

**REPORT *of***  
**RESEARCH ACTIVITIES**

*July 1, 1973 – June 30, 1976*

**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, is intended to sponsor and encourage the development and application of quantitative methods in economics and related social sciences. 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. At that time, the professional research staff of the Commission accepted appointments at Yale and, along with other members of the Yale Department of Economics, formed the research staff of the newly established Cowles Foundation. The members of the professional staff typically have faculty appointments and teaching responsibilities in the Department of Economics or other departments at Yale University.*

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\*As of June 30, 1976.

\*\*During a part of, or the entire period, July 1, 1973 - June 30, 1976.

Note: For a list of GUESTS, see page 40.

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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:

CFP: Cowles Foundation Papers (see p. 49)

CFDP: Cowles Foundation Discussion Papers (see p. 51)

*Monographs* (see p. 46) are referred to by number.

*Other publications* of each staff member are designated by letter in the list on pp. 55-58 and are referred to by author and title in the text.

## RESEARCH ACTIVITIES JULY 1, 1973 – JUNE 30, 1976

### INTRODUCTION

The Cowles Commission for Research in Economics was founded approximately forty years ago by Alfred Cowles, in collaboration with a group of economists and mathematicians concerned with the application of quantitative techniques to economics and the related social sciences. This methodological interest was continued with remarkable persistence during the early phase at Colorado Springs, then at the University of Chicago, and since 1955 at Yale.

One of the major interests at Colorado Springs was in the analysis of economic data by statistical methods of greater power and refinement than those previously used in economics. This was motivated largely by a desire to understand the chaotic behavior of certain aspects of the American economy – the stock market in particular – during the Depression years. The interest in statistical methodology was continued during the Chicago period with a growing appreciation of the unique character and difficulties of statistical problems arising in economics. An important use of this work was made in the description of the dynamic characteristics of the U.S. economy by a system of statistically estimated equations.

At the same time, the econometric work at Chicago was accompanied by the development of a second group of interests explicitly mathematical but not related to econometric estimation. The activity analysis formulation of production and its relationship to the expanding body of techniques in linear programming became a major focus of research. The Walrasian model of competitive behavior was examined with a new generality and precision, in the midst of an increased concern with the study of interdependent economic units, and in the context of a modern reformulation of welfare theory.

The move to Yale in 1955 coincided with a renewed emphasis on empirical applications in a variety of fields. The description of economic growth, the behavior of financial intermediaries, and the embedding of monetary theory in a general equilibrium formulation of asset markets were studied both theoretically and with a concern for the implications of the theory for economic policy. Earlier work on activity analysis and the general equilibrium model was extended as was early work on social choice in non-market contexts such as voting. Analysis of the optimization of resource allocation was extended to consider optimization over time. Along with the profession at large, we have engaged in the development of analytical methods oriented to contemporary social and economic problems, in particular the specifics of

income distribution, the economics of exhaustible resources, and the dynamics of inflation.

For the purposes of this report it is convenient to categorize the research activities undertaken at Cowles during the last three years in the following way:

- A. Descriptive and Optimal Growth Theory
- B. General Equilibrium Analysis and Game Theory
- C. Microeconomics of Information
- D. Macroeconomics and Monetary Economics: Theory and Policy
- E. Econometrics
- F. Public Sector

#### *A. Descriptive and Optimal Growth Theory*

In a lecture given at Stockholm, Sweden, on December 11, 1975 (CFDP 421), Koopmans has summarized his research over the last 25 years on the optimal allocation of resources. The lecture, entitled "Concepts of Optimality and Their Uses," consists of three parts. The first part deals with the early developments in mathematical programming and activity (or process) analysis up to about 1960. It reviews the parallel contributions, made in part independently and in part in interaction by Dantzig, Kantorovich, Koopmans and others. It also links these developments with earlier ideas in economics and in mathematics.

The second part deals with the best allocation of resources over time, and draws its illustrations mostly from Koopmans' own contributions to that field since about 1955. It also contains some observations on the choice of an optimality criterion when population growth is directly or indirectly affected by policy — observations previously made only in a discussion at the World Congress of the Econometric Society in Toronto, August 20-26, 1975. The third and briefest part indicates how the two strands of thought, process analysis and optimal growth theory, find joint application in the growing field of "development programming."

During the period of this report, Koopmans has continued his exploration of the concept of an invariant capital stock described in the previous report. This is a capital stock of a size and composition such that, in equilibrium, discounted utilities from future consumption would require preserving that stock, as long as the given technology, resource base and consumers' preferences are expected to remain constant for the indefinite future. In a paper (CFDP 408), presented at a Conference of the International Economic Association on "The Microeconomic Foundation of Macroeconomics," held in s'Agaro, Spain, in April 1975, he worked out an example involving one capital good, one resource (labor), two consumption goods, and three production processes. It was shown that an interesting anomaly may arise if the



consumption good that is least capital-intensive in its production is at the same time an inferior good – that is, its consumption decreases as real income increases while relative prices remain the same. The possible anomaly is depicted in Figure 1. For intertemporal consumers' preferences represented by an annual discount rate for utility between 0 and some largest value  $\bar{\delta}$ , the capital stock  $\bar{z}$  capable of employing all labor in producing only the superior good (and reproducing that stock) is an invariant capital stock. But, for all discount rates above some smallest rate  $\underline{\delta}$ , which is located somewhere between 0 and  $\bar{\delta}$ , the smaller capital stock  $\underline{z}$  needed to employ all labor in producing only the inferior good (and in reproducing that stock), is also an invariant stock. For any  $\delta$  between  $\bar{\delta}$  and  $\underline{\delta}$ , there is a third invariant capital stock of an intermediate size  $z(\delta)$  that depends on  $\delta$ . This stock is sufficient to reproduce itself and to produce a combination of the two consumption goods. It was proved by Iwai that the intermediate stock  $z(\delta)$  is unstable (for all  $\delta$  between  $\underline{\delta}$  and  $\bar{\delta}$ ) in the sense that starting from a slightly larger initial stock, optimization over time will require the capital stock to increase and ultimately to approach  $\bar{z}$ , while a slightly smaller initial stock will lead to a decrease down to  $\underline{z}$ . Both  $\bar{z}$  and  $\underline{z}$  are stable for all such  $\delta$ ,  $\bar{z}$  for all lower ones as well, and  $\underline{z}$  for all higher ones. This is illustrated in Figure 1. The example raises the question whether this type of instability can occur with many more capital goods and consumption goods.

During the calendar year 1974, Koopmans was on leave from Yale at the recently created International Institute for Applied Systems Analysis in Laxenburg, near Vienna, Austria. While there, he gave some lectures on the ideas of optimal growth theory as they bear on long run problems of energy, of ecology and of water resources. He also served as leader of the methodology project for part of the period. In the summer of 1975, he returned for a few weeks as chairman of a two-week workshop on the Analysis and Computation of Equilibria and Regions of Stability with Applications in Chemistry, Climatology, Ecology and Economics.

Some of the questions that Koopmans considered at IIASA are related to more empirically oriented work by Nordhaus. A major effort Nordhaus has been engaged in over the last three years is modelling energy and natural resource systems. The first work in the area was a theoretical investigation of problems in resource markets ("Markets and Appropriable Resources"), published in abbreviated form in *Energy: Demand, Conservation and Institutional Problems* (M.S. Maccrakis, ed.). This examined the allocation of appropriable exhaustible resources, and concluded that there could be inefficiencies in their allocation in the absence of a full set of futures markets. The study suggested that there are no general results, however, and that a determination of whether the rate of exhaustion is too high or too low can only come from economic analysis of individual markets.

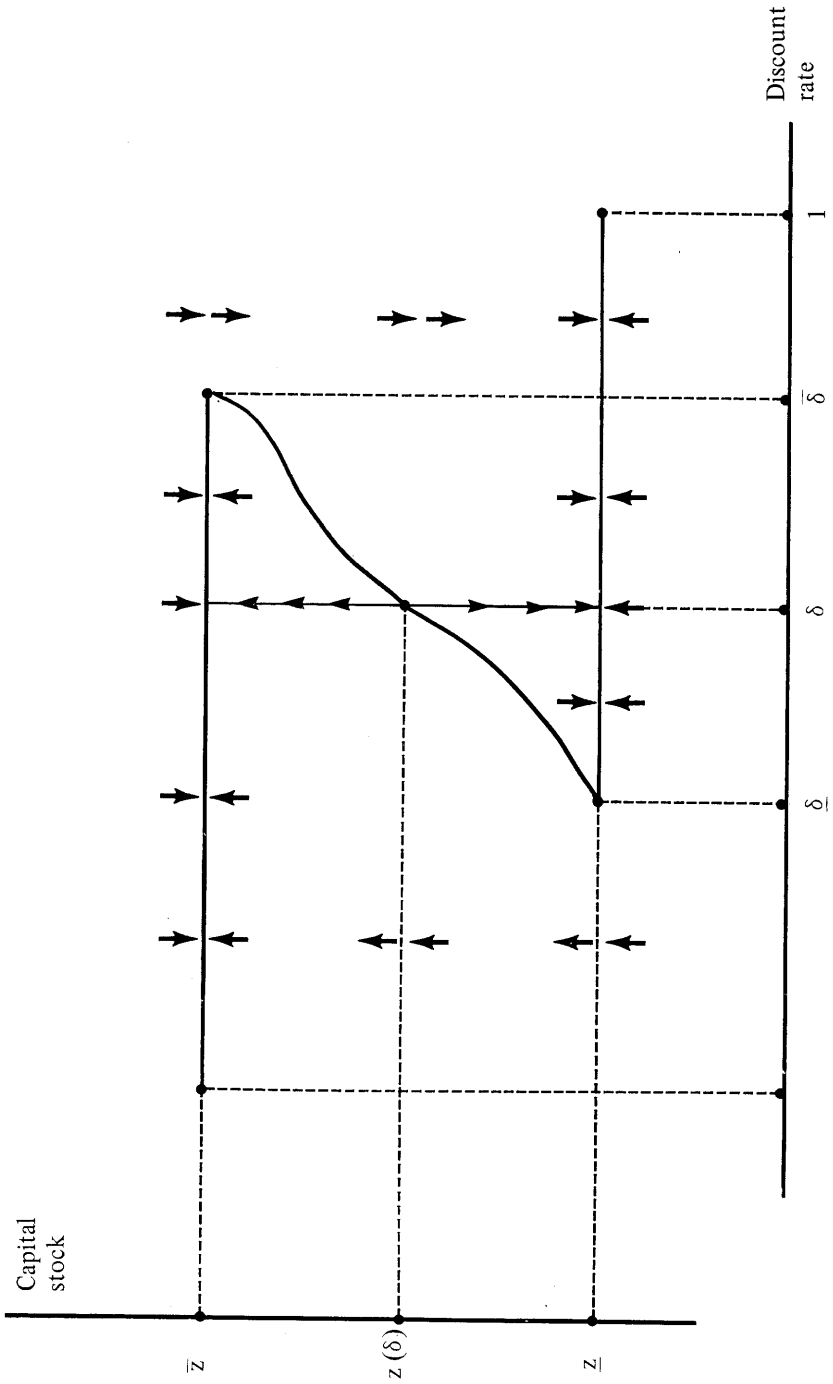


FIGURE 1

Given this conclusion, Nordhaus turned to an examination of the energy market as the best case study of the problem of exhaustion of natural resources. In CFP 401, he presented the results of a preliminary empirical study of the efficiency of the allocation of energy resources. The study is based on a model of energy use which takes account of the costs and availability of alternative energy sources, both now and in the future, as well as demand functions for different energy demand categories. Using linear programming, the model derives the efficient path for allocation of energy resources over the indefinite future; this is the path that would emerge through time in a free competitive market. The technological assumptions in the model are based almost completely on econometric and engineering estimates, and are as realistic as possible.

The results are as follows: Some types of energy are virtually free gifts of nature to mankind, involving very low labor and capital costs, but these are limited in supply and not renewable. In an efficient allocation, such low-cost sources of energy are used first; as they are exhausted, the price of energy rises. In a competitive market, the owner of a low-cost energy source such as a rich field of oil, balances the decision to sell at today's price (and invest the proceeds) against the alternative of keeping his product in the ground and waiting for prices to rise. This assessment determines prices and quantities at all points in time, and generates a rising trend in prices and royalties to the owners of energy resources.

