output to the saving-income ratio is independent of whether technical progress is investment-embodied or "disembodied." In a comment on that paper, R. C. O. Matthews* raised the question whether this result was due to the choice of a production function of the Cobb-Douglas type. In a reply to that comment, Phelps (D) and Yaari found that, if a constant-elasticity-of-substitution production function is used, with a substitution elasticity smaller than unity, then the elasticity of long-run output with respect to the saving ratio does depend upon whether technical progress is embodied or disembodied. But they were unable to show that this responsiveness of output to the saving ratio was greater when technical progress was embodied than when it was disembodied.

The process by which a rise of saving raises productivity has also been examined by several members of the staff in somewhat different "vintage" models. The Solow model supposes that the labor intensity in the use of "machines" of any vintage can always be varied. A somewhat more rigid "vintage" model supposes that the only possibility of varying the labor intensity of a machine arises *ex ante,* that is, before it is constructed. No substitution is possible *ex post,* after construction of the machine.

Phelps studied such a model in CFP 199, expressing *ex ante* substitution possibilities by a Cobb-Douglas production function. The model indicates a new dimension of the connection between investment and productivity. An increase in the proportion of output invested reduces the rate of interest and thereby lowers the labor intensity of new machines. Since a machine will be profitable to operate for a longer time the smaller is its labor intensity, the operating life of retirement age of machines will eventually be increased. Up to a point, such an increase of the operating life of machines ("capital lengthening" Phelps calls it) will increase the productivity of the labor force over and above the effect of the increase of the number of machines per worker ("capital deepening"). It is shown that the retirement age of capital is such as to maximize output per head in the golden rule path.

Tobin, Yaari and Scarf have studied a completely rigid "vintage" model, in collaboration with R. M. Solow and C. von Weizsäcker. In this model there are no substitution possibilities at all, *ex post* or *ex ante.* At each point of time there is just one type of machine superior to all alternatives.

Quarterly Journal of Economics, Feb. 1964.

But, again, there is investment-embodied technical progress: next year's new machine is in turn superior to this year's new machine. In this model too a rise of the proportion of output invested raises productivity, but this rise is in no way attributable to "capital deepening," i.e., to any rise of "capital" per man. Higher investment raises productivity by making it possible to reassign labor from old and relatively unproductive machines to newer machines producing more output per man-hour. In their model, the rise of productivity due to a rise of the investment-to-output ratio can be attributed solely to the resulting decline of the retirement age of machines. For this reason the authors refer to the model as one of "pure quickening." Other points of interest in both vintage models discussed are the determination of labor's relative share, and the determination of the rate of interest or social rate of return to investment.

EMPIRICAL STUDY OF ECONOMIC GROWTH

The MIT-Yale Study of Future United States Economic Growth

Under a grant from the Ford Foundation for the three years beginning September 1963, several economists at the Cowles Foundation are cooperating with a group at the Massachusetts Institute of Technology in a study of United States economic growth. The main objective of the project is to estimate the principal global measures of economic activity in the U.S. and their rates of growth, in one or more years in the intermediate future 1968–75, under a variety of assumptions about public policy and other economic developments. How fast can the capacity output of the economy be expected to rise? Will aggregate demand be sufficient to buy the economy's potential output? Will private and public saving make sufficient resources available for investment to sustain the economy's rate of growth? These are the critical questions that motivate the study.

The project will not try to provide a single tableau of the economy for a future year, but rather alternative tableaux on a variety of assumptions: (i) concerning government policies in effect at the time and in the interim, and (ii) concerning other strategic economic developments. The important variations of government policies relate to: size and composition of budgets, structure and rates of taxation, and ease or tightness of monetary and debt management controls. The important variations in other developments include: cyclical developments over the intervening years, in particular as they affect the capital stock and the state of business expectations of the profitability of investment; the preferences of the

population for gainful employment relative to other uses of time; technological factors affecting the productivity of capital and labor.

The important conclusions of the investigation will stem from comparisons of one tableau with another. These comparisons will indicate, for example:

—the requirements and costs of faster growth in terms of investment and manpower;

—the combinations of fiscal and monetary policies needed to balance demand and potential supply, and to balance investment demand and available saving, at various rates of growth;

—the effects on the rate of steady growth of maintaining, through fiscal and monetary policy, different degrees of "tightness" in the relationship between aggregate demand, on the one hand, and plant capacity and manpower, on the other;

—the effects on the average rate of growth over a period of years of temporary departures from a path of feasible steady growth.

Participants at the Cowles Foundation during the first year of the project have included Tobin, Okun, Phelps, Friedman, and Bodkin. The M.I.T. group is led by Professor Robert M. Solow.

The project draws heavily on related theoretical and empirical investigations at the Foundation: especially (i) the theory of growth, in relation to saving, tangible investment and technological progress, discussed above; (ii) empirical measurement of production relationships and rates of technological improvement in the United States and other advanced economies, described below.

Many of these investigations—as well as other work at Yale, M.I.T., and elsewhere—bear upon some fundamental questions concerning the nature of the "production function" connecting output to inputs of capital and labor. How important are economies of scale? What possibilities are there for substitution between machinery and labor, in operating old installations and in planning new ones? To what extent must technological progress be "embodied" in new plant and equipment? What is the role of research and development in determining the rate of technological progress? How can statistical records of production, employment, and investment be used to shed light on these central questions? Considerable oral and written discussion of these matters is taking place. One contribution is Bodkin's CFDP 157, which questions the frequently used assumption of constant returns to scale.

During his visit to the Cowles Foundation in 1961–62, Mansfield wrote several papers, some begun at the Carnegie Institute of Technology, on the interconnections between industrial research expenditure, market structure and innovation in selected industries in the United States. In CFDP 136 Mansfield formulated and estimated a model to help explain the research and development ("R & D") expenditures of individual firms. This model was constructed in part on the basis of interviews with research directors and other executives of a number of firms in the chemical and petroleum industries. For eight firms where the necessary data could be obtained, the model seemed to fit historical data quite well. Moreover, when supplemented with additional assumptions, it could fit the 1945–58 data for 35 firms in five industries quite well, and it could do a reasonably good job of "forecasting" their 1959 expenditures. He also presented estimates of the relationship between a firm's research expenditure and the number of significant inventions it produced during the relevant period.

In CFP 208 Mansfield examined the extent to which the largest firms in selected industries have been the innovators. Using lists obtained from trade journals and engineering associations of the important processes and products first introduced in these industries since 1918, he found that the giant firms accounted for a disproportionately large share of the innovations in some industries but not in others. He outlined a model which explained this pattern and he tried to estimate whether fewer innovations would have been introduced had these large firms been broken up.

What are the reasons why some firms begin using new techniques before others do? In CFDP 134, Mansfield estimates the effects of each of several factors on how long a firm waits before introducing a new technique.

There is also the question of the intrafirm rates of diffusion of an innovation. Once a firm first adopts a new technique, how quickly does it proceed to substitute it for older methods? In CFP 206 Mansfield singles out for analysis one of the most significant innovations occurring in the interwar period, the diesel locomotive. An econometric model is developed and estimated which helps to explain differences among railroads in the rate at which, once they had begun to dieselize, they substituted diesel motive power for steam.

In an as yet unpublished work, Mansfield examined whether the rates of innovation in selected industries have increased in accord with the spectacular rise of R & D expenditures. He further looks at the connection between the timing of an innovation and the timing of plant and equip-

ment expenditures. His results for the iron and steel and petroleum refining industries encouraged him to believe that his model of investment behavior is superior in these industries to the customary accelerator models in which the dates of innovations play no part.

Finally, in CFP 187, Mansfield is concerned with the pattern of growth, birth, and death of firms in various industries. Estimates are also made of the difference in growth rate between firms that carried out significant innovations and other firms of comparable initial size. The results help to measure the importance of successful innovation as a cause of interfirm differences in growth rates, and they shed new light on the rewards for innovation.

A book bringing together the whole of Mansfield's research in this area is in preparation.

Growth Studies for Other Countries

Friedman and Shubik (CFDP 170) explored the use of techniques of simulation for the study of socio-economic problems of development in a Latin American economy. Stress was laid upon designing the output to be compatible with the National Income Accounts scheme of the country studies program of the Yale Economic Growth Center and with the financial statistics of the International Monetary Fund.

Two other studies of growth and growth planning in other countries are the result of joint projects with the Yale Economic Growth Center.

Edmund and Charlotte Phelps are engaged in a comparative study of postwar economic growth in the United States, Canada, the United Kingdom and West Germany. In the econometric model they are using, the principal sources of productivity growth are tangible investment and scientific manpower (as a proxy for research effort). The model is of the "vintage" variety: it leaves room for investment-embodied technical progress. The ultimate objectives are to estimate the parameters of production functions and to estimate the rates of return to tangible investment and to research effort in the four countries.

The study is now through the stage of gathering and refining data of output, investment, work week, employment and unemployment. Charlotte Phelps has compiled internationally comparable data on the employment of scientists and engineers of the four countries in the years 1950–51 and 1960–61, and is constructing distributions of scientific and technical employment by function (research and development, teaching, and management) and by level of education.

Srinivasan spent the year 1962–63 in India at the Institute of Economic

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Growth at Delhi, collecting data for building a model for Indian planning. This model will attempt to work out the optimal way of achieving a target level of income during 1970–71 (end of the 5th plan). The minimand may be either (a) total investment required or (b) total foreign aid required. Some constraints on the capacity levels to be achieved in various sectors in 1970–71 will be imposed to take into account the future beyond 1970–71.

THEORY OF COMPETITIVE EQUILIBRIUM

Existence

During the last decade, the problem of the mathematical "existence" of a competitive equilibrium has received the attention of a number of authors. By this is meant the logical possibility of an equilibrium in which each consumer maximizes his utility, each producer his profit, all taking market prices as given. In a recent paper (CFP 186) Debreu has unified a number of the previous existence theorems. This has been done by introducing the concept of a quasi-equilibrium and proving a general existence theorem for quasi-equilibria. Essentially a quasi-equilibrium differs from the customary equilibrium in that consumers are treated as cost minimizers for a given utility level rather than utility maximizers facing a budget constraint. Using this device one can avoid some serious technical difficulties, and then by introducing a few simple additional assumptions conclude that a quasi-equilibrium is in fact an equilibrium in the ordinary sense.