As the fuels of today move up in price, alternative sources of energy — tomorrow's fuels — become profitable alternatives. The world economy gradually makes transitions from the lowest-cost sources to the next least expensive fuel and ultimately to technologies that require much capital and labor but are less dependent on scarce, depletable natural resources. The calculations of the model predict a movement from today's heavy reliance on petroleum and natural gas to deep-mined coal, gasified and liquefied coal, shale oil, and nuclear power during the century ahead. In the model it is assumed that a "backstop technology" exists, or will come into being, that provides a virtually infinite energy source but at a relatively high price because of high capital costs. In the limit of the calculations, reached in the twenty-second century, this "backstop technology" supplies almost all of the world's energy needs.

The basic model assumes a world with free international trade and competition in energy. For comparison, Nordhaus explored the case in which the United States achieves complete self-sufficiency in energy sources.

The total cost of meeting energy demand over the next twenty years is about fifty percent higher in this case than with free trade — an added average annual cost of energy of \$16 billion.

Since the initial model was published, several extensions and applications have been made. First, the model was used in a more general examination of

the role of resources as a retarding factor in economic growth (CFP 406, and "Energy and Economic Growth," forthcoming). These further studies speculate on the role of resources in general and energy in particular in the process of economic growth over the next several decades.

More technical applications were pursued by Nordhaus while he also spent a year (1974-75) at IIASA. These were a more detailed examination of the nuclear fuel cycle ("Notes on Inclusion of Nuclear Fuel Cycles," unpublished) and examination of the link between energy systems and climate ("Can We Control Carbon Dioxide?," IIASA working paper, 1975). The former study was undertaken in collaboration with Prof. A. Suzuki of Tokyo University while both authors were at IIASA. This study integrates a more realistic fuel cycle into the original model. The Suzuki-Nordhaus model includes five of the major alternative fuel cycles in the available technology. One of the important results of this analysis will be estimation of a price path for energy resources produced by man (plutonium and  $U^{233}$ ). The second application of the model was to consider the interaction of the energy system with climate through the role of atmospheric carbon dioxide.

One final spinoff of the original work was a project investigating energy demand functions. Because Nordhaus felt the original assumptions were somewhat crude, he initiated, at IIASA, a project of estimating energy demand functions for a number of countries. The project consisted of gathering data for different fuels in three sectors and ten large OECD countries. Preliminary results were presented in CFP 405.

Beyond the formal publications over the last three years, Koopmans and Nordhaus have participated in a number of workshops and conferences, and (together with Heal) twice given a Workshop on Economic Models of Resources at Yale University. This workshop has been primarily oriented toward research, and a number of excellent student papers have emerged.

Further work on resources was done by Heal during his visit to Cowles in the Fall of 1975. This followed up some of his earlier theoretical work on the economics of exhaustible resources (some of which was done during an earlier visit) with an empirical study of the determinants of resource prices. In recent years, there have been many analyses of the rate of resource depletion, some concerned with analyzing the optimal depletion rate and others focussed on analyzing the market determined rate. In CFP 407, Heal applied these theories to an empirical study of three crude commodity markets, copper, zinc and lead. After extensive examination of different specifications, he concluded that these three resource prices are systematically related to interest rates, output, and their own past behavior. A puzzling finding is that resource demand seems to depend not only on the rate of change of the resource price, but also on its level. This is inconsistent with earlier work on resource pricing.

### B. General Equilibrium Analysis and Game Theory

A number of members of the Cowles staff are actively engaged in the study of general equilibrium models. Some of this work is concerned with analysis of the Walrasian model and its generalizations, including research on efficient means of computing competitive equilibria and analysis of purely competitive economies where the number of consumers is large. Other work is concerned with game theoretic formulations of general equilibria. Extensions of these lines of research are currently underway dealing with such difficult problems as indivisibilities, increasing returns to scale, aggregative properties of competitive equilibria and explicit incorporation of price adjustment mechanisms.

Continuing beyond the development of computational methods described in the Cowles Foundation monograph *The Computation of Economic Equilibria* by Scarf with Hansen, Scarf and others have further investigated computational algorithms. A major mathematical paper on computation by Scarf and Eaves (of Stanford University, who visited Cowles in 1974-75) demonstrates the use of piecewise linear techniques and shows that virtually all of the fixed point computational methods which have been developed over the past decade can be placed in this framework. It is expected that these techniques will prove to be of considerable importance in the future for the numerical solution of large economic models.

In this paper, "The Solution of Systems of Piecewise Linear Equations" (CFDP 390), Eaves and Scarf studied the solution of systems of piecewise linear equations involving one more variable than the number of equations. It considers a set  $P$  in  $(n+1)$  dimensional space which is the union of a finite number of convex polyhedra, each of which has a non-empty interior, and no two of which have interior points in common. A mapping  $F$  is given, which takes the point of  $P$  into a Euclidean space of one lower dimension. The

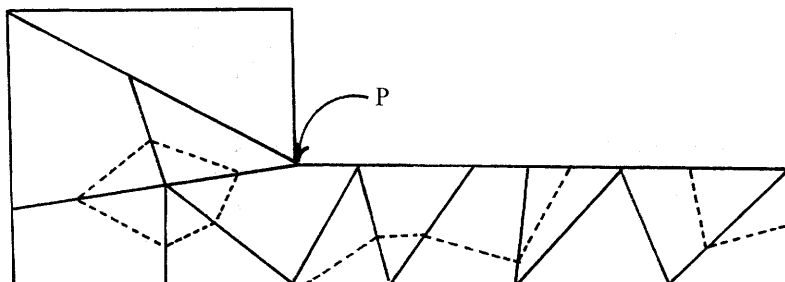


FIGURE 2

mapping is completely general aside from the conditions that it be continuous in  $P$  and linear in each piece of linearity. The system of piecewise linear equations referred to in the title of the paper arises from the study of those points in  $P$  which map into a preassigned point  $c$  in  $n$ -dimensional space.

It is demonstrated that if  $c$  is a "regular" value of the mapping, then its inverse image is a finite union of paths and loops. (A path is a curve, linear in each piece of linearity of  $P$ , which touches the boundary of  $P$  in precisely two points; a loop is a piecewise linear curve with no boundary.) Figure 2 illustrates a solution set which is composed of a single loop and two paths.

As an illustration of these elementary geometrical ideas, consider a mapping of the unit simplex  $[0,1]$  into itself. Eaves and Scarf introduce the product of this simplex with another unit interval (in this case forming a square) which is then decomposed into a number of small triangles. The method proceeds by constructing a simple mapping of the top of the square into itself, with a unique fixed point, combining this mapping linearly with the given mapping on the bottom of the square and tracing out the set of fixed points as one moves from the top to the bottom. See Figure 3. In addition to providing a computational method, these arguments can be used to give a proof of Brouwer's theorem, for an arbitrary mapping of an  $n$  dimensional simplex into itself, similar to the proof given by Hirsch in 1963.

The geometrical setting of the paper leads naturally to an index theory – analogous to that arising in the study of differentiable manifolds – which is

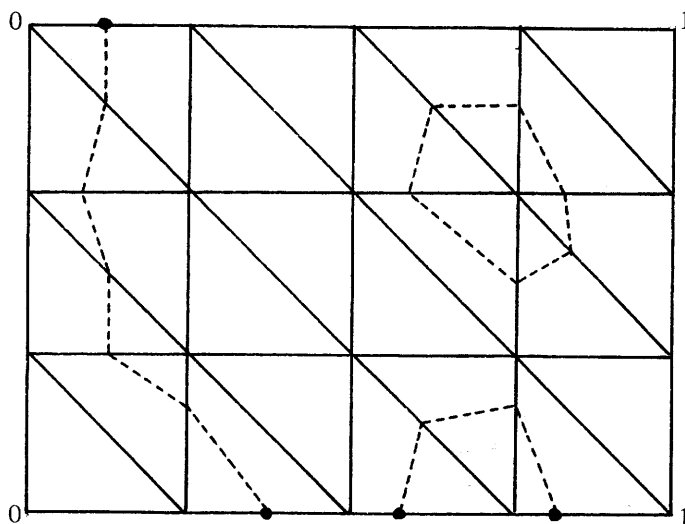


FIGURE 3

an important tool in the analysis of the monotonicity of computational procedures, and the uniqueness of solutions to systems of equations.

In CFDP 389, Eaves proposed an algorithm for solution of the classical model of exchange in which each consumer has a linear utility function. Although the solution to this problem can be obtained by use of the fixed point methods, Eaves' algorithm takes advantage of the special structure of the problem and is considerably more efficient.

During the summer of 1973 Mycielski of the Institute of Theoretical Physics, University of Warsaw, visited the Cowles Foundation. He collaborated with Scarf on the development of computational techniques for the determination of equilibrium exchange rates in a general model of international trade.

During the last year or so, Scarf has also been concerned with the application of fixed point methods to the solution of economic problems involving indivisibilities in production. The basic idea is to associate a piecewise linear

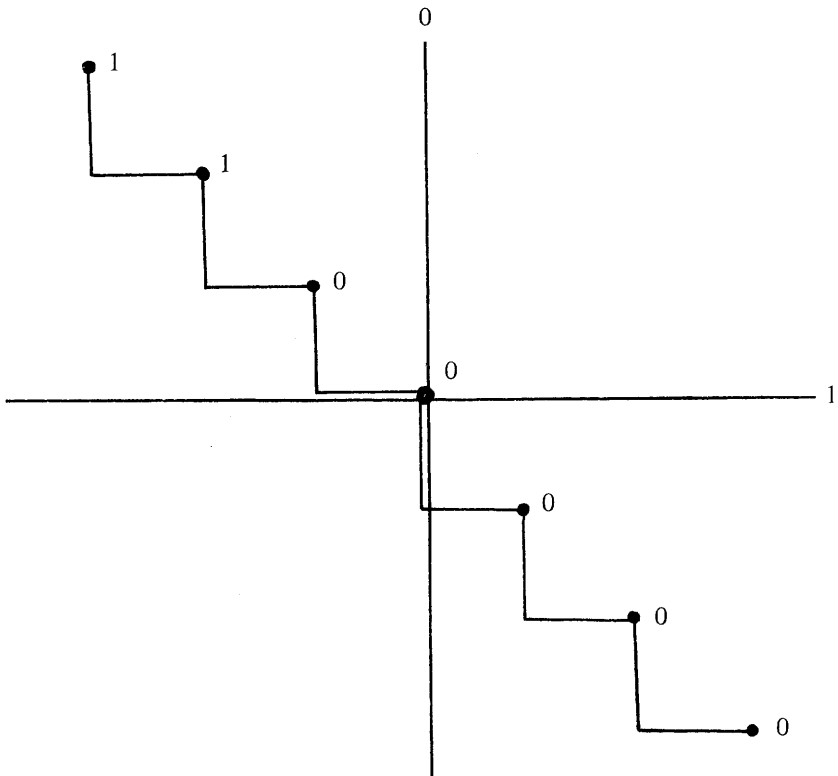


FIGURE 4

manifold with the discrete set of production plans arising from an activity analysis model with integral activity levels. See Figure 4. The problem of maximizing output, subject to constraints on the availability of factors, can then be solved by associating with each vertex of this manifold an integer label depending on the specific constraints violated at this vertex and then searching for a simplex in the manifold, all of whose labels are distinct.

This approach is quite general in the sense that an arbitrary discrete programming problem can be cast in this form. There are, however, considerable difficulties in practice, since the sequence of small steps required to implement the algorithm may be of substantial complexity in themselves. Scarf's recent research has been devoted to an examination of those discrete activity analysis models for which these small movements can be carried out easily.

An alternative to Scarf's method for computing fixed points is the Global Newton method developed by Smale during his visit to the Cowles Foundation and by Kellogg, Li and Yorke of the University of Maryland. These methods construct a differentiable curve starting at the boundary of the unit simplex and terminating at a fixed point. The process of following the curve may be cast into the form of a set of differential equations which are immediately seen to be equivalent to Newton's method in the vicinity of the fixed point.

Yet another alternative to fixed point methods for the computation of equilibria is being explored by Mantel. The investigation centers on the search for social welfare functions which can be used in order to obtain a competitive allocation as a solution to a maximization problem. Special cases are known where this is possible and where the equilibrium prices emerge as the Lagrangian multipliers associated with the resource constraints. One such special case is that of homothetic preferences — either equal, or different but with a constant relative income distribution. Mantel shows that the linear utility case analyzed by Eaves implies that the welfare function is concave so that the computation of the equilibrium reduces to a concave programming problem. He has also found a social welfare function for the general pure trade model which satisfies the condition that it be monotone in the individual utilities so that it can be defined without previously solving the equilibrium equations for the economy. In contrast to the special case of homotheticity of preferences, however, this welfare function depends on information about all the tastes as well as endowments in the economy. This function will be non-concave unless the competitive allocation for the economy is unique.