Aside from this unification, the article presents a new technique for dealing with the fact discovered by L. W. McKenzie that an assumption previously made about the irreversibility of all production processes is superfluous. Other concepts and techniques are used to strengthen earlier results.

Equilibrium and Game Theory

During the last several years there has been a growing awareness of the connection between the strategic considerations of n-person games and competitive equilibria. Von Neumann and Morgenstern introduced, some fifteen years ago, a concept of the solution of an n-person game based on the consideration of those allocations which can be enforced by various coalitions of participants in the game. Their solution concept is rather complex, and does not seem to be related to previous results in economic theory.

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Alternative solution concepts have been proposed, however, and one of them, the "core," has turned out to be intimately related to the theory of competitive equilibria.

The core of a game is defined to be the set of those allocations which cannot be improved upon by *any* coalition of players so as to benefit all members of that coalition. If the strategies of a coalition are restricted to a refusal to engage in exchange with the remaining players, then the core is a generalization of the Edgeworth contract curve. A competitive equilibrium of a pure exchange economy is always in the core; no coalition can improve all of its members' positions by redistributing the assets of the coalition. Generally there will be many allocations in the core, with the competitive equilibria occupying a central position.

In (A), Scarf studied the core of a general exchange economy with the number of participants tending to infinity, in the following fashion: First he assumed that there are a finite number of types of consumers, with all consumers of a given type having the same preferences and the same distribution of initial holdings. Next he studied the limiting behavior of the core if the number of participants of each type is assumed to tend to infinity. This idea is the direct generalization of the model considered by Edgeworth for two types of consumers. Edgeworth proved, in *Mathematical Psychics* that as the number of consumers of each type became larger, the core (or the contract curve in his terminology) would become smaller and in the limit contain only those points which were competitive equilibria in the original economy. Debreu and Scarf (CFP 200) have demonstrated the generalization of this result to an arbitrary number of types of consumers.

Instead of making the number of consumers tend to infinity, one may assume that there are an infinite number of consumers of each type to begin with, and then demonstrate that the only allocations in the core are in fact competitive allocations. For this result, due to Scarf, a simpler proof under weaker assumptions was given by Debreu (CFP 203).

Debreu and Scarf also consider a case in which production takes place. They assume that one and the same aggregate production set is available to all coalitions, and that this set is a convex cone, expressing constant returns to scale, and constant or decreasing returns to any single input. The core of such an economy may be easily described, and it is shown that as the number of consumers tends to infinity in a suitable fashion, the cores will again become smaller and, in the limit, contain only competitive equilibria.

In the study of the core attention is focused on the possibility that any group of members of an economy may form a coalition if it is to their advantage to do so. No behavioral assumptions are made concerning the

response to prices; in fact prices are not explicitly introduced into the analysis. The results of these studies may be summarized rather loosely by saying that in a pure exchange economy with a large number of participants, the possibility of coalition formation will generate competitive prices.

The core may be studied when the aggregate production set is more general than a convex cone. Production sets may be selected which exhibit increasing returns to scale and other deviations from classical assumptions. The behavior of the core for a large number of consumers is then overshadowed by the question of whether there will be any allocations in the core. Since there may be no competitive equilibrium to suggest a particular point in the core, it is possible that every allocation which is proposed will be overruled by some coalition on the basis of the coalition's assets and productive knowledge.

Scarf has shown that if the aggregate production set satisfies certain minimal regularity conditions and is different from a convex cone in any slight way, then there will be an economy using this production set, and whose consumers have conventional preferences, for which there is no core. However, the consumer preferences which are used to construct these counterexamples while respectable from the point of view of convexity and other regularity conditions, are somewhat unsatisfactory in that they require consumers to value the direct consumption of all of the commodities in the economy. If one divides the commodities into two categories, those which do enter directly into preferences (consumer goods) and those which do not (producer goods), then there will be many production sets exhibiting increasing returns to scale, and which always give rise to a core. The way this is demonstrated is to exhibit a specific allocation, which though similar to a competitive equilibrium differs in one important respect, and then to show that this allocation is in the core. In a competitive equilibrium consumers maximize utility subject to the budget constraint, and the aggregate production decision is taken so as to maximize profit with respect to all alternative production plans. When the production sets above are used the production plan is obtained by maximizing profit with respect only to those alternatives which use no more of the producer commodities than are initially available. Future work in this area will attempt to study increasing returns in a dynamic context.

Problems in Welfare Economics

Another study in welfare economics by Whinston in collaboration with O. A. Davis of Carnegie Institute of Technology has been concerned with the optimality properties of "second best" solutions to allocation problems

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(CFDP 146). A "second best" problem arises if one of the units in the economy deviates from behavior leading to Pareto optimality; one is then interested in compensating behavior of the other units that attains the closest approximation to Pareto optimality that is possible given this non-optimal behavior. Davis and Whinston study a number of examples, one of which is concerned with two firms having external diseconomies. From a welfare point of view production decisions should then be taken with the external effects explicitly considered. A second best problem arises if one of the firms pursues profit maximization rather than welfare maximization. As Davis and Whinston show, the solution which is obtained by maximizing a welfare function subject to this non-optimal behavior does in fact give rise to conditions which, for the other units in the economy, are similar in form to the Pareto conditions that would prevail if social welfare were maximized in the original problem.

Whinston has also been concerned with studying methods of generating price guides within a decentralized firm (CFDP 141). One system studied in this paper can be described in the following terms: Preliminary plans are made by divisions. On the basis of these plans the central staff scales down the tentative plans of the divisions in order to make them consistent with aggregate constraints, and provides a set of price guides. On the basis of these new price guides the divisions communicate new proposals and so on. The system (which is related to the Dantzig-Wolfe decomposition principle of linear programming*) is workable only if there is a rapid convergence of successive revisions. This planning model may be extended to cases where externalities are present, that is, where choices of the method of production by one division affect the outcome of similar choices by another division.

Stability and Uncertainty

During his stay at the Cowles Foundation in the year 1962–63, Muth began a study of the stability of competitive systems. In the Walrasian market model of "tatonnement," the adjustments of supply and demand are meant to be completed before the physical transfer of commodities takes place. Muth, on the other hand, has given several examples of adjustment mechanisms which proceed in the midst of other economic activity. This work, which at present has been restricted to an isolated market for a single commodity, will be continued.

Hooper has been working with Muth on the problem of uncertainty in a model of a competitive economy. The work is at present in a preliminary

*Econometrica, Oct. 1961.

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stage. An attempt will be made to generalize in several directions the point of view originated by Arrow and Debreu in which some commodities are contingent on the occurrence of uncertain events.

STABILITY AND FLUCTUATIONS IN NATIONAL INCOME

The Quantitative Basis of Stabilization Policy

In pursuing the social goals of full employment and price stability, policy-makers must make quantitative decisions about the application of fiscal and monetary tools. In recent years, both policy-makers and academic economists have shown a keen interest in the development of more refined quantitative knowledge about aggregative economic relationships. Work at the Cowles Foundation has added to this fund of quantitative knowledge.

The tasks of stabilization policy are partially defined by the distance of the economy from full employment. One measure of that distance is the discrepancy between potential and actual levels of Gross National Product. Okun presented estimates of potential GNP in CFP 190 and discussed their analytical underpinnings and their relevance for economic policy. He found that the overall rate of unemployment as a fraction of the civilian labor force serves as a good proxy for unused resources. The size of the output "gap" has been an important consideration in the recent tax reduction and in public discussion of expansionary fiscal policy.

The latent strength of investment demand is a major concern in the formation of stabilization policy. The underutilization of resources and the slowdown in the rate of growth in the United States economy during recent years has been marked by especial weakness in business outlays for fixed investment. The low level of capital spending is partly cause and partly symptom of the slowdown in economic activity. Investment outlays would be stronger in a full-employment environment with higher sales and higher profits. But it is difficult to say how much stronger they would be. In CFP 202, Okun appraised the latent strength of investment demand, using a variety of prototype investment functions to estimate investment demand under hypothetical conditions of full employment. The weight of the evidence suggests that fiscal-monetary policies must be more expansionary than they were in 1962 if the economy is to attain full employment. Okun concluded that, while a sharp temporary stimulus to aggregate demand might lift the economy out of a "rut," a sustained stimulus is probably necessary to keep the full employment target within range.

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Inventory investment has been a major determinant of the pattern of fluctuations in Gross National Product during the postwar period. Lovell continued to investigate the determinants of inventory investment, supported in part by a grant from the National Science Foundation. He has been particularly interested in analyzing sales expectations, because errors made by firms in anticipating their sales volume may contribute to the explanation of cyclical fluctuations in inventory investment. But expectational variables are directly observed and measured only in rare instances. Except for these instances, a proxy for anticipated sales volume must be employed by the researcher. Where observations on expectations are available, the validity of certain proxy variables as measures of expectations can be tested by confronting the rationale underlying the proxy procedure with the data on expectations. In order to test certain proxy procedures, a technique was developed for reconstituting data on railroad shippers' forecasts collected by the American Railroad Association. The procedure, which could be applied with precision only to the cement industry, yielded approximations of actual sales forecasts that could be utilized in equations explaining inventory behavior and also to evaluate various proxies for actual anticipations. One outcome of the investigation was the conclusion that the actual change in sales from the preceding year, rather than the change from the immediate past quarter, constitutes a useful proxy for the forecast error when dates that have not been subjected to seasonal adjustment are employed. Perhaps this results from the customary business practice of making crude allowances for seasonal variation by comparing the current level of operating-variables with their level on the same-date-last-year. It is hoped that the four quarter change will prove a useful proxy in analyzing inventory data when expectational variables have not been recorded. The results of this investigation were presented at a National Bureau of Economic Research Conference on Income and Wealth at Chapel Hill in February, 1962, (Lovell, D).

Lovell's earlier work had emphasized the importance of order backlogs in determining inventory investment, and newer available information on government defense orders permitted him to study the impact of military procurement on inventory investment. Preliminary least squares estimates were presented to the Joint Economic Committee of the U.S. Congress (Lovell, A). This study revealed that, when obligations (orders) are placed for durable goods, they exert a positive pull upon inventory as they lead to the accumulation of goods in process.

Lovell has assumed responsibility for explaining the behavior of inven-

tories held by manufacturing firms for the interuniversity econometric model constructed under the auspices of the Social Science Research Council. He intends to incorporate the Department of Defense orders variables as well as a measure of capacity utilization in the equation predicting durable manufacturing inventories.

A limited amount of progress has been made in the analysis of the multisector inventory model. Under the assumption that all industries have the same marginal desired inventory and reaction coefficients, the characteristic roots of the transitions matrix of this model can be derived by a simple transformation of the characteristic roots of the Leontief matrix of technological coefficients. It has been possible to compute the characteristic roots for a 5 x 5, a 10 x 10, and a 20 x 20 matrix of 1947 flow coefficients on the new Yale computer. Most of the roots turn out to be real and positive; these computations imply that any cycle would be highly damped.

A theoretical result has also been derived under the strong uniformity assumption that there are no interindustry differences in the marginal desired inventory and reaction coefficients. In earlier work the implications of the assumption that entrepreneurs have static expectations (expected sales equal current sales levels), was contrasted with the situation in which future sales were anticipated without error; only the first assumption is compatible with stability. Lovell's more recent work suggests that if entrepreneurs consistently foresee a particular positive fraction of the changes in sales volume that actually come about, the economy will again be unstable, suggesting that a little foresight, as well as perfect expectations, leads to difficulties. These preliminary results are paradoxical and are being carefully checked and reevaluated.

James Friedman has been analyzing fixed investment demand in connection with the MIT-Yale Study of Future U.S. Economic Growth. He formulated a model in which investment depends on the difference between the rate of return on investment and the long-term government bond yield, cash flow and utilization rate. The model will be tested for two digit manufacturing industries as soon as the relevant data are assembled on an industry basis which is consistent.

Prices, Wages, and Inflation

The behavior of prices and wages in the aggregate is of great importance in understanding and controlling economic activity. Ronald Bodkin explored wage-price relationships in CFDP 147. He developed a static model of output and the price level which served as a framework for the empirical study. Specific equations explaining changes in manufacturing

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wages, wholesale prices of finished goods, and output per man-hour in the private domestic economy were fitted by ordinary regression techniques; the parameters of the tentative equations were then reestimated by the method of two-stage least squares. Several tests for asymmetry of response were made for both the wage change and the price level equations; in general, little evidence was found of this type of irreversibility, especially for the wage change equations.

The relationships obtained can be used to calculate a trade-off between the conflicting goals of full employment and price level stability. Subject to qualifications pointed out in the discussion paper, it appears that much unemployment is required for price level stability, while the price stability "cost" of full employment (defined as 3 per cent unemployment) might be expected to be an inflation of consumer prices approximately equal to 1½ per cent per annum.

A revised version of CFDP 147 will be published in 1965 by the University of Pennsylvania Press. One part of this work has already appeared (C).

The welfare effects of anticipated inflation have been examined by Phelps (CFDP 161R). It is shown, first of all, that if fiscal and monetary tools are effective and unconstrained, then there is no necessary connection between the rate of anticipated inflation and the real rate of interest (hence investment and growth). The government can bring about a high-investment or a low-investment inflation in the same way that it can generate high or low investment and keep the price level stationary.

Second, if the government has unlimited power to buy and sell claims on wealth (shares in the model under consideration) and has the power to pay interest on money, then there are no welfare consequences from fully anticipated inflation. But if the government cannot pay interest on money, then anticipated inflation may prevent the simultaneous attainment of the desired levels of liquidity and investment. A sufficiently high anticipated rate of inflation may imply a nominal rate of interest so high as to create incentives to economize on the holding of cash in transactions balance, thus preventing a state of "full liquidity."

The third part of the paper deals with the "Vickrey problem," in which the government, in addition to being unable to pay interest on money, faces a constraint on the quantity of private wealth it can monetize. In this case, the investment-liquidity optimum may not be attainable. The best feasible investment-liquidity combination may require a rising anticipated price trend. However, it is shown that, if the government can tax money holding, the possibilities of achieving the optimum are enhanced.

Lovell has also devoted further attention to certain theoretical problems arising from the analysis of inflation (CFP 198).

Brainard and Lovell have considered some aspects of cost-push inflation. At the Econometric Society meetings in September 1963, they presented a joint paper on the problem of measuring the inflationary impact of increases in profit markups and wage rates within the framework of a multisector model.

The Role of Money in Economic Stabilization

The role of money in the determination of national income has been an important subject of investigation by economists throughout the history of our profession. Currently, a modern version of the quantity theory of money is being advanced by Professor Milton Friedman and his associates at the University of Chicago. Two recent papers by Cowles staff members discussed M. Friedman's findings. In CFP 197, Okun questioned the analytical plausibility of some of the conclusions in "Money and Business Cycles," a paper jointly authored by M. Friedman and Anna J. Schwartz. In particular, Okun doubts the Friedman-Schwartz view that interest rates are unimportant in explaining substitution between money and other assets, when, at the same time, Friedman and Schwartz attribute great significance to relative yields in encouraging substitution among various types of nonmonetary assets. Okun also is skeptical of the high income-elasticity of demand for money estimated by Friedman and Schwartz. In general, Okun argues that money is less powerful—for policy and explanation—than Friedman and Schwartz believe.

A similar opinion emerged from a recent study by Hester. Professors Milton Friedman and David Meiselman have compared two highly simplified macro-economic theories, a quantity theory and an autonomous expenditure (Keynesian) theory, for the Commission on Money and Credit.* Essentially they report that the correlation between consumption and the money supply exceeds the correlation between consumption and one measure of autonomous expenditure and conclude that the quantity theory fares better than the autonomous expenditure theory. In a forthcoming comment in the November, 1964, *Review of Economics and Statistics,* Hester indicates that their results are very sensitive to the definition of autonomous expenditure. He argues that their definition does not correspond to usual definitions of

*Milton Friedman and David Meiselman, "The Relative Stability of Monetary Velocity and the Investment Multiplier in the United States, 1897–1958," *Stabilization Policies,* A Series of Research Studies prepared for the Commission on Money and Credit, Englewood Cliffs: Prentice-Hall, Inc., 1963, pp. 165–268.

autonomous expenditure and that, when a more conventional definition is used, the empirical evidence does not support their general conclusions.

Another contribution to our quantitative knowledge about monetary policy is Okun's study of interest rates for the Commission on Money and Credit (CFP 210). Of particular interest is the controversial finding that open-market operations involving "swaps" of long-term for short-term government securities are not likely to have dramatic effects on the term structure of interest rates. This is a pessimistic conclusion in the current environment where high short rates and low long rates if achievable may be ideally suited to the conflicting domestic and international needs of the United States economy.

Monetary specialists have also been interested in Okun's conclusion that large movements in central bank instruments are required to exert a significant influence on interest rates and that relatively large movements can be initiated without disrupting financial markets.

These results emerged from a multiple regression analysis of quarterly time-series data for 1946–59. The long and short rates on government securities are explained by the level of national output and the size and composition of various liabilities of the Treasury and Federal Reserve System. The qualitative findings on the maturity structure of yields tend to confirm the Keynesian view that expectations of future interest rates are inelastic; the results also suggest that long and short securities are close substitutes for some significant groups of investors.

Tobin's study for the Commission on Money and Credit (CFP 195) developed the criterion that optimal debt management "consists in accomplishing the task of monetary stabilization at the least cost to the Treasury." This criterion points toward a number of adjustments in policy such as 1) a preference for higher reserve requirements (as opposed to open market sales) to tighten money; 2) the imposition of secondary reserve requirements on banks and reserve requirements on other financial intermediaries; 3) a refunding policy attuned to anticipated movements in market interest rates; 4) greater centralization of security purchases and sales by the Federal Reserve and the Treasury; and 5) the issuance of bonds with purchase-power escalation, geared to the Consumer Price Index.

FINANCIAL BEHAVIOR AND ASSET MARKETS

Monetary Theory

Investigation of monetary and financial institutions and capital markets, and their relation to economic fluctuations and growth, has been an important part of the work of the Cowles Foundation in recent years. The aim of this research is to develop a theoretical framework for understanding and interpreting monetary and financial institutions and behavior, and to test and apply this framework empirically, mainly to the experience of the United States. The research is strongly motivated by considerations of public policy: (a) the mechanism of monetary control and its effectiveness, (b) the effects of structural changes (e.g., emergence of new financial institutions and markets, changes in the regulations to which various financial institutions are subject) on economic stability.

Work on these subjects at the Cowles Foundation is based on an approach which is recognized to be distinctive and which seems to be fruitful.* The basic elements of this approach are:

(a) interpretation of the financial behavior of individuals and institutions in terms of a theory of portfolio choice, relating their characteristic requirements and preferences to the properties (risks, liquidity, etc.) of available assets and debts.

(b) so far as overall financial and capital markets are concerned, attention to the requirements of simultaneous equilibrium in the balance sheets of all individuals and institutions in the economy.

A general exposition of the approach is given in a forthcoming book on monetary theory by Tobin. The nature of the book is indicated by the following titles of chapters, which have been circulated in tentative form in mimeograph:

National Wealth and Individual Wealth
Properties of Assets
The Theory of Portfolio Selection
The Demand for Money
Growth and Fluctuation in a Two-Asset Economy
The Monetization of Capital
The Theory of Commercial Banking
The Monetary Mechanism

*See the review article "Monetary Theory and Policy" by Harry G. Johnson, *American Economic Review*, June, 1962, pp. 335–384, esp. p. 347.