This computational approach of Mantel's obviously involves analysis of aggregation problems. In closely related work, he has been exploring the decomposition properties of aggregate excess demand functions and of market demand functions. The usual assumptions on the preference maxi-



mizing behavior of consumers subject to a budget constraint imply that individual excess demand functions are essentially characterized by Walras' law, homogeneity of degree zero in prices and lower boundedness. It has been conjectured that these properties are inherited by the aggregate excess demand function. A sequence of papers by various authors permit one to assert that this conjecture has been proven. This work is summarized in Mantel's CFDP 409. Perhaps a more important part of the investigation, however, refers to market demand functions. Mantel shows by means of examples that some restrictions can be inferred from microeconomic theory in addition to the characterizations mentioned above: He also shows that some of the results that apply to excess demand functions do not carry over to market demand functions. A surprising result is that there does exist a characterization of the Jacobian of a differentiable demand function. This theorem, a converse of a theorem by Diewert, will appear in Chapter 6 of *Frontiers in Quantitative Economics III* (M. Intriligator, ed.).

In work on Walrasian general equilibrium, mathematical economists have given several formulations to the naive notion of a competitive economy as one in which individual economic agents have a negligible effect on the outcome of the economic process. These formulations are referred to on pages 6-7 of the preceding Report of Research. All of them involve the concept of "largeness" in some sense. Earlier work has shown that if the concept of the number of traders in an economy being "large" is formalized through (a) the application of nonstandard analysis, (b) use of the notion of a continuum of traders, or (c) analysis of a sequence of replications of a finite economy, then it is true that the equilibrium concept of the "core" is equivalent to the concept of competitive equilibrium in the sense that competitive allocations of goods to traders are identical to points in the cores for market games. Brown considered the relationship between nonstandard economies and economies with a continuum of agents in a paper "The Core of a Purely Competitive Economy" which was presented in 1974 at a Symposium on Computation of Equilibria organized by the Computation Centre of the Polish Academy of Sciences. In that paper, he constructed a nonstandard economy from a continuum economy such that (1) an allocation is in the core of the continuum economy if and only if the nonstandard representation of the allocation is in the core of the nonstandard economy and (2) the core of the continuum economy is non-empty if and only if the core of the nonstandard economy is non-empty.

Another important equilibrium concept is the Shapley value. Brown, in a paper with Peter Loeb (of the University of Illinois) shows that it is also equivalent to the notions of the core and competitive equilibria (CFDP 406). Brown and Loeb apply the technique of nonstandard analysis to an exchange economy. In independent work, Dubey (in his doctoral dissertation at Cornell

University) also showed the equivalence of the Shapley value and competitive equilibria. Dubey used the continuum model of Aumann and Shapley and was able to introduce production.

Other aspects of mathematical analysis of Walrasian general equilibrium rely heavily on assumptions of smoothness or differentiability. Recently, Debreu has shown that the rate at which the core converges to the set of competitive allocations when a standard economy is replicated is, under a particular assumption, inversely proportional to the number of replications. Grodal has shown that this result can be derived from the properties of a continuum economy viewed as a limit of the replicated economies. Brown is using the assumption that traders have utility functions that are differentially convex in an attempt to extend the Debreu-Grodal result to nonstandard economies.

Use of differentiability conditions to consider price adjustment processes in exchange models and models with production was an important part of Smale's work at Cowles. In one part of CFDP 378, Smale analyzes the conditions for a Walrasian price equilibrium, in a pure exchange model, to be "catastrophic" in the sense that it is discontinuous in the endowment alloca-

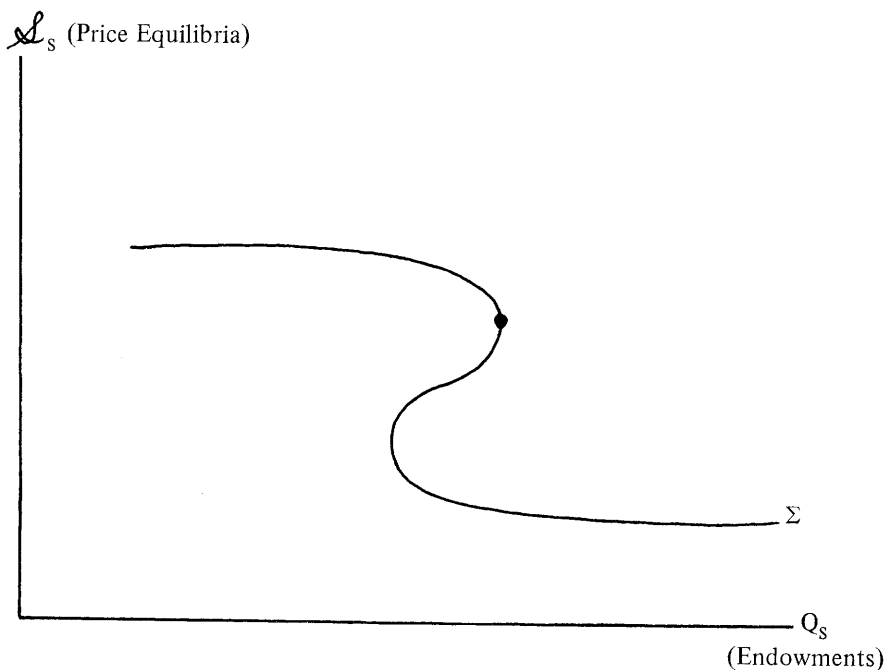


FIGURE 5

tions. He considers the question, for what combinations of initial endowments, final allocations and associated equilibrium prices will it be the case that a small change in the initial endowments could produce a large jump in prices. In Figure 5, the dot is an example of a catastrophic point. Smale suggests some perspective on circumstances associated with such points. One circumstance is when the difference between the initial endowments and the final allocation becomes large. Another is when the curvature of the indifference surfaces becomes large.

An essential feature of the Walrasian models and their extensions discussed thus far (with the exception of the work of Scarf on indivisibilities) is the assumption of linear or convex production technologies. The efficient allocation of resources in the presence of increasing returns to scale in production is a problem which Brown and Heal are currently exploring. The basic idea which they are extending can be illustrated in the following way: If a firm has a nonconvex production possibility set, then it will have efficient production programs which are not supported by any linear price system. If the firm is a price-taker, but faces nonlinear prices, then efficient points which lie in a region of non-convexity can be supported. In the figure below, which shows a

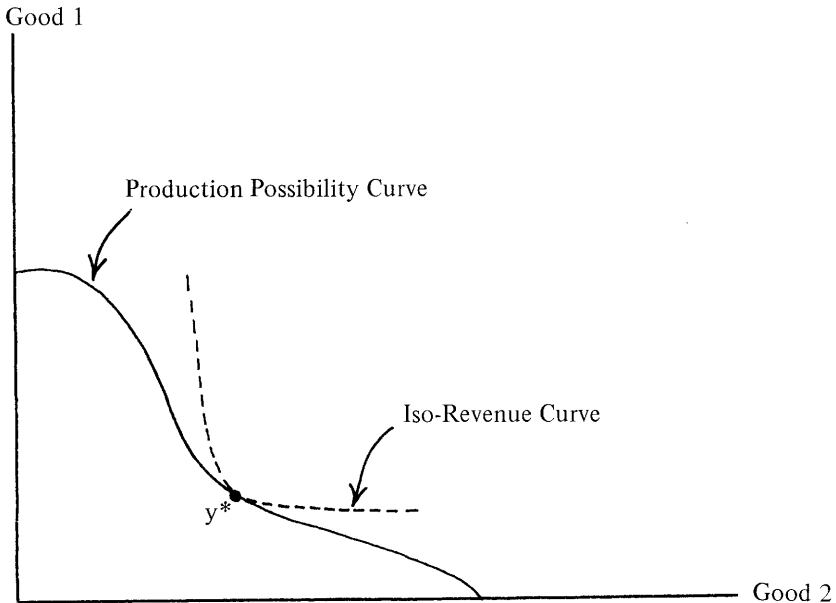


FIGURE 6

two-commodity nonconvex production possibility set,  $y^*$  is one such point. It cannot be supported by any linear price system but can be supported by a nonlinear price schedule in which the relative prices at  $y^*$  are equal to the marginal rate of transformation at  $y^*$ , i.e. the broken line is an iso-revenue curve of one such price schedule.

Another type of nonconvexity is considered by Starr in a paper with Heller (of the University of Pennsylvania), "Equilibrium with Non-convex Transactions Costs: Monetary and Nonmonetary Economies." In this model, the transactions demand for money is associated with a set-up cost on transactions between money and other assets. This contradicts the usual convexity requirements of general equilibrium theory. The resolution is by the technique of using large numbers to smooth out in the aggregate the discontinuities in individual behavior. The existence of approximate equilibria in a monetary economy is demonstrated.

Shubik's central concern has been the application of a number of different game-theoretic solution concepts to problems in general equilibrium theory. There are many results in game theory which are clear and well defined for side-payment games but are not so easily dealt with when no-side-payment games are considered. As the economy as a whole is best modelled as a no-side-payment game, it is natural to ask if the results establishing the relationships between the set of competitive equilibria and the core for side-payment games also hold for no-side-payment games. In an as yet unpublished paper, Shapley and Shubik have defined the *inner core* of a no-side-payment game. This is the set of imputations within the core such that, if we associate with any point,  $p$ , in the core of the no-side-payment game, a side-payment game constructed by passing a tangent hyperplane through that point and assuming that side-payments can be made among members of coalitions at the rates given by the direction cosines of the tangent plane, then the point of tangency between the side-payment game and the no-side-payment game is in the core of the side-payment game. Not all points in the no-side-payment core have this property. It has been shown that the competitive equilibria of any exchange economy associated with the same no-side-payment market game are in its *inner core*.

A paradox appears to be present with this result inasmuch as the competitive equilibria and the core are ordinally defined solutions whereas the inner core definition makes use of a cardinal utility. This paradox is resolved by showing that there exists a transformation of the utility functions which will bring any point in the core into the inner core. This result is related to the recent work of Debreu in establishing the conditions under which preferences can be represented by a concave utility function.

Gordon Bradley (formerly of the Department of Administrative Science at Yale) and Shubik have provided an (unfortunately) negative answer to the

hope that there might be a way to construct an intrinsically transferable utility measure by finding transformations to flatten the Pareto optimal surface. In CFP 417, they ask the following simple question: Given  $n$  individuals and  $m$  prospects over which each individual has a strong preference ordering, how many prospects are required before it is not possible to find a set of order preserving transformations which place the set of Pareto optimal prospects on a hyperplane. The answer is 6 for  $n = 3$  and 4 for  $n \geq 4$ .

Noncooperative equilibrium notions, formulated in economics by Cournot and generalized by Nash, are also a major interest of Shubik. These solution concepts seem to be the natural ones to use in the analysis of problems in oligopoly theory. They have also been applied by Dubey and Shubik to the analysis of markets where firms can choose to enter, i.e. to become active, or to exit. Finally, the notion of noncooperative equilibria seems to have a natural application to games where agents bid for goods with money and where information and trust are less than complete. In a game where agents bid for goods with commodity money, Shubik and Shapley were able to establish the existence of a noncooperative equilibrium. Shubik's extensions of this model to incorporate fiat money and financial institutions are discussed in Section C.

### *C. Economics of Information and Microeconomic Investigations of Money and Financial Institutions*

Although the market mechanism is informationally efficient by comparison to a process of complete central planning, the conventional analysis of competitive equilibria nonetheless assumes that agents have a great deal of information about the alternatives available to them. In a world of heterogeneous products and services and where agents differ in many characteristics, it seems desirable to relax these assumptions. Early work in this area was done by Akerlof, Arrow and Spence. In closely related work, Stiglitz (CFDP 354, published in the *American Economic Review*, June, 1975) examined a model in which workers differed in productivity but employers could not readily identify these differences, either before or after hiring, in the absence of screening. Stiglitz noted that given certain screening costs, there could exist multiple equilibria in one of which there might be no screening and in another of which there might be full screening. It is quite possible that the equilibria with screening will not be Pareto optimal.

In CFDP 375, Stiglitz examines a reverse situation — one in which workers do *not* differ in productivity but in which a distribution of unequal wages may exist. The type of model he considers can be seen in this simple example: Assume that the quit rate of individuals is affected by the wage distribution. Note also that the wage paid by a firm with given training costs will be determined by the quit rate function. Then wage rates and quit rates both depend

on the distribution of training costs and must be such, in equilibrium, that firms just break even.

Wilson has been concerned with an analysis of self-selection models. The fundamental problem is perhaps best illustrated in the context of an insurance market (CFDP 432). Firms are assumed to be unable to differentiate among consumers on the basis of their probability of having an accident. It can be shown, however, that consumers of different risk classes will tend to have different preference orderings over the set of insurance policies. Therefore, firms may have an incentive to structure the menu of insurance policies so that different risk classes purchase different policies. The most striking result of this analysis is that equilibria will not necessarily exist under the assumption that firms behave as if they expect no response on the part of other firms.

This result led Wilson to search for simple expectation rules for which there is a stationary equilibrium. Under very strict assumptions relating the preference ordering of consumers to their risk class (or profitability to firms) such a rule has been found. Under those assumptions, if firms expect other firms to withdraw unprofitable policies and copy profitable policies, an equilibrium will exist. This result has been demonstrated in an abstract model which captures many of the essential features of other "self-selection" models such as Spence's signalling models, Akerlof's assembly line problem, and several other models of labor and loan markets. Wilson has also demonstrated that these equilibria need not be Pareto optimal even with the information constraints taken into account.

Starr, during the period of this report, analyzed the role of money as a medium of exchange in reducing the level of information needed for trade to take place. In two papers on this topic, Ostroy-Starr, "Money and the Decentralization of Exchange," and Starr, "Decentralized Non-Monetary Trade," a model is set forth which emphasizes the bilateral nature of barter and the requirements for information and organization to achieve an equilibrium allocation even when it is assumed that equilibrium prices are already established. It is then shown that the use of monetary trade allows a significant reduction in the needed trading time or required level of organization and information.

In the past three years, Shubik's work has concentrated heavily on micro-economic aspects of money and financial institutions studied by means of models of a closed economy solved as a noncooperative game. The first satisfactory model was obtained in connection with an oligopoly problem, as was noted in Section B. The thrust of the work since then has been primarily on the monetary and financial aspects of the models. This work was divided into several parts. They can best be described as: (1) A critique of general equilibrium theory; (2) An outline of the methods to be employed in

modelling financial and information conditions; (3) Models of market structure describing price formation and bidding or trade conditions; (4) Models of markets with exogenous uncertainty; (5) Markets with production as well as trade; (6) Dynamics; and (7) The role of the “float” and bankruptcy conditions.

It is Shubik’s belief that the process models and the noncooperative game analysis applied to them provide a more promising approach to the development of microeconomic monetary theory than do direct modifications of general equilibrium theory. The reasons for this belief and the critique of general equilibrium theory appear in two papers, CFP 432 and CFDP 417 which will be published in *Economie Applique*.

The approach suggested as an alternative to the general equilibrium models is to construct explicit market mechanisms specifying the process of trade in detail, using the extensive form representation of a game followed by its strategic form representation. Details such as the sequencing of financial and marketing moves are brought into focus using these methods. These are described (as previously noted) in CFDP 330 which appears in the *International Journal of Game Theory* and in CFDP 377, “Mathematical Models for a Theory of Money and Financial Institutions,” which has appeared as a chapter in a book edited by Day and Groves entitled *Adaptive Economic Models*.

In his original paper (CFP 391) Shubik formulated a market in which traders were required to offer all of their nonmonetary possessions for sale. This is somewhat restrictive and unrealistic. In an as yet unpublished work, Shapley and Shubik considered several variants of this model. Shubik formulated a double auction market (CFDP 368) as an alternative market clearing mechanism. Dubey and Shubik have completed the analysis of a model in which individuals may both bid and decide what to offer to the market. This model was originally formulated jointly by Shapley and Shubik. There is an indeterminacy in this model which results in there being a large class of noncooperative equilibria. This indeterminacy disappears if an extra condition is introduced. The appropriate condition appears to be to minimize cash flow (CFDP 414). A further paper by Shubik considers in general the number of types of markets there may be when individuals bid simultaneously and when the mechanism generates a single price for each commodity in a “reasonable” way (CFDP 416).

Dubey and Shubik have considered economic models of trade with exogenous uncertainty and nonsymmetric information about the outcomes of the random variables. This work is related to the treatment of uncertainty by Arrow and Debreu and the treatment of nonsymmetric information conditions by Radner. Dubey and Shubik (CFDP 410) obtain a price system which reflects the lack of symmetry in information and suggest a general way in which to define Pareto optimality under nonsymmetric information conditions.

In attempting to construct a process model of the economy to be studied as a noncooperative game where production is present it is necessary to consider a multistage process. In particular firms must obtain raw materials or other inputs before they can produce. Dubey and Shubik (CFDP 429) have been able to construct a multistage model with traders and managers of the firms, and with trade in shares of the firms as well as in raw materials and final goods. They have been able to establish the link between the noncooperative equilibrium points in this model and the competitive equilibria in the Walrasian model.

Shubik has collaborated with Whitt (of Yale's School of Organization and Management) and with Evers (during his visit at Cowles) in considering infinite horizon models of exchange with money. Shubik and Whitt (CFP 389) analyzed trade with fiat money and a single commodity. Evers and Shubik (CFDP 431) considered a competitive infinite horizon economy with trade in money.

Two key items in understanding the functioning of a monetary economy are the float, i.e. the amount of money in transit which "greases the system," and the bankruptcy conditions which indicate the penalties to be assessed if individuals fail to meet their obligations. Shubik has considered these phenomena in several papers (CFDP 394, 395 and 417). It is suggested that the optimal bankruptcy rule needed in order to design a noncooperative game using fiat money, which will give noncooperative equilibria appropriately related to the competitive equilibria, must be related to the Lagrangian multipliers obtained from solving the Walrasian system for its competitive equilibria. It is further suggested that bank and fiat money play different roles, the first in financing intertemporal trade and the second in covering the float.

#### *D. Macroeconomics and Monetary Economics: Theory and Policy*

Research in macroeconomics, including its monetary aspects, has been pursued along both theoretical and empirical paths. On the theoretical side, work has been guided by two major objectives. One is to develop models that are consistent in linking short- and long-run phenomena and in accounting for changes in stocks of real and financial wealth as well as all flows of income and spending. A second objective is to define more persuasively and precisely the short-run responses of microeconomic units to imperfectly foreseen contingencies, or shocks to the system, in order to understand better such aggregate phenomena as persistent unemployment or inflationary bias in the economy. Empirical investigation has been guided by these same objectives. Investigations have included specification and estimation of models, of the entire economy and of particular sectors, which satisfy the consistency re-



quirements mentioned above, as well as investigation of the behavior of specific variables such as wholesale prices and the cost of capital.

One of the issues in current macroeconomic theory is whether fiscal stimulus without printing money is effective in increasing aggregate demand — or to put the question another way, in increasing the velocity of money. The possibility that whatever short run impact pure fiscal stimulus may have is reversed by the longer-run monetary effects of accumulated public debt was addressed in CFDP 384 by Tobin and Buitier (formerly a graduate student at Yale and subsequently at Princeton University). Their answer is negative — if fiscal policy is expansionary or inflationary in the short run, it has qualitatively the same effects in the long run. The analysis involves a dynamic extension of traditional “IS-LM” macroeconomic models to account for the shifts in these loci as stocks of assets change.

In closely related work, Buitier and Smith are developing a compact “IS-LM” model, in the spirit of Keynes-Hicks-Patinkin, that is contemporaneously and sequentially consistent in accounting for all flows of funds. This is intended to remedy shortcomings of textbook models regarding the effects of monetary and fiscal policies — in particular, to remedy the inadequate analysis of the question of short- and long-run “crowding out” to which the Tobin-Buitier paper was also addressed.

A related question is whether aggregate demand, as determined by some version of the IS-LM model, will necessarily be brought into equality with aggregate supply, as determined by labor market behavior and production relations, through the adjustment of prices and money wages. One line of inquiry on this topic is reported by Tobin in CFP 428. He notes that Keynes aspired to explain persistent involuntary unemployment as an equilibrium phenomenon but that it is difficult, from a theoretical point of view, to swallow the Keynesian notion that persistent excess supply of labor will fail to induce wage adjustments leading to increased employment. Tobin therefore begins with the assumption that wages are flexible and that only full employment equilibrium exists. He then proceeds to show that the dynamics of wage and price adjustment and of the generation of expectations during these adjustments may well make the equilibrium unstable, globally if not locally. The result is that unemployment may arise which is not eradicable except by policy measures, even though the unemployment is not a feature of equilibrium.

Many macroeconomic phenomena, both static and dynamic, are best understood as the aggregative outcomes of continuous readjustments of individual households, firms, and markets to stochastic disturbances. Tobin, Brainard and Iwai have been seeking to model precisely the responses of economic units to imperfectly foreseen shocks, and the system-wide consequences of such shocks.

The concept of stochastic macro-equilibrium, in which shifting micro-economic disequilibria exist within fairly stable aggregates, was described in Tobin's presidential address (CFP 361) to the American Economic Association. In such an equilibrium, both job vacancies and unemployment persist; likewise, overall balance of supply and demand for goods and services is consistent with excess demand in some markets and excess supply in others. In Tobin's address, he argued that inflationary bias results from stochastic shifts in demand, even in the absence of aggregate excess demand, because wages and prices in individual sectors are more responsive to excess demand than to excess supply. Consequently it takes excess supply in aggregate to maintain zero inflation, or any steady rate. Tobin further argues that the corresponding unemployment rate has no normative or "natural" significance.

Tobin has constructed a computer simulation model for illustrating these points. The model focuses on disequilibrium in labor markets and provides a framework for investigating structural changes affecting the speed of adjustment of wages and of movement between labor markets. Lepper has used a variant of this model to examine the effects of long-term labor contracts, and of cost-of-living clauses in such contracts, on the inflation bias of the simulated economy and on the allocational loss of simultaneous vacancies and unemployment.

Does rationality of expectations and behavior imply a unique natural rate of unemployment, so that there is no durable tradeoff between output and inflation? This is the conclusion of simple aggregative models, and of some disaggregated models, notably those of Lucas. Brainard (together with F. T. Dolbear of Brandeis) has constructed a disaggregated model, similar in spirit to Tobin's, which can be used to investigate this issue. In disaggregated models the "rationality" of individual agents by itself is not sufficient to establish the existence of a natural rate. Brainard and Dolbear find, for example, that if price adjustments are more sluggish downward than upward, a variety of levels of utilization of the economy may be consistent with non-acceleration of inflation, even if all agents accurately anticipate the rate of inflation. Whether or not there is a "natural rate" depends on subtle features of the way the price adjustments to real disequilibria are affected by inflationary expectations.

The subjects so far discussed are standard issues of macroeconomic theory which disaggregated models can illuminate. In addition there are other important questions, some suggested by recent world events, which cannot be analyzed at all without explicit disaggregation.

One set of questions related to the effects of large disturbances to the demand or supply of particular commodities, for example oil, which require changes in relative prices for restoration of equilibrium. Tracing the infla-

tionary and allocational consequences of such shocks requires the use of a model which articulates the market mechanisms by which prices, consumption and production of other commodities are affected. The Tobin and Brainard-Dolbear models can be used for this purpose.

In an economy with downward price rigidities, the relative price adjustments required to restore equilibrium when the economy is subjected to such shocks are difficult to achieve without inflation. Hence the tradeoff between lost output and inflation is quite different from the one associated with an economy-wide inflationary or deflationary gap. Brainard and Dolbear have used their model to illustrate how this tradeoff differs, and to investigate the sensitivity of the difference to variations in behavioral parameters, e.g. the costs, and consequent speeds, of price adjustments in particular markets.

Iwai's exploration of disequilibrium dynamics is similar in spirit to Tobin's and Brainard's work but places greater emphasis on mathematical modelling of the behavior of individual agents. He is considering, in particular, the adjustment of wages and prices in an economy of monopolistically competitive firms. These firms are subject to stochastic shocks and set prices and wages in accordance with subjective expectations. The supply of labor to a single firm is a function of the firm's wage offer relative to that of other firms, and the demand for the firm's product is a function of the firm's announced price relative to other prices. Iwai has developed and analyzed a number of models within this general framework (CFP 415, CFDPS 369, 385, 386, 411, 423).