In addition, the book will contain material from Tobin and Brainard's CFP 194, from Tobin's CFP's 195 and 205, and from his paper "Money, Capital, and Other Stores of Value."*

One theme of this work is to dethrone "money"—demand deposits and currency—and commercial banks, some of whose liabilities are money, from the overriding central position they have traditionally held in monetary analysis and policy. Instead, assets which serve as means of payment are viewed as competing with a variety of substitutes for place in the portfolios of individuals and business firms. Likewise, commercial banks are viewed as quite similar in economic function and effect (if not in legal position) to competing types of financial intermediaries. The general point of view is expressed in popular language in CFP 205, and in more rigorous form in CFP 194. In his Yale doctoral dissertation (A), Brainard has considered in detail the theoretical monetary implications of the competition between other financial intermediaries and commercial banks.

These studies bear upon certain important questions of public policy:

Does the existence of uncontrolled financial intermediaries vitiate monetary control? In recent years some observers have concluded that Federal Reserve controls over commercial banks are an empty gesture so long as other intermediaries—savings institutions, life insurance companies, pension funds—are not subject to similar controls. Others have responded that control of commercial banks is sufficient, because they alone create "money." Brainard and Tobin conclude that monetary control is weakened—i.e., bigger doses of Federal Reserve medicine are needed to get the same effects —but not rendered ineffectual by the actions of uncontrolled financial intermediaries.

Is it desirable to make the financial system more responsive to central bank instruments of control? Not necessarily, according to Brainard, because a structural reform designed to do so may also make the system more responsive to uncontrolled and unforeseen economic events.

What economic variable should be the strategic target for monetary policy? There are numerous contenders in economic and popular discussion —the money supply, market interest rates, bank reserves, bank loans, etc. Tobin and Brainard argue that the relevant variable is the rate of return the public requires in order to absorb the existing stock of real capital into their portfolios. Actions which make this required rate higher discourage investment and are therefore properly regarded as deflationary or contractionary; actions which lower this rate encourage new investment and accordingly are inflationary or expansionary. It is not difficult to find cases where

*American Economic Review, May, 1961.

other criteria in common use give indications which, according to this fundamental criterion, are misleading.

What are the effects of regulation governing interest rates payable by commercial banks and other financial intermediaries? The importance of this question is attested by recent changes in ceiling rates for time and savings deposits and by proposals that such ceilings be eliminated altogether. However, economic analysis has paid little attention to this aspect of monetary control. At the end of 1961 when the Federal Reserve raised ceiling rates, opinions differed widely whether this move was expansionary or contractionary. The Tobin-Brainard model implied—correctly, the event seems to indicate—that the action was expansionary.

Empirical Studies

Considerable empirical work, parallel to the theoretical investigations just described, is under way. The empirical studies concern (a) the behavior of commercial banks, other financial intermediaries, and non-financial corporations, and (b) the characteristics of assets available for portfolio managers.

During 1963–64, Pierce completed a doctoral dissertation (Berkeley 1964) which analyzed portfolio decisions of large commercial banks. In the study (part of which is reported in CFDP 168) a bank is conceived to have at its disposal a supply of funds equal to its deposit liabilities (less required reserves) plus its capital, and to distribute these funds among three basic categories of assets: a transactions balance composed of highly liquid *reserve assets,* a portfolio of relatively long-term bonds or *investment assets,* and non-financial *loan assets.* The analysis concerns the shares of each asset category in the bank's portfolio. The share of reserve assets in the portfolio is assumed to depend on the risk that loss of deposits will leave the bank short of legal required reserves. The desired shares of investment and loan assets in the total portfolio are assumed to depend on the size and reliability of the earnings they yield.

These assumptions are given statistical content by relating each of the three shares to a common set of variables, as follows: The need for liquid assets as a precaution against withdrawals depends on the composition of the bank's liabilities; the level and nature of its demand deposits, the level of its time deposits (less likely to be withdrawn), and the size of its capital account. The yield on 3–5 year Government securities is a measure of the inducement to hold investment assets. The availability to the banks of profitable commercial loan opportunities cannot be directly measured; it is approximated by an indication of overall business activity. Furthermore,

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it is argued that the cyclical pattern of bond prices induces banks to shift sharply into investment assets as soon as loan demand begins to decline at the top of a cycle. This hypothesis is also tested statistically.

The three equations were estimated from weekly balance sheet data aggregated over 85 large commercial banks. The estimates indicate: that the supply of funds is a prime determinant of the share of the loan portfolio; that the yield on 3–5 year Government bonds has a relatively large negative effect on the loan portfolio; that the overall state of business activity has, after the other variables are allowed for, a relatively small impact on the portfolio; that banks do, as expected, shift into investment assets to take advantage of a rising bond market.

Evidently banks do not blindly distribute constant proportions of their available funds to the three portfolio categories. Neither do they passively respond to fluctuations in loan demand.
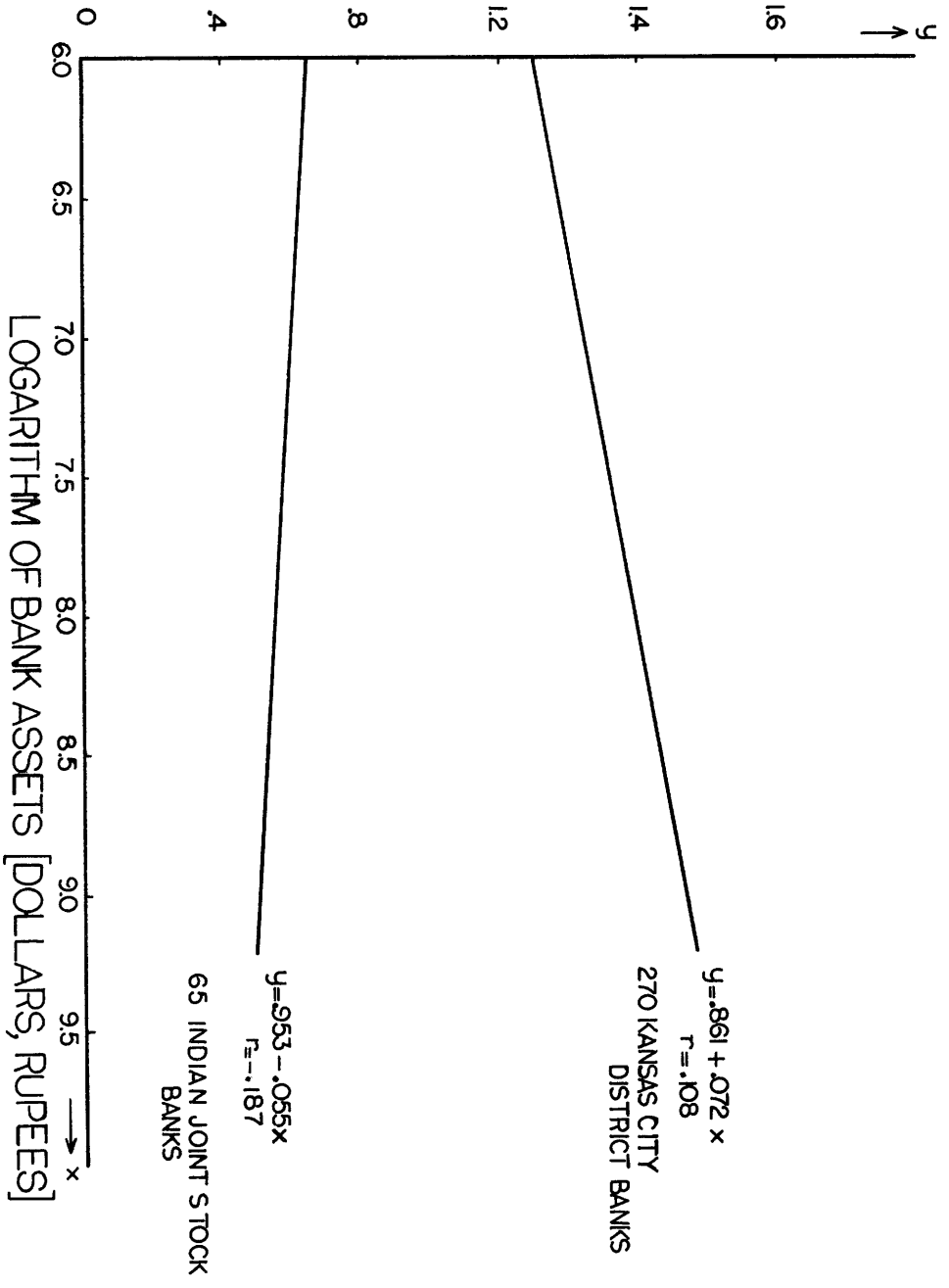
Hester spent the 1962–63 academic year in India on a Ford Foundation exchange program where he completed an empirical study of Indian commercial banks, (B), based on published data and on interviews. He estimated the net profitabilities of different bank services and activities, by relating differences in earnings among a sample of banks to the differences in their balance sheets. He found evidence of substantial *dis*economies of scale; small banks' ratio of profits to assets is about 30 percent larger than that of big banks. The apparent excessive centralization in Indian banking contrasts sharply with American experience. Here large banks have been found to be the more profitable.* The diagram on page 27 shows the relationship of bank earnings to size in the two countries. Perhaps surprisingly, earnings on loans by Indian banks were found to be quite similar to interest rates earned by American banks. The efficiency of Indian banks appears to be impaired by collusive pricing policies and by the absence of cost accounting.

Hester is applying the same technique of profit analysis to samples of Connecticut commercial and mutual savings banks. This study will permit tests of hypotheses about the relation between a bank's services and earnings and the degree of competition it faces. This study is, in part, a pilot study for more comprehensive analyses of commercial banks (with Pierce) and mutual savings banks, for which data are presently being acquired. Briefly, for both classes of banks the investigators will analyze the degree of deposit predictability, the net earnings from different bank assets and liabilities, and the pattern of adjustment of bank portfolios in response to changes in deposit levels and interest rates. These results will then be the empirical basis for two simulation studies: one of a typical commercial

*"Relationship of Bank Size and Bank Earnings," *Monthly Review of the Federal Reserve Bank of Kansas City,* December 1961.

NET CURRENT EARNINGS OR PROFITS

[AS A PERCENTAGE OF BANK ASSETS]

$y=.861+.072 x$
$r=.108$

270 KANSAS CITY
DISTRICT BANKS

$y=.953-.055 x$
$r=-.187$

65 INDIAN JOINT STOCK
BANKS

LOGARITHM OF BANK ASSETS [DOLLARS, RUPEES]

bank and one of a typical mutual savings bank. These simulation studies are expected to shed considerable light on how financial institutions behave and on how monetary policy may affect their behavior.

In regard to the characteristics of assets available to portfolio managers, Feeney and Hester completed a study of prices and rates of return of the 30 common stocks included in the Dow Jones industrial average. This study considered two related questions: 1) how well can stock prices or rates of return be represented by a single index number and 2) to what extent will portfolio diversification reduce risk. If a perfect index number exists, diversification cannot reduce risk; all stocks move together in the market, and the risk of their common fluctuation cannot be avoided or diluted. Using data from a recent period of 50 quarters, the investigators computed the "principal components" of the prices of 30 stocks. These components may be regarded as fictitious "mutual funds." In each fund, every one of the original 30 stocks has a certain fixed weight. But, unlike the constituent stocks, the components or funds are constructed so as to be uncorrelated with each other.

Approximately 76% of the 30 stocks' variance in price was accounted for by the first component. In that component almost all stocks had weights of the same sign, reflecting the positive postwar trend in stock prices. The first component was very highly correlated with both the Dow Jones and Standard and Poor industrial stock price indices. The second component accounted for 14% of the total variance; it might be called an "accelerator component" since weights of consumer and producer goods stocks bore opposite signs.

A principal component analysis was made also for rates of return. Only about 40% of the 30 stocks' variance in rate of return was accounted for by the first component. This component might be interpreted as "the market"; rates of return of all stocks bore weights of the same sign. The investigators suggested that the remaining 60% of variance in return is not common to the 30 stocks and may be partly avoided through judicious diversification.

Finally, Feeney and Hester examined the stability of the components when they were estimated from each of two successive 25 quarter subperiods. They found that weights of individual stocks in price components were quite unstable between subperiods and were thus not reliable. Weights were stable for the first rate of return component, but not for subsequent components. In the years 1951–56 firms in various industry groups had similar weights in each of the first ten components; this was less true in the years 1957–63. A possible interpretation is that competition among firms within an industry was more severe in the second subperiod.

DECISION-MAKING BY INDIVIDUALS, HOUSEHOLDS, AND FIRMS

Consumer Behavior: Theory and an Experiment

Yaari (CFDP 155) reexamined the theory of the consumer's lifetime allocation process. In a framework of utility maximization he examined the implications of various assumptions which are commonly made in this area. One of these assumptions is the absence of a "bequest motive." Another is the assumption that planned consumption is proportional to wealth. He showed that if the first of these assumptions is dropped a rise in the rate of interest may depress consumption in all periods, and depress bequests as well, depending on the time-profile of the income stream. He also showed that the second of these assumptions (proportionality of consumption and wealth, even with a changing factor of proportionality over time) has a very restrictive effect on the shape of the utility function.

He also studied (CFDP 156) how a consumer can optimally plan future consumption in view of the fact that he cannot be sure how long he will live to see this future. This question was investigated under the assumption that the consumer makes use of mortality tables. Insurance is then introduced into the picture, and it is observed that, to some extent, this permits the consumer to plan future consumption as if the uncertainty of lifetime did not exist.

In allocation over time, one often encounters problems in which the "choice variable" is a point in infinite-dimensional space. The existence of an optimal choice (in the set of all permissible choices) then becomes a somewhat intricate question. Yaari (in CFDP 158) dealt with this question for a special class of allocation problems, to find conditions for existence of an optimal choice which are relatively simple to apply.

Tobin and Dolbear made a survey (CFP 191), of the frontiers where psychology and economics converge, written by economists and addressed to general psychologists. It attempts to clarify the "utility" assumptions of economic theory, in relation to consumer behavior, business motivation, decisions in uncertain situations, and game strategies. It also discusses the usefulness of psychological or attitudinal measurements in empirical explanations of economic behavior.

Professors Milton Friedman and Leonard J. Savage have argued* that the utility function for wealth is non-concave. If we look upon gambles as points in some vector space, then the Friedman-Savage hypothesis im-

* *Journal of Political Economy*, Aug. 1948.

plies that it is possible for a weighted sum of two gambles each of which is no worse than a given gamble to be actually inferior to the given gamble. Results of experiments by Yaari (CFDP 171) show that preferences with such a property are actually rather rare and, furthermore, that the coexistence of gambling and insurance need not imply such preferences.

Consumer Behavior: Other Empirical Studies

Watts continued his studies of the division of household income between consumption and saving, in particular testing several aspects of Milton Friedman's "permanent income" hypothesis. One implication of the hypothesis is that, apart from temporary variations in consumption and income, consumption is the same constant fraction of income regardless of the absolute level of income. Watts tested this implication on a cross-section of cities and found that a proportional consumption function does not adequately represent household behavior (CFDP 128).

A second implication of the "permanent income" hypothesis is that temporary variations in income do not affect consumption but are wholly absorbed in saving. During a year of leave in Norway (1961–62), Watts tested this proposition against Norwegian budget survey data (CFDP 149). The data provided both two-year and one-month incomes, and one-month expenditures, for 765 households of salaried employees for 1957–58. Thus it was possible to measure transitory income more directly than survey data usually permit. Contrary to the "permanent income" hypothesis, it turned out that consumption was strongly correlated with transitory deviations of one-month incomes from the two-year averages.

Perhaps more important, this correlation was not symmetrical. Positive deviations led to increased consumption in almost the same degree as would be expected from permanent increases in income. But negative deviations were not associated with any appreciable reduction of consumption.

As shown in the diagram on page 31, the consumption function in a particular month (solid curve) has a kink at (Y, C) which is a point on the "permanent" consumption function (dashed line). If total monthly income temporarily exceeds Y, then consumption increases by almost as much as the "permanent" function would indicate. If it temporarily falls short, consumption is reduced only slightly. The point (Y, C) is, of course, variable among households and over time. For example a change in circumstances might prompt a household to revise its estimate of its own permanent income. If permanent income increases to Y', the solid curve shifts upward and to the right along the dashed line until its "kink" is at (Y', C').
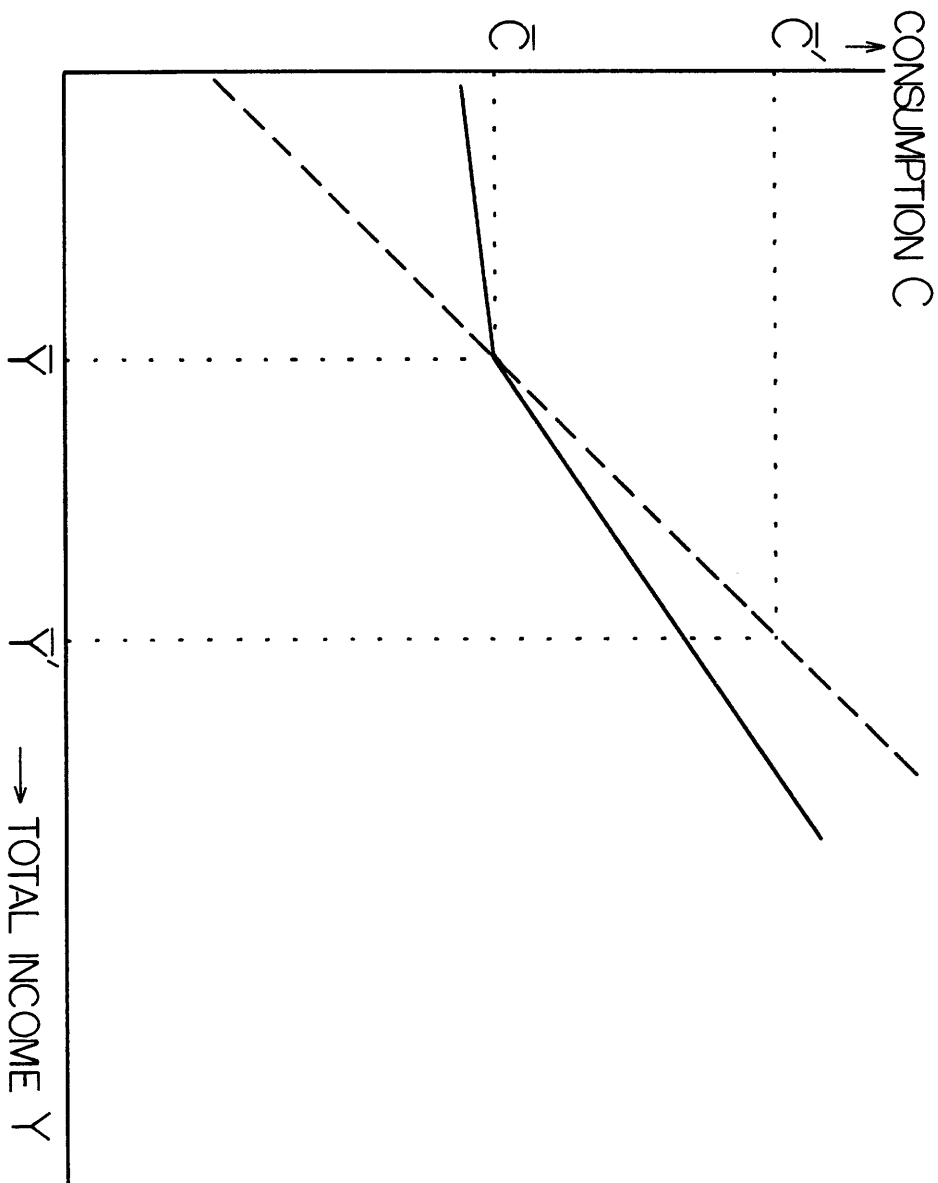
It is quite easy to devise *ex post* explanations of this finding of asymmetry—e.g., persistent habit, upward mobility. It will take further study of more comprehensive data to choose the correct explanation.

Watts will include these two studies, along with others mentioned in the previous research report, in a monograph presenting a coordinated evaluation of the permanent income hypothesis and modifying M. Friedman's theory to make it more consistent with empirical evidence.