In the earlier papers, Iwai examined the conditions for an equilibrium in which firms' expectations are mutually consistent and self-fulfilling. This was shown to require "Say's condition" that aggregate demand and aggregate supply balance. Iwai distinguishes two forms of disequilibrium. The first and trivial form of disequilibrium is caused by disturbances of expectations while Say's condition continues to hold. The natural-rate theory of unemployment and, more generally, Walrasian equilibrium theory have been confined to this case. In this case, the analysis of disequilibrium is reduced to the analysis of processes by which economic agents revise their expectations. The second and more fundamental type of disequilibrium occurs with the disturbance of Say's condition, which automatically disturbs a majority of firms' expectations. When, for example, aggregate demand exceeds aggregate supply, most firms try to raise their prices and wages relative to others' and end up with expectations betrayed. Their revisions of expectations further raise prices and wages and generate a cumulative inflation process in which expectations continuously lag actual events. During this cumulative process unemployment tends to be lower than its natural rate. Since this process continues as long as aggregate demand exceeds aggregate supply, the stability of long-run equilibrium

hinges upon the central question of whether or not cumulative increases in prices and wages can themselves restore Say's condition. This is the same question that Tobin explored, in the aggregate, in CFP 428 discussed above.

In later papers, Iwai incorporates a real cost associated with firms' adjustment of money wages. He is able, with some further assumptions, to prove convergence to a stochastic macro-equilibrium where firms' expectations are fulfilled on average. This equilibrium is a stochastic steady state in which labor demands and supplies at individual firms constantly fluctuate, sometimes yielding excess demand, sometimes excess supply. Aggregate unemployment in this model is governed by the dispersion of labor market disequilibria among firms, and its level will exceed the natural rate of unemployment pertaining in the absence of adjustment costs. Furthermore, if the costs of reducing money wages exceed the cost of raising them, then aggregate unemployment will be inversely correlated with the average rate of increase of money wages. The method used to prove the existence of the stochastic macro-equilibrium employs both random walk theory and the theory of renewal processes.

Price determination as well as wage determination plays an important part, of course, in the inflation process. Nordhaus has been engaged in several research projects in this area. The longest project is a continuation of a long-term investigation, in collaboration with Wynne Godley and others at the Department of Applied Economics in Cambridge, England, of the process of price setting and the transmission of inflation in United Kingdom manufacturing. Their first published article came out in 1972 (CFP 371), examining manufacturing as a whole; since then, they have disaggregated their analysis to examine seven individual manufacturing industries. Among the questions the study examines are the following: First, is the "normal pricing hypothesis" an accurate description of the price formation process in U.K. manufacturing — in particular, does inflation respond to the pressure of demand as well as to "normal" or cyclically corrected costs? In the industries examined so far, they have found, perhaps surprisingly, that the normal pricing model is an excellent description of price formation. Second, to what extent are changes in corporation taxes and investment allowances passed through into prices, i.e., shifted forward? This part of the study has been especially difficult because it requires building a new data base as well as developing a methodology, for analyzing shifting in a markup model. Third, to what extent have the variety of incomes policies tried in the U.K. during the period under study affected pricing behavior? They have constructed an explicit model of the functioning of incomes-price policies (rather than the usual dummy variable approach) and have constructed an index of the strength of these policies. Finally, they have constructed a model to measure the importance of world manufacturing prices in influencing the domestic British price level. From

preliminary results, it appears that the effect of world prices is much less than had previously been thought. In addition, Nordhaus is using some of the ideas introduced in the U.K. work to study price behavior in the United States. As a preliminary step, in CFDP 415 presented to the American Economic Association in 1975, he has outlined a simple model of a dual economy — part of the economy functioning along the lines of the normal price model, part along the lines of auction markets.

A somewhat different strand of work in inflation theory and policy concerned the structure of price indices. Nordhaus and John Shoven (of Stanford University) undertook a careful examination of the structure of the United States Wholesale Price Index which has been reported in “Techniques for Decomposing Inflation” (forthcoming in a Universities — NBER conference volume). The study examined the weighting system and analytical basis of the WPI and concluded that, in light of modern developments, it was seriously deficient. A new index was proposed and calculated over selected recent periods, and it was shown that the official index could differ by a factor of fifty percent from the theoretically more sound index during a period of rapid commodity inflation.

Empirical work on the relationship of output and labor input was done in the fall of 1974 by Sims, who was then visiting Cowles. The particular question with which he was concerned is the paradox of shortrun increasing returns to labor that frequently appear in econometric studies which use quarterly data and treat the quantity of labor demanded as a distributed-lag function of output in a single-equation model. Sims’ results, based on monthly data for production workers in manufacturing, shrinks this paradox in two ways. First, his estimates show that the response of man hours to a change in output is essentially complete within six months and that the total response is fully proportionate. Second, the theoretical discussion shows that, if the formation of expectations is treated realistically, the sum of coefficients of estimated lag distributions of labor on output would not correspond to the static optimum response of employment to output.

Theorists working in macroeconomics have had a strong incentive for interest in consumer theory. The life-cycle and permanent income hypotheses of household consumption behavior originated with macroeconomists and have been the subject of continuing research interest at Cowles (e.g. see pp. 22-23 of Report of Research Activities, 1970-73). Extension of this interest to the expenditure behavior of perpetual institutions is a newer phenomenon. Work on this topic was begun at Cowles by Donald Nichols (who visited here from the University of Wisconsin in 1971-72) in cooperation with Tobin and others. The practical issue is to design a rule for annual expenditure from endowment, as at a university like Yale, which (a) is neutral as between generations of faculty and students (as the trustees of immortal institutions

desire), (b) does not compel abrupt changes in expenditure levels, and (c) faces the difficulty of distinguishing between temporary and permanent changes in the return (dividends, interest, and capital gains or losses) earned on the endowment. A paper by Tobin, "What Is Permanent Endowment Income," was given at the American Economic Association meetings in 1973.

In the field of macroeconomic theory, Brainard (with R. Cooper) presented a review paper, "Empirical Monetary Macroeconomics: What Have We Learned in the Last 25 Years?" (CFP 427), at the American Economic Association meetings in 1974. Recent Cowles research in this field has involved extensive empirical analysis. Brainard and Tobin have investigated the way in which the stock market's valuation of a corporation depends on the firms' characteristics (CFDP 427). The paper includes a discussion of the rationale for using "q" as a measure of the incentive for investment rather than using bond or stock market yields and attempts to obtain a measure of "q" — the ratio of stock market valuation to replacement cost — purified of compositional changes. The first step in the computation is to relate "q" to "fundamental" characteristics of corporations: past growth, and current level of earnings on real investment, cyclical sensitivity of these earnings, coverage of debt charges and of dividends, volatility of earnings and their covariance with other corporations, dividend pay-out policy and the stability of dividends. This is done by a series of cross-section regressions for fifteen years; changing coefficients of the several characteristics are thus estimated. These are of interest in themselves and permit the computation of the value of "q" for a representative firm for the fifteen year period (1960-1974).

Another major part of monetary research at Cowles is concerned with the specification and estimation of a flow-of-funds model for the U.S. economy. Earlier work on this project, partly in collaborations with researchers at MIT and the University of Pennsylvania, American University, and elsewhere, was described on pages 24-25 of the Report of Research Activities, 1970-73. During the past three years, this collaborative work has continued, involving Brainard, Smith and Tobin. The monetary sector on which work has been focused thus far has several distinguishing features. One is that the model specifies each sector's real and financial transactions in an integrated and consistent way. This flow-of-funds approach is a major departure from the usual reliance on a collection of seemingly unrelated quasi-reduced form equations.

A second distinguishing feature of the model will be its explicit treatment of disequilibrium markets which are cleared by non-price mechanisms. Brainard and Smith describe this approach in "Estimation of the Savings Sector in a Disequilibrium Model" (American Economic Association meeting, 1974) and present an estimation of the savings and loan and mutual savings bank sectors which allows for the possibility of credit rationing in the mortgage market. They found that these sectors were apparently never far from

their notional demand schedules, which is consistent either with there not being major disequilibria in the mortgage market or with these sectors not absorbing any of the market disequilibria when it does arise. It is hoped that a consideration of the demand equations for other sectors will allow them to distinguish between these alternative explanations.

A third distinguishing feature is the liberal use of *a priori* information in estimating the parameters of the model. There has been a growing recognition that there is not nearly enough independent variation in aggregate time series data alone to yield parameter estimates which will give reliable predictions in a variety of forecasting situations. While the inadequate effective dimensionality of the data makes it easy to find models which fit a particular historical period quite well, it also makes it difficult for models estimated from such data to forecast satisfactorily during other periods in which the intercorrelations among the explanatory variables are unlike those for the sample period.

In a variety of papers, Smith has formally analyzed the effects of high intercorrelations on forecasting accuracy and criticized some of the popular responses (such as pretesting, stepwise regression, principle components, and ridge regression) which impose parameter restrictions based upon the characteristics of the data rather than the nature of the parameters. A paper by Brainard and Smith (CFDP 382) used the savings and loan and mutual savings bank sectors to illustrate the practical value of *a priori* information as opposed to *ad hoc* pseudo information. They found that the data was indeed very receptive to prior information in that it was relatively easy to pull into reasonable regions and peculiar estimates that resulted from using only the data. The use of a mixed estimation technique improved the model's out-of-sample forecasting model; and, surprisingly, using their prior means as exact restrictions (with only the intercept terms estimated from the data) gave predictions which were as good as or better than estimates drawn solely from the data. Buttressed by these results, they are applying this estimation strategy to other sectors.

Econometric work on British "building societies," an institution similar in many respects to U.S. savings and loan associations, is reported in CFDP 398 by Hendry (of the London School of Economics and a visitor at Cowles in the fall of 1975) and Gordon Anderson (Southampton University). This paper contains a small dynamic simultaneous equations model of this sector which formulates the primary objectives of these institutions as relending for mortgages a relatively constant fraction of their expected total deposits, satisfying "reasonable" mortgage applications and maintaining their long-run reserve ratio. Further specification of the dynamic adjustments of the building societies permits the authors to derive a completely specified model of short-run disequilibria. Statistical tests of the various implicit hypotheses

were then performed yielding suggestions of appropriate ways of revising the formulation.

A complete and closed short-term macroeconometric model has also been estimated at Cowles by Fair. The theoretical foundations for the model were developed while Fair was at Princeton and are published in *A Model of Macroeconomic Activity, Volume I: The Theoretical Model*. In this model, he integrates the behavior of financial institutions (“banks”), firms and households at the microeconomic level in a recursive model in which prices are set by monopolistically competitive banks and firms which also set maximum quantities they will sell or buy at these prices. This information passes to households which then decide simultaneously how much labor to supply, how many goods to buy and how many financial assets to acquire, subject to their flow-of-funds constraints. The choice variables of each of the sectors are determined by maximization of utility or profits. Aggregate flow-of-funds constraints are observed at all times and financial earnings, including capital gains, are taken into account in households’ flow-of-funds constraints. In contrast to the flow-of-funds modelling by Brainard, Smith and Tobin, however, more emphasis is placed on disaggregated detail in the real sectors (price setting, production, hiring and investment decisions by firms) and the financial sector is more highly aggregated.

The empirical or econometric model, published as *Volume II*, is motivated by characteristics of the theoretical model. The empirical model accounts explicitly for disequilibrium effects. For example, the relations explaining consumption behavior and labor force participation include “constraint” variables incorporating the possibility that firms may not choose to employ – at the posted relative prices which are also included in the relations – the full amount of labor households wish to supply. Similarly, the relations pertaining to firms’ price and wage setting include a constraint variable to incorporate the effect of labor market tightness, and a “credit rationing” variable to reflect various aspects of household and firm behavior. The model is dynamic in several respects: stocks of real and financial assets are augmented by investment flows and latted values of variables appear frequently in order to capture gradual adjustments of expectations and behavior to actual events. Finally, it is true of the empirical model, as it was of the theoretical model, that the flows-of-funds comprise a completely closed system.