Bodkin has also been concerned with the division of transitory income between consumption and saving. In an earlier paper (*American Economic Review,* September, 1959), he analyzed the disposition of 1950 National Service Life Insurance dividends received by veterans who happened to be in the Bureau of Labor Statistics consumer budget survey that year. He concluded that—again contrary to M. Friedman's hypothesis—these windfalls were largely consumed. Subsequent discussion of this finding has led him to refine his original analysis. The results still suggest that a larger proportion of dividend receipts were consumed than the permanent income hypothesis would imply. However, the recipients also appear to have saved more of these windfalls than of similar gains in permanent income. Bodkin will publish the new results in an article written jointly with Roger C. Bird of Lafayette College. In a recent note (A), Bodkin has discussed the apparent inconsistency between his results for American veterans and the findings of Kreinin concerning the disposition of windfall payments in Israel.

Experimental Gaming

During 1963–64 James Friedman worked on two oligopoly experiments. The first experiment was carried out in 1962 and the results are being subjected to additional analysis. The second experiment was planned and carried out during 1963–64.

The first experiment consisted of two sets of oligopoly games. The first set involved only duopolies, while the second set consisted of two- three- and four-person games. In both sets, the model used was sufficiently simple that a payoff matrix afforded a subject all relevant information regarding profits, both to himself and to the other players in his game.

A measure of "cooperativeness" was defined for each subject, of which the value was zero if the player's actions appeared to be motivated by a simple regard for his own profit with no thought for the profit of others. It equalled 1 when he acted as if he were indifferent between a dollar increase in his profits or a dollar increase in his competitors', and —1 if he was motivated solely by the excess of his profit over that of the other players. This measure could assume any value on a scale from —1 to +1,

and it was hypothesized that a player's cooperativeness was a linear function of the mean of the measure of cooperativeness of the others in the game. Data from each player's performance were used, by regression analysis, to estimate for each subject the behavioral equation described above. The results were statistically significant and generally encouraging: Nearly all subjects manifested a willingness to be more cooperative when others are, while doing no more than match the increases in cooperativeness of others.

The second experiment involved duopoly experiments in which the two subjects who each represent a firm in the same industry are able to communicate by sending written messages. They can thus negotiate about what prices to charge and have the opportunity to find a pair of mutually satisfactory prices.

There are two particular divisions of the profits which are interesting: equal profits for both and the profits dictated by the "Nash solution" for noncooperative games. Friedman wanted to see if, and under what circumstances, these two outcomes describe behavior. Also, it was of interest to see if the outcomes satisfy a number of criteria postulated as being reasonable for a division of profits.

During 1963 and 1964 Shubik continued to work on the development of a business game for teaching and experimental purposes. This involved joint work with Richard Levitan, several graduate students and others in the writing of analysis programs and in the running of games to investigate competitive behavior. It appears that in competitive games "large numbers" start at around 7–10 firms.

Shapley and Shubik (CFDP 167) applied several different concepts of solution of an n-person cooperative game to the description and analysis of the single example of several individuals cultivating a single field. Emphasis was laid upon different ownership conditions.

Competitive Bidding

Feeney (CFDP 138) has considered a market in which a number of sellers compete through sealed bids to buyers who always select the lowest bidder so long as the lowest bid does not exceed some maximum acceptable level. The behavior of such markets is of interest both because of their widespread use and practical importance and because they provide an extremely simple but realistic framework within which the general problem of oligopolistic behavior may be studied.

This research departs from previous efforts in ologopoly theory in several respects, particularly in the specification of the decision variables of the

firms and in the description of their competitive intent. Incorporating these departures, the original problem is transformed into a continuous non-constant-sum game possessing a unique non-cooperative (Nash) equilibrium point which may be interpreted as a prediction of the price level that will emerge and the share of business that will be captured by each firm. These predictions are explicit functions of the number of competitors and their individual costs.

The results have been generalized to cover broader market characteristics including: (1) price announcement conventions other than sealed bids, (2) differentiated products, (3) varying degrees of cooperation or competition among the sellers, (4) capacity constraints, and (5) decreasing returns to scale in the cost functions of the sellers.

The analysis of competition has been extended to non-price markets in which competition is realized through such marketing activities as product design differences, advertising, selling effort, physical availability, etc. In addition Feeney has also treated the important special case in which the sales of each firm depend not only upon its current marketing effort but also upon the level of its sales during some prior period. In such markets it is no longer meaningful to treat competitive strategy on a single-stage basis, and static theories of oligopolistic competition are inapplicable. A new approach has been developed which examines competitive strategy as a multi-stage planning problem, and a computational procedure has been devised which yields a solution for any finite planning.

Theory and Econometrics of the Firm

Farrell in the autumn of 1962 embarked on a long-term project for a reformulation of the Theory of the Firm, which should ultimately take into account uncertainty, diversity of objectives, and the forces of natural selection acting upon firms. As a first step, he attempted a more precise formulation of the traditional theories of the firm, which for the most part can be described as rich rather than precise. He set up a theory of a multi-period profit maximizing firm under conditions of certainty, and used this to generate a number of simple theories intended to approximate the traditional theories. The resultant theories, of course, approximate only roughly the traditional theories since they are at once simpler and more rigid; they seem however to provide a more satisfactory basis for further analysis.

Edwin S. Mills (CFDP 123) estimated decision rules which relate price and output decisions in four industries (lumber, cement, tires, shoes) to sales, inventory levels, and other current variables. This research formed

a major part of his book, *Price, Output, and Inventory Policy,* John Wiley & Sons, New York, 1962.

METHODS AND TOOLS

Statistical Tools of Econometric Research

In a study (CFP 185) virtually completed before he joined the staff, Konijn examined some of the estimation problems that occur when estimating regression relations from sample survey data. One of the results is that no consistent estimator of certain regression parameters exists despite the fact that these parameters are identified. This led to further work in this area and Konijn gave other examples of the non-existence of consistent or unbiased estimators for identified parameters (CFDP 144, 145).

Seasonal variation in economic time series may create a number of problems in the estimation of regression models. For this reason a prevalent practice is to seasonally adjust such time series but the criteria by which to make such seasonal adjustments have not usually been stated. In CFP 290 Lovell provides an explicit motivation for the process of seasonal adjustment and employs an axiomatic approach to demonstrate the advantages, in terms of certain consistency requirements, of a regression procedure for seasonal adjustment.

Watts presented (A) some results from his investigation of the methodological problems of econometric studies based on cross-section data of micro-economic units.

Hooper has been concerned with exploring the applicability and relevance of the major techniques of multivariate statistical analysis to economic models. Hooper has been enabled, through a Social Science Research Council Fellowship to devote the year 1964–65 full-time to a systematic study of this topic.

Mathematical Programming

The most efficient computational procedure for the solution of a linear programming problem is the simplex method developed by George Dantzig. The method systematically examines neighboring vertices of the constraint set, until a point is reached where the linear objective function attains a maximum. Much is known about the more general problem of maximizing an arbitrary concave function subject to constraints defining a convex set; the major result, due to Kuhn and Tucker, does in fact specialize to the duality theorem for linear programming. On the other

hand no algorithm comparable in efficiency to the simplex method is known for the general convex programming problem.

There are a number of convex programming problems arising in applied work, in which the objective function is quadratic and the constraints are linear. Portfolio selection is one example, least squares regression with linear inequalities as constraints is another.

If the Kuhn-Tucker theorem, which gives conditions for an optimum for a convex programming problem, is applied to quadratic programming, the resulting inequalities define a convex polyhedron in an enlarged constraint space, and the optimal solution will be found at a vertex of this new polyhedron. On the basis of this observation a number of authors have been concerned with the extension of Dantzig's simplex method to the quadratic programming problem.

Whinston, in a paper written in collaboration with C. E. van de Panne of the Econometric Institute, Rotterdam (A) presents a straight-forward generalization of the simplex and the dual method for linear programming to the case of convex quadratic programming. The two algorithms are applicable when the matrix of the quadratic part of the objective function to be maximized is negative definite or semi-definite. In the case where the quadratic part is zero the two methods are equivalent to the corresponding methods for linear programming. Unlike a previous algorithm of Wolfe no special routine is needed if the quadratic form is semi-definite.

Whinston has also described two special purpose algorithms which incorporate features previously used in linear problems. The first is an algorithm to handle quadratic programming problems where the variables are restricted by numerous upper bounds besides the usual linear constraints. The second extends the decomposition algorithm for linear programming of Dantzig and Wolfe to the quadratic case. The algorithm is suited to handle problems where the constraint matrix of a subset of the rows is decomposable into various submatrices.

In another paper (CFDP 162) Whinston has considered the relationship of conjugate function theory to various topics in nonlinear programming. Geometrically, instead of considering a function as a locus of points, conjugate function theory views it as an intersection of tangent hyperplanes. Based on a theorem relating functions and their conjugates, Whinston developed duality relations between nonlinear programs. Certain theorems relating homogeneous dual systems were also shown to be derivable from this theorem. Other work is in process which generalizes certain symmetric duality theorems originally presented by Dantzig, Eisenberg, and Cottle, and applies these theorems to nonlinear programming and game theory.

GUESTS

The Cowles Foundation is pleased to have as guests scholars and advanced students from other research centers in this country and abroad. Their presence contributes stimulation and criticism to 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 visited or were associated with the organization in this manner during the past three years.

KARL H. BORCH (Norwegian School of Economics, Bergen, Norway). Visited in November 1961.

ALPHA C. CHIANG (Denison University, Granville, Ohio). September 1963–June 1964. Visit sponsored by the National Science Foundation.

M. M. GOLANSKII (Laboratory of Economical-Mathematical Methods of the Academy of Sciences of the U.S.S.R., Moscow). May, July, August 1962. Visit sponsored by the American Council of Learned Societies.

TORE JOHANSEN (Institute of Economics of the University of Oslo, Norway). September 1961–August 1962. Sponsored by the Rockefeller Foundation.

BERTIL NASLUND (Stockholm School of Economics, Sweden). November-December 1961. Visit sponsored by the Stockholm School of Economics.

GERARD F. W. M. PIKKEMAAT (Catholic School of Economics, Tilburg, The Netherlands). September 1963–April 1964. Visit sponsored by The Netherlands Organization for the Advancement of Pure Research.

ROBERT SHAPIRO (University of Pennsylvania, Philadelphia, Pennsylvania). September 1963–August 1964. Visit sponsored by Social Science Research Council.

NOBORU TAKAMOTO (Kansai University, Osaka, Japan). July-October 1963. Visit sponsored by Kansai University.

KARL D. VIND (Statistical Institute of the University of Copenhagen, Denmark). January 1963. Visit sponsored by the Rockefeller Foundation.

COWLES FOUNDATION SEMINARS

July 1, 1961–June 30, 1964

1961

October 2. HERBERT SCARF, Stanford University, "Game Theory and Economic Equilibrium."

October 30. KARL BORCH, The Norwegian School of Economics and Business Administration, "Uncertainty and Market Equilibrium."

November 13. STEPHEN A. MARGLIN, Harvard University, "The Social Rate of Discount and the Opportunity Costs of Public Investment."

November 30. JUERG M. NIEHANS, Johns Hopkins University and the University of Zurich, "Interest Rates in an Open Economy: The Swiss Case."

1962

February 15. HAROLD W. KUHN, Princeton University, "Remarks on the Turnpike Theorem."

February 26. DALE JORGENSON, University of California, "Capital Theory and Investment Behavior."

March 12. ALBERT ANDO, Massachusetts Institute of Technology, "An Empirical Model of the U.S. Economic Growth: An Exploratory Study in Applied Capital Theory."

April 9. FRANKLIN FISHER, Massachusetts Institute of Technology, "Decomposability, Near-Decomposability, and Balanced Growth under Constant Returns to Scale."

April 30. JOHN F. MUTH, Carnegie Institute of Technology, "Stochastic Equilibrium and Dynamic Stability."

May 10. HIROFUMI UZAWA, Stanford University, "Topics Related to the Problem of Economic Growth."

November 2. ROBERT DORFMAN, Harvard University, "Economic Interpretation of Nonlinear Programming and an Application."

November 30. KELVIN LANCASTER, Johns Hopkins University, "The Analysis of the Economy as a System."

1963

February 8. ROBERT P. ABELSON, Yale University, "A Psychologist Looks at Subjective Probability and Utility."

February 28. A. W. PHILLIPS, Massachusetts Institute of Technology and the London School of Economics, "Objectives of Economic Policy."

April 5. EDWARD F. DENISON, The Brookings Institution, "Sources of Economic Growth."

April 19. MARSHALL KOLIN, Harvard University, "Tests of Alternative Specifications of the Budget Constraint in Models of the Economic Behavior of the Household Sector."

May 10. LOUIS LEFEBER, Massachusetts Institute of Technology, "A Dynamic Model of Regional and National Economic Development."

November 21. PHILIP WOLFE, The RAND Corporation, "On the Theory of Quadratic Programming," (Joint Seminar, with Department of Statistics and Department of Industrial Administration).

December 20. JACQUES DRÈZE, University of Chicago and the University of Louvain, "Bayesian Estimation of Simultaneous Equations," (Joint Seminar, with Department of Statistics).

1964

January 7. ANDREW WHINSTON, Yale University, "Research in Quadratic Programming," (Joint Seminar, with Department of Industrial Administration).

January 17. EDWIN MANSFIELD, University of Pennsylvania and Harvard University, "Returns from Industrial Research, Rates of Technical Change, and the Effects of Concentration on Technology Levels."

January 24. JAN SANDEE, Massachusetts Institute of Technology and the Central Planning Bureau of The Netherlands, "A Long-term Planning Model for The Netherlands."

February 4. MARTIN SHUBIK, Yale University, "Experimental Gaming," (Joint Seminar, with Department of Industrial Administration).

March 26. RICHARD LIPSEY, University of California, "Inflation and Economic Growth: The Post-War Experience in Britain."

April 7. FRANKLIN M. FISHER, Massachusetts Institute of Technology, "On the Supply Curve of Petroleum Discoveries."

April 17. JAMES S. DUESENBERRY, Harvard University, "The SSRC Econometric Model."

May 1. CLOPPER ALMON, Harvard University, "A Convergent Method of Predicting Investment Requirements and its Application of Forecasting the American Economy in 1970."

May 29. MARTIN McGUIRE, Harvard University, "Economic Models of Arms Races and the Role of Information."

YALE MANAGEMENT SEMINARS

1961–1963

These seminars, aimed at promoting knowledge in the management sciences, have been sponsored jointly by the Department of Industrial Administration and the Cowles Foundation until May, 1963. The meetings have served as a medium for the two-way exchange of ideas between members of the Yale academic community and management people in Connecticut industries.

1961

November 27. RALPH E. GOMORY, IBM Research Center, "Large and Non-Convex Linear Programming Problems."

December 11. GEOFFREY CLARKSON, Princeton University, "A Model of Trust Investment Behavior."

1962

January 15. PETER R. WINTERS, Carnegie Institute of Technology, "Constrained Inventory Rules for Production Smoothing."

February 5. STUART DREYFUS, Massachusetts Institute of Technology, "Dynamic Programming and Modern Control Theory."

April 2. ANDREW STEDRY, Massachusetts Institute of Technology, "Explorations In the Theory of Budget Control."

April 16. K. S. KRETSCHMER, General Electric Company, "Contributions to Discriminant Analysis."

May 1. CHRIS ARGYRIS, Yale University, "Research in Organizational Effectiveness."

November 12. MARTIN GREENBERGER, Massachusetts Institute of Technology, "Management, Automation, and the Computer of the Future."

December 3. MYRON J. GORDON, University of Rochester, "Joint Factors, Joint Products, and the Optimal Use of Standard Cost Systems."

1963

February 4. SALAH E. ELMAGHRABY, Yale University, "Theory of Networks and Management Systems."

March 4. HAROLD W. KUHN, Princeton University, "On Graph Theory in Management: The History of a Problem."

April 8. DONALD IGLEHART, Cornell University, "Some Properties of Optimal Policies for Dynamic Inventory Problems."

May 6. MARSHALL K. WOOD, National Planning Association, "PARM—A Detailed Model of the U.S. Economy."

LIBRARY OF THE COWLES FOUNDATION

Kathryn M. Benedict, *Librarian*

The principal goal of the Cowles Foundation Library is to make readily accessible to staff members important past and current literature in economics, especially quantitative economics, and related works in mathematics and statistics. The library is also used by other members of the Department of Economics and by graduate students.

The library collection includes some 4,450 books, 170 journals, thousands of pamphlets, and a rotating collection of recent unpublished material. About 650 of the books were acquired during the three-year period covered by this report. These can be divided by subject into the following categories: economics, 64%; collections of statistical data, 7%; statistical theory, 6%; mathematics, 14%; reference books, 4%; all others, 5%. Current books, ordered shortly after their publication, accounted for 90% of the new acquisitions.

Books circulate for a period of one month and journals overnight. They may be renewed by staff members only. Some 300 books which are in demand for graduate economics courses are kept on reserve, circulating overnight and weekends only.

MONOGRAPHS

1934–1964*

The monographs of the Cowles Commission (Nos. 1–15) and Cowles Foundation (Nos. 16–18) are listed below:

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. Monthly indexes of stock prices, stock prices adjusted for reinvestment of cash dividends, and yield expectations; and annual indexes of yields, divided 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.

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. The modern theory of economic equilibrium (as stated by J. R. Hicks and others) applied to an important field. (Out of print.)

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 depression 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.

No. 10. *Statistical Inference in Dynamic Economic Models,* edited by TJALLING 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, 4, and 8 should be sent to Principia Press of Trinity University, 715 Stadium Drive, San Antonio, Texas. Orders for subsequent monographs should be sent to John Wiley and Sons, 605 Third Avenue, New York City. Prices are subject to change.

No. 12. *Social Choice and Individual Values,* Second Edition, by KENNETH J. ARROW. 1963. 124 pages. Price $4.50. Presents the original text on the theory of social choice with an appended commentary containing a series of reflections on the text and on some of the more recent literature.

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 WILLIAM 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.

No. 16. *Portfolio Selection, Efficient Diversification of Investments,* by HARRY M. MARKOWITZ. 1959. 344 pages. Price $7.50. Presents methods for translating anticipations about future yields of securities, and about their interrelations, into investment decisions that give minimum expected risk for given expected return.

No. 17. *Theory of Value, An Axiomatic Analysis of Economic Equilibrium,* by GERARD DEBREU. 1959. 114 pages. Price $4.75. A rigorous presentation of the theories of producers' behavior, consumers' behavior, Walrasian equilibrium, Paretian optimum, and of their extensions to uncertainty.

No. 18. *Studies in Process Analysis: Economy-Wide Production Capabilities,* edited by ALAN S. MANNE and HARRY M. MARKOWITZ. 1963. 427 pages. Price $14.00. Methods for estimating the production capabilities of an economy or an industry, using engineering information and mathematical programming techniques. Applications to petroleum, chemical, metal and metalworking industries, to agriculture, and to economic development. Includes spatial aspects of production.

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 FOUNDATION PAPERS

July 1, 1961–June 30, 1964

*No. 166. MARTIN J. BECKMANN, "Production Smoothing and Inventory Control," *Operations Research,* Vol. 9, No. 4, July-August 1961.

*No. 167. ALAN S. MANNE, "Comments on INTERINDUSTRY ECONOMICS," *Naval Research Logistics Quarterly,* Vol. 7, No. 4, December 1960.

*No. 168. RICHARD C. PORTER, "A Model of Bank Portfolio Selection," *Yale Economic Essays,* Vol. 1, No. 2, 1961.

*No. 169. MICHAEL C. LOVELL, "Manufacturers' Inventories, Sales Expectations, and the Acceleration Principle," *Econometrica,* Vol. 29, No. 3, July 1961.

*No. 170. MARTIN SHUBIK, "Some Experimental Non-Zero Sum Games With Lack of Information About the Rules," *Management Science,* Vol. 8, No. 2, January 1962.

*No. 171. JOHN W. HOOPER and ARNOLD ZELLNER, "The Error of Forecast for Multivariate Regression Models," *Econometrica,* Vol. 29, No. 4, October 1961.