It is illustrative to consider properties of the model that relate to several issues in macroeconomics. One such issue is the relationship of the rate of inflation to the unemployment rate. The specification of the model suggests that one is unlikely to observe a stable Phillips curve. Wage and price changes are affected by variables such as tax rates and import prices in addition to a variable measuring labor market tightness. Similarly, since unemployment is determined residually as the difference between employment and the labor



force, it is influenced by all the factors determining households' labor supply decisions (including the level of transfer payments from the government and the marginal personal tax rate) as well as the factors determining firms' employment decisions (including lagged as well as contemporaneous output). Hence, it is unlikely that there would be a stable relationship between the unemployment rate and real output. For analogous reasons, one could not necessarily expect the relationship between aggregate demand and the rate of inflation to be stable.

Issues concerning stabilization policy are addressed by a number of simulations presented in the book. On the controversial question of "crowding out," the evidence from Fair's model is that a bond-financed increase in the real value of government purchases is *expansionary* but considerably *less* so than if the increase in purchases is financed through the monetary system. Fair has subsequently used the model for optimal control analysis of policy issues.

In addition to the work reported above Tobin has presented lectures and papers addressed to problems of current policy. Tobin's Janeway lectures at Princeton, "The New Economics a Decade Older," were published in 1974. At the 1973 Economic Outlook Conference, he presented an analysis of current inflation, distinguishing structural sources from excess demand. In early 1974 he presented at the Federal Reserve Consultants meeting, and published in *Brookings Papers on Economic Activity*, an analysis of the monetary requirements for avoiding serious recession in 1974 and of the recessionary implications of monetarist recommendations at that time ("Monetary Policy in 1974 and Beyond"). "Monetary Policy, Inflation and Unemployment" is a general expository article by Tobin on the relationship of fiscal and monetary policies to inflation and unemployment, attempting to reconcile "Keynesian" and "monetarist" approaches and to show the crucial importance of distinguishing short- and long-run effects.

#### *E. Econometrics*

Applied econometric work by staff members and visitors at the Cowles Foundation is described in the appropriate substantive sections of this report. Research in econometric methodology is discussed here.

In a series of papers completed while Hendry was at Cowles, Hendry (CFDP 399), Hendry and Srba (CFDP 400), and Hendry and Anderson (CFDP 398) studied the consequences of misspecification of a model for estimation. Since economic theory often provides only tentative or conflicting specification of a relationship to be estimated, misspecification is likely to be present in most empirical applications. This is particularly likely for the dynamic specification of the model. Hence the distributions of conventionally used econometric estimators will not be those found under the usual assumption that the specification is correct; many conventionally appropriate pro-

cedures will be inconsistent. In CFDP 399, Hendry analyzed the effects of misspecification on members of the class of Generalized Instrumental Variables Estimators (GIVE) including Ordinary and Two Stage Least Squares (OLS and 2SLS). For simultaneous and dynamic models the misspecifications analyzed include ignoring serial correlation of the disturbances and the use of instruments which are correlated with the disturbances. Large sample limiting distributions are found, and their accuracy in explaining small sample outcomes is checked by Monte Carlo experiments. Close agreement is found for both first and second moments of OLS and 2SLS, indicating the usefulness of asymptotic approximations in small samples. Some remarks on earlier findings of Maddala and Rao in CFDP 302 are also made.

In CFDP 400, a Monte Carlo approach is taken to studying the finite-sample behavior of the Autoregressive Least Squares (ALS) and Autoregressive Instrumental Variables (AIV) estimators in a dynamic simultaneous model, where inappropriate use of Ordinary Least Squares (OLS) or Two-Stage-Least Squares (2SLS) is especially likely to result in misleading inferences about dynamics. Hendry and Srba study the efficiency of "control variables" for Monte Carlo work and find substantial gains. (A control variable is one whose moments can be derived analytically and which is positively correlated with the stochastic variable of interest, typically an estimator. Use of such a control variable in Monte Carlo estimates can reduce the variance.) Concerning the estimators, they find that AIV is optimal in large samples with substantial autocorrelation of the disturbances; 2SLS is optimal in large samples with low autocorrelation; ALS is optimal for small samples and high autocorrelation; and OLS is best for small samples with low autocorrelation.

In CFDP 398 mentioned in Section D, Hendry and Anderson develop and apply a sequential procedure for testing statistically the dynamic, error process, and economic theory components of the full specification of a model of building society behavior in the United Kingdom.

In CFDP 404 Peck investigates another problem of misspecification and strategy in a dynamic single-equation regression. He considers the procedure of first testing for serially correlated errors and, then, adopting an appropriate estimator depending on the outcome of the test, reestimates the equation as a whole in order to examine the effects on the final estimates. This test and reestimate process can be viewed as a preliminary test estimator with respect to a nuisance parameter. The three components of a strategy, the test employed, the significance level chosen, and the alternative estimator used if correlation is found, are studied by Monte Carlo methods. Peck finds that the maximum likelihood estimator is usually superior, that the test should usually be performed at a significance level algebraically much higher than customary, and that the theoretically inappropriate Durbin-Watson test is acceptable when used at these high levels.

In work begun elsewhere ("On the robust Estimation of Econometric Models," *Annals of Economic and Social Measurement*, October, 1974), Fair estimated a large nonlinear econometric model using a number of robust estimation procedures including the Least Absolute Error (LAE) estimator. This estimator is less affected by large disturbances than conventional estimators minimizing the sum of squared errors. Fair and Peck, in "A Note on an Iterative Technique for Absolute Deviations Curve Fitting," have considered some issues of the computation of LAE estimators as an iterated weighted least squares estimator.

Work by Sims ("Output and Labor Input in Manufacturing," *Brookings Papers on Economic Activity*, 1974:3), mentioned in Section D, uses methods previously developed by him to analyze problems in the estimation of the relationship between output and labor input in manufacturing. Considerations leading to poor estimates of the dynamic structures of that relationship are discussed and tests of exogeneity are performed.

Smith (CFDP 383) and Campbell and Smith (CFDP 402) consider the problem of multicollinearity as an obstacle to empirical determination of the correct specification of a relationship. A number of possible and actual strategies used by researchers to overcome the problems of near and perfect multicollinearity are discussed. The strategies include reducing the number of exogenous variables by arbitrary constraints or by preliminary test procedures and the use of Bayesian and quasi-Bayesian methods to include weak prior knowledge in the estimation process. It is argued that pretest procedures are not a substitute for economic theory in formulating the model. Particular attention is paid to the consequences of these procedures for forecasting. While properly applied *a priori* knowledge is found useful, it is argued in CFDP 402 that one method which implicitly uses prior information, ridge regression, is typically motivated by the characteristics of the data rather than by *a priori* knowledge of the parameters. In fact, the restrictions are often placed on transformed data where it is extremely difficult to interpret the prior information which is being incorporated.

A further paper by Smith, CFDP 381, considers difficulties with the coefficient of multiple determination, the  $R^2$ , as a measure of predictive precision or as a decision tool for improving the accuracy of the estimated coefficients through the deletion of variables whose coefficients are statistically insignificant.

A paper by Sargan, CFDP 370, extends available results on the existence of finite-sample moments for estimators in systems of equations. Sargan establishes that for a slightly modified form of Three Stage Least Squares (3SLS), the order of the highest moment which exists of the estimator for the coefficients of any equation in the model is the same as for the 2SLS estimator, i.e., the number of overidentifying restrictions. The conditions

found for existence of moments are generally sufficient for Monte Carlo work and for allowing Nagar approximations (which are asymptotic in sample size) to the finite-sample moments to be developed. Similarly, these results can be used to justify other limiting approximations to finite-sample moments of the estimator, such as the Kadane approximations developed for k-class estimators (CFP 364) in which the error variance tends to zero.

Peck has analyzed the finite-sample properties of instrumental variables estimators for a dynamic equation using small variance asymptotic approximations. Approximate expressions for bias and mean squared error are found for an arbitrary error covariance matrix without the necessity of stability assumptions. This work (CFDP 433) extends earlier efforts reported in CFDP 325.

Fair has proposed a computationally feasible method for estimating large nonlinear simultaneous equations models by full information maximum likelihood (FIML) and has obtained these estimates for a subset of the parameters in his macroeconomic model discussed in Section D. He has also proposed a computationally feasible method (called FDYN) of obtaining estimates of such models based on minimizing a generalized variance of dynamic simulation errors.

In a short note, Mirer and Peck explored issues related to the combined use of simulation and regression procedures as proposed by B. Bergmann. Also, in work discussed preliminarily in the previous Report, Peck demonstrated that, in the New Jersey-Pennsylvania Graduated Work Incentive Experiment, there was bias in findings on labor supply, due to attrition from the experimental population.

In 1973-74, Hannan (Australian National University) visited the Cowles Foundation and the Department of Statistics. During his visit Hannan pursued research on a variety of topics in the field of time series analysis. One was the study of the estimation of ARMAX (Autoregressive Moving-Average systems with exogenous variables) systems. These systems, of great importance in economics, are fully equivalent to the stationary state-space systems that are important in systems analysis. In a paper written jointly with W. Dunsmuir ("Vector Linear Time-Series Models" in *Advances in Applied Probability*, vol. 8), Hannan gave a definitive analysis of the asymptotic properties of an estimator for ARMA systems. In order to estimate such a system, the calculations have to be iterative and in another paper ("The Estimation of ARMA Models," *The Annals of Statistics*; vol. 3, no. 4), he proved the consistency of an initiating estimator. Another topic Hannan studied was the application of time series techniques to the measurement of properties of wave forms propagated through space. An article on this topic ("Time Series Analysis") appeared in the *Institute of Electrical and Electronics Engineers Transactions*

during the Fall of 1974), is to imbed the problem in a more dynamic context. The competition for votes is assumed to extend across an indefinite series of elections, and, over time, a sequence of policies is generated, which depends on the policy choices of the parties and the outcomes of the intervening elections. These sequences, or trajectories, are shown to converge on a relatively small subset of the feasible policies, and to remain in the vicinity of that set. This set, which can be explicitly characterized, thus constitutes a sort of "dynamic equilibrium" which gives a useful characterization of the behavior of a competitive electoral system under quite general conditions. Moreover, the equilibrium set also has an interesting social choice interpretation, for it turns out that there exists an essentially Arrowian social ordering over the alternatives, whose maximal elements are precisely the points contained in the equilibrium set. The ordering itself seems an interesting and plausible one from a normative point of view. It has been given a precise axiomatic characterization by Douglas Blair, in a Yale Economics Ph.D. thesis (Brown and Kramer, advisers).

Kramer has also been working on a theory of multi-party electoral competition, a subject on which there are few useful results. One serious complication, which does not arise in the two-party context, is the problem of strategic voting, since, when there are three or more parties or alternatives to vote on, some voters or groups will generally have incentives to misrepresent their true preferences and vote "strategically." These strategic distortions are generally too complex to be usefully characterized and pose a serious obstacle to the analysis of multi-party competition. In "A Theorem on Proportional Representation" (unpublished, Center for Advanced Study in the Behavioral Sciences Paper, 1974), however, Kramer shows that (under the classic Downs-Hotelling assumptions) strategic voting will not arise under a proportional representational electoral rule, in the sense that there are no individual or collective incentives towards insincere voting. Kramer has also been working on a more general model of electoral competition in which parties are assumed to have policy as well as electoral objectives. These premises seem to lead to a much richer and more complex set of models, the implications of which he is still exploring.

Parallel with Kramer's work on analytical modelling of electoral competition is axiomatic work on the problem of group decision making and social choice. This work, by several different investigators at the Cowles Foundation, has involved a number of different techniques and approaches. One of these is game-theoretic, and involves the analysis of power indices as measures of the *a priori* distribution of power among "players" of a game when voting is employed for decision making. Such measures have found considerable application in political science and to practical policy questions of apportionment and electoral reform. The Shapley-Shubik power index has been extensively

on *Automatic Control* (Vol. AC-19, No. 6). These techniques are relevant to economic problems involving distributed lags where the lags are unknown.

#### F. *The Public Sector*

Research at Cowles on the economics of the public sector has continued along three lines: voting and political mechanisms for social choice; the inter-relationship of legal policy and economic theory; and issues related to public expenditure, taxation and income redistribution.

1. Voting and Political Mechanisms for Social Choice. Kramer has been involved during the past three years in a number of theoretical analyses of political mechanisms for resolving differences in preferences and reaching collective decisions. "Formal Theory," a paper done with a student, Joseph Hertzberg (published as Chapter 7 in Volume 7 of *Handbook of Political Science*, F. I. Greenstein and N. W. Polsby, eds.), is a non-technical survey of political science literature concerned with modelling political institutions. In "Theories of Political Processes" (presented at the Econometric Society, Third World Congress, 1975, and to appear in *Frontiers in Quantitative Economics III*, M. D. Intriligator, ed.) Kramer presents a more rigorous overview of recent work on the modelling of political processes in political science and economics and discusses its relation to the social choice literature.

A major project of Kramer's, begun during his stay at the Center for Advanced Study in the Behavioral Sciences in 1973-74, is a model of electoral competition. This extends the original analysis of Downs and Hotelling which showed that under certain conditions, an equilibrium will exist in an electoral "market" in which two political parties compete for votes by offering rival programs or governmental policies to the electorate. This equilibrium is of intrinsic interest, and has potential application to the economics of the public sector. For example, these electorate models might be exploited to construct an endogenous public sector in a general equilibrium framework; and the efficiency and equity characteristics of the allocations resulting from this voting mechanism might be compared to those resulting from alternative mechanisms, such as a private market, or the various iterative procedures for centrally planned goods allocation proposed by Dreze, Malinvaud, Groves and Ledyard, and others. The Downs-Hotelling equilibrium is too restrictive for these purposes, however, for it exists only when the underlying policy space is essentially one-dimensional. There have been many subsequent attempts to extend their analysis to more realistic multi-dimensional situations, but none has succeeded in giving a useful general characterization of the behavior of a competitive electoral system in such situations.

The approach taken in Kramer's CFDP 396, which draws in part on insights from work in economics by Smale (a visitor to the Cowles Foundation

employed in such questions, as has the somewhat different index proposed by Banzhaf. Dubey, working partially with Shapley, has developed an axiomatization of these two indices which provides an interpretation of their differences (“On the Uniqueness of the Shapley Value,” forthcoming in the *International Journal of Game Theory* and “Some Properties of the Banzhaf Power Index,” with Shapley, forthcoming as a Rand report). This work suggests the existence of other indices that are intuitively acceptable as *a priori* evaluations of games, some of which may be better suited to certain applications. An axiomatic characterization of these other indices as prior probabilistic weightings of marginal contributions to a winning coalition appears in Blair’s Ph.D. thesis. In further unpublished work, Dubey has extended the work of Shapley, Blair and Owen to describe this class of generalized values of games.

The game theoretic approach to collective choice has also been pursued by Shubik in collaboration with Trotter (formerly of School of Organization and Management at Yale) and a graduate student, van der Heyden. They have started to explore a class of games called “budget allocation games.” In these games,  $n$  individuals are required to vote the potential inclusion of  $m$  items within a budget which may be constrained to prevent the players from accepting all  $m$  items. They have been able to show that if this is modelled as a game with side payments, there is no logrolling scheme which enables the individuals to find an equilibrium price for their votes. Shubik and van der Heyden have extended these results to no-side-payment games with the aid of a result of Shapley.

Kramer has also been exploring related issues, dealing with procedural and agenda rules used by committees, as evolved under parliamentary practice and codified in the Rules of Order. The analysis of “Due Process and the Rules of Order” (presented at the 1973 Meeting of the American Society for Political and Legal Philosophy, New Orleans, December 1973) and “Some Procedural Aspects of Majority Rule” (to appear in *NOMOS; Due Process*, R. I. Pennock and J. W. Chapman, eds.), drawing in part on game-theoretic concepts and results of Farquharson, shows that the Rules of Order, in contrast to the many other possible rules that might be used, do have intrinsic advantages as social decision mechanisms, and minimize incentives for certain types of strategic distortions.

Brown also has been doing axiomatic work on social choice theory. One objective of this work is to demonstrate the existence of social welfare functions that, in a qualitative sense, approximately satisfy the conditions set forth by Arrow in his classic work on this subject. As is well known, the only social welfare function satisfying all Arrow’s conditions is dictatorial. In CFP 419, Brown shows that there exist social welfare functions which “approximately” satisfy Arrow’s conditions in an explicitly defined sense.

In these social welfare functions, the dictator who emerged in Arrow's formulation appears in the weaker form of a "veto player." That is, instead of there being one individual whose preferences are always ratified in the social welfare function, independent of the preferences of the other individuals, there is one individual with veto power but whose preferences must be ratified by at least one other member of society. Brown's social welfare functions, which weaken the Arrow requirement that such functions be complete and transitive and, instead, require acyclicity, can be ordered with respect to their social decisiveness. That is,  $\sigma$  is at least as socially decisive as  $\mu$  if, for every profile of preferences, when  $x$  is socially preferred to  $y$  under  $\mu$ , then  $x$  is socially preferred to  $y$  under  $\sigma$  for all  $x$  and  $y$ .

In CFDP 391, Brown extends his earlier work on acyclic voting rules. In CFP 431 (discussed in the last Report of Research) he showed that if there are at least as many alternatives as there are individuals, and a few other mild restrictions are placed on the voting rule, then voting cycles can be prevented only by requiring that at least one individual accede to every social choice. In the more recent paper, he defines and characterizes a comparable class of acyclic voting rules over a set of alternatives smaller than the number of voters. This class is defined in terms of the intersections of winning coalitions; mathematically, this is an application of lattice theory which Brown has also used in other work on social choice. An interesting example of such an acyclic aggregation rule, due to Craven, is the rule that  $x$  is preferred to  $y$  if and only if the proportion of individuals who prefer  $x$  to  $y$  strictly exceeds  $(m-1)/m$ , where  $m$  is the number of alternatives. Brown is able to show that Craven rules are only a subset of acyclic aggregation rules. He characterizes rules within the broader set with respect to the degree of "domination" of the rule (heuristically, the extent to which the same few individuals always determine the outcome of the social choice), the decisiveness of the rule (cycling being an acute case of social indecision) and whether or not the rule is anonymous (the outcome of a choice depends on the number of affirmative votes, not on who these voters are). In another paper (CFDP 393), Brown has used lattice theory and model theory to investigate properties of individual preference orderings that are preserved under aggregation procedures satisfying the ethical and institutional conditions suggested by Arrow.

Empirical research on voting has also continued at Cowles. Much of this work is an outgrowth of the original work by Kramer of some time ago (CFP 344) on the effect of economic conditions on the outcome of elections. Recently, it was argued in an article by Arcelus and Meltzer (*American Political Science Review*, December 1975) that earlier findings of such an effect by Kramer and others are largely illusory because these studies did not take account of differential effects on voter turnout. Kramer and a student, Saul Goodman, in a "Comment on Arcelus and Meltzer, 'The Effect



of Aggregate Economic Conditions on Congressional Elections,' ” (*American Political Science Review*, December 1975) point out some serious problems of specification and interpretation in the Arcelus-Meltzer analysis, and re-analyze their data to show that economic conditions are indeed an important electoral influence. This finding is substantiated in work on U.S. presidential elections by Bruno Frey and Fritz Schneider, of the University of Konstanz, done during their visit to the Cowles Foundation in the fall of 1975.

Independent work on the effect of economic events on votes for president has been done by Fair (CFDP 418). He uses the same sample period of U.S. data as Kramer (1896-1972) but focuses exclusively on votes in presidential elections. His specification is more general than Kramer's in that he allows voters to remember the performance of a party when it was previously in office and he considers the possibility that economic performance during a larger part of a presidential term than the year of the election itself may be relevant to voters. Despite these generalizations, he finds that, although economic events do have an important effect on the presidential vote, voters are quite myopic. The rate at which they discount the relevance of past events is so high that they consider neither the economic performance of the opposition party during its last term in office, nor the performance of the incumbent party in years prior to the election year. Of the three measures of economic performance that were tested (growth in per capita real GNP, the unemployment rate, and the rate of price inflation) the rate of growth of real income was found to be clearly the most salient.

The results just reported have striking implications for the behavior of a party trying to retain power. Earlier work by Nordhaus (CFP 425) had noted that even if voters have an aversion to inflation as well as to slow growth of income, a flatter Phillips curve in the short run than in the long run will induce governments to pursue a cyclic and, on average, pro-inflation policy. Fair's conclusion that voters do not respond independently to inflation, however, implies that the only constraint on government's pursuit of expansion is the basic structure of the economy. Fair has done extensive work developing a computationally feasible method of solving optimal control problems for macroeconomic models. Application of these techniques to his own model of the U.S. economy (described in Section D) indicates that single-minded pursuit of electoral victory would call for generating a recession that would reach its trough some time during the first three-quarters of the year preceding the election; this would then permit a maximum growth rate of real GNP of about 20 per cent to be achieved in the election year (CFDP 397).

A new way of evaluating the economic performance of an administration is also suggested by the optimal control theory approach. Fair developed such a measure of economic performance (CFDP 420) which takes into ac-

count both the existence of exogenous shocks and lagged influences over which a given administration has no control, and the effects that a given administration's policies may leave behind after it has left office. If a loss function is postulated — e.g. loss is a quadratic function of the deviations of real GNP and the rate of inflation from respective target values — Fair then suggests that an appropriate measure of an administration's misbehavior,  $M$ , would be the actual loss in the administration's term less the loss that would have occurred if the administration had optimally determined the variables under its control, plus the expected loss to the following administration resulting from the future effects of non-optimal actions of the administration in question. Fair has calculated approximations to such a measure for five administrations (the first Eisenhower administration through the first Nixon administration) using two different loss functions and assuming that the real value of government purchases is the administration's control variable while monetary policy is managed to maintain a target interest rate.

2. Legal Policy and Economic Theory. In his paper "Law and Economic Theory," CFP 424, Klevorick gave his views, as a participant in the law and economics enterprise, of the types of contributions economic theory can make to law — to legal decision making, to the study and development of legal doctrine, and to the study and analysis of legal structure.

The first kind of contribution an economic theorist can make in law arises when economic concepts become important in understanding some aspect of a particular legal case. The second involves instances where the entire structure of the problem area has economic roots. The objectives and design of the institutions and doctrine are explicitly stated in economic terms, and the economist is called upon to evaluate and give advice about the best ways to achieve the specified objectives.

The third role Klevorick sees for the economic theorist in the joint enterprise of law and economics envisions the economist or economic theorist as the propounder of a new vocabulary, a new analytical structure for viewing a traditional legal problem. In contrast to the economist's approach in the first two categories of interaction, in this third role he no longer takes the problem as framed by the lawyer. Rather he takes the general problem area with which the lawyer is concerned — say, torts, or property, or procedure — and poses in his own terms — that is, in economic terms — the problem he sees the legal structure or legal doctrine confronting. He provides, thereby, a different way of looking at the legal issue which yields alternative explanations of how current law came to be what it is and new proposals for new law. Klevorick goes on to examine the kinds of problems which confront the economist when he presents a new vocabulary or a new structure for analyzing a legal problem.

The facilities and processes governments provide for resolving legal dis-

putes constitute an important public service only recently analyzed by economists. For the resolution of some of these disputes, society turns to a body of laymen — a jury. In considering the jury as a conflict-resolving instrument, several interrelated questions arise concerning the jury's size, the way its members are selected, and the voting rule it uses in reaching its decision. In his paper, "Jury Size and Composition: An Economic Approach" (presented at International Economic Association Conference on the Economics of Public Services, 1974), Klevorick presented a theoretical structure to help address these questions. The model, which uses a statistical decision-theoretic framework, is then used to examine the specific issue of how "representative" a jury should be. The paper suggests and explicates the analogy between the selection of a jury and the selection of a portfolio of assets by an investor. Pursuing this analogy, with the consequent delineation of the similarity between representativeness of a jury and diversification of an investment portfolio, Klevorick draws upon portfolio selection theory to suggest the kinds of circumstances under which representatives would make the jury a more effective fact-finding body and the types of situations in which representativeness would not serve that end.

Together with Michael Rothschild of Princeton University, Klevorick has also developed a simple, testable model of the jury decision process. They view a jury's deliberation as a continuous-time, birth-and-death process whose state at any point in time is the number of persons voting for acquittal at that time. The critical assumption in the model concerns the transition probabilities from one state to another. If a transition occurs at time  $t$ , the probability that the acquittal vote increases by one is assumed to be equal to the fraction of the jury voting for acquittal at that time; the probability that the number of votes for conviction increases by one is equal to the fraction of the jury voting for conviction at that time. By assumption, the probability that more than one juror's vote is switched at any instant in time is negligibly small. This specification is the simplest one which captures the idea that the momentum of the majority increases with its size. The model can be used to determine the effect on the expected deliberation time of changing from a unanimous jury standard to a non-unanimous decision standard. The model also makes it possible to calculate the percentage of cases which would be decided differently if the decision standard were changed. For example, changing from unanimity to a 10-2 standard results in a substantial percentage reduction in expected jury deliberation time but has very little effect on the verdicts reached. It is, of course, critically important to test the theory which underlies such predictions. Fortunately, the theory can be tested in a way which does not compromise the secrecy of the jury.