*No. 172. ALAN S. MANNE, "Capacity Expansion and Probabilistic Growth," *Econometrica,* Vol. 29, No. 4, October 1961.

*No. 173. JOHN C. HARSANYI, "Bargaining in Ignorance of the Opponent's Utility Function," *The Journal of Conflict Resolution,* Vol. 6, No. 1, March 1962.

*No. 174. WALTER D. FISHER, "Estimation in the Linear Decision Model," *International Economic Review,* Vol. 3, No. 1, January 1962.

*No. 175. ALAN S. MANNE, "Product-Mix Alternatives: Flood Control, Electric Power, and Irrigation," *International Economic Review,* Vol. 3, No. 1, January 1962.

*No. 176. DONALD D. HESTER, "An Empirical Examination of a Commercial Bank Loan Offer Function," *Yale Economic Essays,* Vol. 2, No. 1, 1962.

No. 177. THIRUKODIKAVAL N. SRINIVASAN, "Investment Criteria and Choice of Techniques of Production," *Yale Economic Essays,* Vol. 2, No. 1, 1962.

*No. 178. MARTIN SHUBIK, "Incentives, Decentralized Control, the Assignment of Joint Costs and Internal Pricing," *Management Science,* Vol. 8, No. 3, April 1962.

*No. 179. MICHAEL C. LOVELL, "Buffer Stocks, Sales Expectations, and Stability: A Multi-Sector Analysis of the Inventory Cycle," *Econometrica,* Vol. 30, No. 2, April 1962.

*No. 180. LAWRENCE B. KRAUSE, "United States Imports, 1947–1958," *Econometrica,* Vol. 30, No. 2, April 1962.

*No. 181. PHOEBUS J. DHRYMES, "On Devising Unbiased Estimates for the Parameters of the Cobb-Douglas Production Function," *Econometrica,* Vol. 30, No. 2, April 1962.

*No. 182. JOHN W. HOOPER, "Partial Trace Correlations," *Econometrica,* Vol. 30, No. 2, April 1962.

*No. 183. A. D. BAIN, "The Growth of Television Ownership in the United Kingdom," *International Economic Review,* Vol. 3, No. 2, May 1962.

No. 184. ROY RADNER, "Team Decision Problems," *The Annals of Mathematical Statistics,* Vol. 33, No. 3, September 1962.

*No. 185. H. S. KONIJN, "Regression Analysis in Sample Surveys," *Journal of the American Statistical Association,* Vol. 57, September 1962.

*No. 186. GERARD DEBREU, "New Concepts and Techniques for Equilibrium Analysis," *International Economic Review,* Vol. 3, No. 3, September 1962.

*Single copies available on request.

*No. 187.   EDWIN MANSFIELD, "Entry, Gibrat's Law, Innovation, and the Growth of Firms," *American Economic Review*, Vol. 52, No. 5, December 1962.

*No. 188.   EDMUND S. PHELPS, "The New View of Investment: A Neoclassical Analysis," *The Quarterly Journal of Economics*, Vol. 76, November 1962.

*No. 189.   LAWRENCE B. KRAUSE, "Import Discipline: The Case of the United States Steel Industry," *The Journal of Industrial Economics*, Vol. 11, No. 1.

No. 190.   ARTHUR M. OKUN, "Potential GNP: Its Measurement and Significance," *Proceedings of the Business and Economic Statistics Section of the American Statistical Association*, 1962.

No. 191.   JAMES TOBIN and F. TRENERY DOLBEAR, JR., "Comments on the Relevance of Psychology to Economic Theory and Research," *PSYCHOLOGY: A Study of a Science*, Vol. 6, Edited by SIGMUND KOCH, McGraw-Hill Book Company, Inc., New York, 1963.

*No. 192.   EDMUND S. PHELPS, "The Accumulation of Risky Capital: A Sequential Utility Analysis," *Econometrica*, Vol. 30, No. 4, October 1962.

*No. 193.   HAROLD W. GUTHRIE, "Intergeneration Transfers of Wealth and the Theory of Saving," *The Journal of Business of the University of Chicago*, Vol. 36, No. 1, 1963.

*No. 194.   JAMES TOBIN and WILLIAM C. BRAINARD, "Financial Intermediaries and the Effectiveness of Monetary Controls," *The American Economic Review*, Vol. 53, No. 2, 1963.

*No. 195.   JAMES TOBIN, "An Essay on the Principles of Debt Management," from *Fiscal and Debt Management Policies*, Commission on Money and Credit, 1963.

*No. 196.   A. D. BAIN, "The Growth of Demand for New Commodities," *Journal of the Royal Statistical Society*, Series A, 1963.

No. 197.   ARTHUR M. OKUN, "COMMENT ON Friedman's and Schwartz's 'Money and Business Cycles'," *The Review of Economics and Statistics*, Vol. 45, No. 1, Part 2 Supplement. 1963.

*No. 198.   MICHAEL C. LOVELL, "A Keynesian Analysis of Forced Saving," *International Economic Review*, Vol. 4, No. 3, 1963.

*No. 199.   EDMUND S. PHELPS, "Substitution, Fixed Proportions, Growth and Distribution," *International Economic Review*, Vol. 4, No. 3, 1963.

No. 200.   GERARD DEBREU and HERBERT SCARF, "A Limit Theorem on the Core of an Economy," *International Economic Review*, Vol. 4, No. 3, 1963.

*No. 201.   HAROLD W. GUTHRIE, "Demand for Tourists' Goods and Services in a World Market," *Papers and Proceedings of the Regional Science Association*, Vol. 7, 1961.

*No. 202.   ARTHUR M. OKUN, "Investment Demand at Full Employment," 1963 *Proceedings of the Business and Economic Statistics Section of the American Statistical Association*.

*No. 203.   GERARD DEBREU, "On a Theorem of Scarf," *Review of Economic Studies*, Vol. 30, No. 3, 1963.

*No. 204.   EMMANUEL M. DRANDAKIS, "Factor Substitution in the Two-Sector Growth Model," *Review of Economic Studies*, Vol. 30, No. 3, 1963.

*No. 205.   JAMES TOBIN, "Commercial Banks as Creators of 'Money'," *Banking and Monetary Studies*, edited by Deane Carson, for the Comptroller of the Currency, U.S. Treasury, Richard D. Irwin, Inc., Homewood, Illinois, 1963.

*No. 206.   EDWIN MANSFIELD, "Intrafirm Rates of Diffusion of an Innovation," *The Review of Economics and Statistics*, Vol. 45, No. 4, 1963.

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*Single copies available on request.

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*No. 210. ARTHUR M. OKUN, "Monetary Policy, Debt Management and Interest Rates: A Quantitative Appraisal," from *Stabilization Policies,* prepared for the Commission on Money and Credit, 1963.

*Single copies available on request.

COWLES COMMISSION NEW SERIES PAPERS
AND COWLES FOUNDATION PAPERS

To June 30, 1961

Single copies of the following articles are available on request; others, listed in previous research reports, are in short supply or exhausted, but can be referred to in the journals in which they appeared.

ALFRED COWLES and HERBERT E. JONES, "Some A Posteriori Probabilities in Stock Market Action," *Econometrica,* Vol. 5, No. 3, July 1937.

No. 45. GERARD DEBREU, "The Coefficient of Resource Utilization," *Econometrica,* Vol. 19, No. 3, July 1951.

No. 56. GEORGE H. BORTS, "Production Relations in the Railway Industry," *Econometrica,* Vol. 20, No. 1, January 1952.

No. 57. HARRY MARKOWITZ, "The Utility of Wealth," *Journal of Political Economy,* Vol. 60, No. 2, April 1952.

No. 63. ERLING SVERDRUP, "Weight Functions and Minimax Procedures in the Theory of Statistical Inference," *Archiv for Mathematik og Naturvidenskab,* Vol. 51, No. 7, 1952.

No. 68. CLIFFORD HILDRETH, "Alternative Conditions for Social Orderings," *Econometrica,* Vol. 21, No. 1, January 1953.

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. 3, June 1953; LIONEL W. MCKENZIE, "Specialization and Efficiency in World Production," *Review of Economic Studies,* Vol. 21, No. 56, June 1954.

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, No. 3, July 1953.

No. 77. KENNETH J. ARROW, "Le Role des Valeurs Boursiers pour la Repartition la Meilleure des Risques," *International Colloquium on Econometrics,* 1952. Paris: Centre National de la Recherche Scientifique, 1953.

No. 79. JOHN GURLAND, "Distribution of Quadratic Forms and Ratios of Quadratic Forms," *Annals of Mathematical Statistics,* Vol. 24, No. 3, September 1953.

No. 80. GERARD DEBREU, "A Classical Tax-Subsidy Problem," *Econometrica,* Vol. 22, No. 1, January 1954.

No. 81. JOHN S. CHIPMAN, "A Note on Stability, Workability, and Duality in Linear Economic Models," *Metroeconomica,* Vol. 6, No. 1, April 1954.

No. 83. GERARD DEBREU, "Numerical Representations of Technological Change," *Metroeconomica,* Vol. 6, No. 2, August 1954.

No. 85. JOHN GURLAND, "An Example of Autocorrelated Disturbances in Linear Regression," *Econometrica,* Vol. 22, No. 2, April 1954.

No. 86. S. G. ALLEN, "Inventory Fluctuations in Flaxseed and Linseed Oil, 1926–1939," *Econometrica,* Vol. 22, No. 3, July 1954.

No. 88. CLIFFORD HILDRETH, "Point Estimates of Ordinates of Concave Functions," *Journal of the American Statistical Association,* Vol. 49, September 1954.

No. 89. HERBERT A. SIMON, "Spurious Correlation: A Causal Interpretation," *Journal of the American Statistical Association,* Vol. 49, September 1954.

No. 90. KENNETH J. ARROW, "Import Substitution in Leontief Models," *Econometrica,* Vol. 22, No. 4, October 1954.

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132 EDWIN MANSFIELD, Intrafirm Rates of Diffusion of an Innovation.

133 EDMUND S. PHELPS, Substitution, Fixed Proportions, Growth and Distribution.

134 EDWIN MANSFIELD, The Speed of Response of Firms to New Techniques.

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