Peck has also been involved in an application of econometric theory to a legal problem. A statistical debate on the deterrent effect of capital punish-

ment was published in the December 1975 issue of the *Yale Law Journal*. Peck has evaluated this debate in an article "The Deterrent Effect of Capital Punishment: Ehrlich and His Critics" (*Yale Law Journal*, February 1976). The debate included disagreements over statistical methodology — use of regression analysis vs. paired-state or matching methods — econometric specification — e.g. linear or logarithmic functional form — and choice of data — aggregate or disaggregate. Peck suggests ways of resolving some of these disputes through application of more sophisticated techniques, and identifies technical weaknesses in the statistical support actually demonstrated for the conclusions the debaters drew.

Klevorick has continued his work on public utility regulation (discussed on pp. 32-33 on the last Report of Research). One paper he has prepared on this subject is "An Excess-Profits-Taxation Approach to Public Utility Regulation" (presented at the Econometric Society Meetings, 1974). It analyzes a proposal for regulatory reform, advocated most recently by Posner, which would substitute an excess-profits tax on public utilities for the current form of rate regulation. Regulatory commissions' responsibilities would be sharply curtailed. They would continue to set the "fair rates of return" for regulated firms and to establish the value of the firms' rate bases. A regulated firm, however, would then be treated in the same way as any other firm except that if its net revenue exceeded the fair rate of return on its rate base, this excess profit would be taxable at a rate higher than the ordinary rate on corporate profits. In the model Klevorick considers, the firm at any point in time uses labor and its current stocks of capital and knowledge (or technology) to produce its (single) output. The labor input is perfectly variable while the stock of capital and the stock of knowledge can be increased but not decreased over time. The firm's rate base consists only of its physical capital which grows with each unit of capital investment. The addition to the stock of knowledge resulting from a unit of investment in research is uncertain and is assumed to be governed by a known stationary stochastic process. The firm, operating under an excess-profits-taxation system of regulation, is assumed to maximize the expected discounted present value of its new cash flow. Dynamic programming techniques are used to characterize its optimal capital investment and research policies. One interesting result is that for a wide class of production functions and demand conditions, an *increase* in the excess-profits tax rate will lead to an *increase* rather than a decrease in the amount of research and development the firm undertakes. Klevorick is also engaged in other research on the process of public utility regulation focusing, in particular, on the interaction between the regulated firm and the regulatory agency.

3. Taxation, Income Redistribution and Public Expenditures. As noted on pages 33-34 of the 1970-73 Report of Research, the negative income tax is

perhaps the most widely discussed of redistribution schemes and one that has been of considerable interest at Cowles over several years. Within the period of this report, Brainard and Tobin (with Shoven, now at Stanford and Bulow, a student) carried out a calculation of the effects on various groups of the population of several proposed packages of tax and welfare "reform." These calculations, which were presented at the 1974 meetings of the American Economic Association and Econometric Society, all pertained to "reforms" incorporating "cashable tax credits" or negative income tax principles for integrating income assistance with the regular personal income tax. A number of features of the current tax and transfer payment system were considered — e.g. eligibility of mortgage interest payments as an income tax deduction, the "effective tax rate" resulting from eligibility limitations in the welfare and food stamp programs, and the treatment of family units by income tax exemptions — and alternatives were considered which would be more smoothly integrated into the income tax structure and would intrude fewer tax incentives into individuals' choices.

Lepper has continued her work on the issues of horizontal and vertical equity in the supply of public services across communities differing in the size and composition of the tax base. The last research report mentioned her preliminary analysis of data on local expenditures for public primary and secondary education in the towns of Connecticut. This econometric analysis has been extensively revised and the results reported in CFDP 376 which emphasizes possible horizontal inequities that might arise from application of some proposed equalization formulae. The possible flaw she finds in these formulae is that, while they do compensate for differences in the size of the total tax base per pupil, they ignore such differences between central cities and suburbs as the distribution of the tax base between residential and business property, and the incidence of poverty.

## 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. The Foundation has accorded office, library, and other research facilities to the following guests who were in residence for various periods of time during the past three years.

JOSEPH J. M. EVERS, Tilburg School of Economics.

BRUNO FREY, Universitat Konstanz.

VICTOR A. GINSBURGH, Universite Catholique de Louvain.

V. L. MAKAROV, Academy of Sciences of the USSR.

JERZY MYCIELSKI, Institute of Theoretical Physics, University of Warsaw.

STEPHEN SMALE, University of California, Berkeley.

EDUARDAS VILKAS, Vilnius University, Institute of Physics and Mathematics, Lithuanian Academy of Sciences.

## CONSULTANTS

The following scholars, not directly affiliated with the Cowles Foundation during the period of this report, collaborated actively in Cowles research or published Cowles Monographs containing work conceived and initiated at Cowles.

DONALD D. HESTER (University of Wisconsin), JAMES L. PIERCE (Board of Governors of the Federal Reserve System), ABRAHAM ROBINSON (Yale University), LLOYD S. SHAPLEY (Rand Corporation), JOHN SHOVEN (Stanford University).

## COWLES FOUNDATION SEMINARS

In addition to periodic Cowles Foundation staff meetings, at which members of the staff discuss research in progress or nearing completion, the Foundation also sponsors a series of Cowles Foundation Seminars conducted occasionally by staff but most frequently by colleagues from other universities or elsewhere in Yale. These speakers usually discuss recent results of their research on quantitative subjects and methods. All interested members of the Yale community are invited to these Cowles Foundation Seminars, which are frequently addressed to the general economist including interested graduate students. The following seminars occurred during the past three years.

*July 1, 1973 – June 30, 1976*

1973

- October 17.* AXEL LEIJONHUFVUD, U.C.L.A., "Informal Talk on Macroeconomics."
- October 19.* TONY ATKINSON, Essex University, England, "The Distribution of Wealth."
- November 2.* GARY CHAMBERLAIN, Harvard University, "Returns to Schooling and Ability as an Unobserved Component."
- November 9.* ARTHUR M. OKUN, The Brookings Institution, "Perspectives on the 1973 Inflation."
- December 14.* E. J. HANNAN, Yale University and the Australian National University, "On Measuring Leads and Lags."

1974

- January 17.* RAY FAIR, Princeton, "General Disequilibrium Model of Macroeconomic Activity."
- February 22.* ANNE KREUGER, Massachusetts Institute of Technology, "The Political Economy of the Rent-Seeking Society."
- March 1.* JERRY GREEN, Harvard University, "Insurance and the Economics of Liability Law."
- March 8.* LLOYD S. SHAPLEY, The Rand Corporation, "Noncooperative Models of General Equilibrium."
- April 5.* J. D. SARGAN, London School of Economics and Yale University, "Data Mining and Model Specification."
- April 12.* ARNOLD HARBERGER, Princeton University, "Distributional Weights in Cost Benefit Analysis."
- May 6.* GEORGE STIGLER, University of Chicago, "The Theory of Enforcement."

*May 10.* WILLIAM J. FELLNER, Council of Economic Advisers, "On Current Economic Policy."

*May 24.* JOHN WILLIAMSON, International Monetary Fund, "The Impact of Increased Exchange Rate Flexibility on International Liquidity."

*May 31.* RICHARD NELSON, Yale University, "Factor Price Changes and Factor Substitution in an Evolutionary Model of Economic Growth."

*June 7.* S. DECANIO, W. PARKER, and C. VANN WOODWARD, roundtable on Fogel and Engerman, *Time on the Cross*.

*June 21.* JEROME STEIN, Brown University, "Inside the Monetarist's Black Box."

1975

*September 19.* BRUNO S. FREY, Universitat Konstanz, "Modeling Politico-Economic Interdependence."

*October 3.* RAY FAIR, Yale University, "On Controlling the Economy to Win Elections."

*November 7.* BARRY SALTZMAN, Yale University, "The Theory and Practice of Modelling the Climate."

*November 14.* WILLIAM D. NORDHAUS, Yale University, "Can We Control Carbon Dioxide?"

*November 21.* WILLIAM J. BAUMOL, Princeton University and New York University, "The Weak Invisible Hand and the Multi-Product Monopoly."

*December 3.* D. HENDRY, T. C. KOOPMANS, and G. ORCUTT, Yale University, "Is There a Use for Theory in Econometric Modelling?"

*December 11.* M. W. HIRSH, University of California and Harvard University, "A Global Newton Method for Solving General Systems of Equations."

1976

*January 9.* JEAN WAELBROECK, University of Brussels, CORE, and World Bank, Washington, "The Price of Energy and Potential Growth."

*February 13.* PETER DIAMOND, Massachusetts Institute of Technology, "Reforming Social Security."

*March 26.* RUDIGER DORNBUSCH, Massachusetts Institute of Technology, "Exchange Rates in the Short Run."

*April 2.* ROBIN MARRIS, University of Maryland, "The Public Goods Paradigm."

*April 23.* ROBERT MERTON, Massachusetts Institute of Technology, "The Pricing of Contingent Claims and Its Relationship to Option Pricing."



- May 14.* KARL SHELL, University of Pennsylvania, “The Hamiltonian Approach to Economics Dynamics.”
- May 18.* ROBERT J. AUMANN, Hebrew University and Stanford University, “Power and Taxes in a Multicommodity of Economy.”
- May 28.* DONALD J. BROWN, Yale University, “Existence of a Market Equilibrium in an Economy with Increasing Returns to Scale.”

## FINANCING AND OPERATION OF THE COWLES FOUNDATION

Since the Cowles Foundation was founded, gifts from Alfred Cowles and members of his family have provided the cornerstone of its financial support. In 1970, the Cowles family started an endowment at Yale to provide permanent support of the Cowles Foundation. In June, 1974, the entire principal of the Cowles Commission was added to this endowment. The income from the endowment replaces the income previously received in the form of gifts. This income is supplemented by income from the smaller Marcus Goodbody Foundation endowment. In addition, Yale University provides the use of the building at 30 Hillhouse Avenue and supports the Foundation's research and administration through paying or guaranteeing the salary of the Director and half of the salaries of two other Cowles professors. These three sources of financial support provide dependable discretionary funds permitting a degree of intellectual and administrative flexibility which is essential to the successful operation of an organization engaged in basic research.

During the period of this report, the Cowles Foundation was also fortunate in receiving a substantial amount of external support in the form of large, institutional grants from the National Science Foundation and the Ford Foundation. The continuing, institutional grant from the National Science Foundation was for the period 1973-76 and replaced the previous institutional award which had covered the 1968-73 period. The Ford Foundation grant provided support both for the general program of the Cowles Foundation and for a visitors program to facilitate visits especially by Eastern European scholars and scholars from other disciplines. This grant was for the period 1968-76. Funding also continued to be received from the Office of Naval Research which has financed work at Cowles on operations research and game theory since the late 1940's.

The major part of Cowles Foundation expenditures is accounted for by salaries (and associated fringe benefits). The rest of the budget consists of office and library expenses for materials, the cost of duplicating and distributing Cowles Foundation Papers and Discussion Papers, computing services and travel to professional meetings and conferences and overhead expenses charged by the University against grants and contracts.

The pattern of Cowles Foundation income and expenditures in recent years is outlined in the table.

During the period of this report, the research staff of the Cowles Foundation included 18 or 19 members in faculty ranks (including visiting faculty and one to three staff members on leave). This size has changed very little over the last decade. Excluding visiting appointments, the staff included seven or eight tenured faculty in the Departments of Economics and Poli-

## ANNUAL INCOME AND EXPENDITURES OF THE COWLES FOUNDATION

Average for	INCOME					EXPENDITURES		
	Total	---- Permanent ----- Cowles Family Gifts, and Endowments			Temporary, including project support	Total	Salaries	Other
		Yale		Total				
1961-64	179	41	12	53	126	180	112	68
\$ (000)								
%	100	22.9	6.7	29.6	70.4	100	62.2	37.8
1964-67	250	44	14	58	192	244	148	96
\$ (000)								
%	100	17.6	5.6	23.2	76.8	100	60.7	39.3
1967-70	357	49	17	66	291	346	221	125
\$ (000)								
%	100	13.7	4.8	18.5	81.5	100	63.9	36.1
1970-73	416	59	19	78	338	404	230	174
\$ (000)								
%	100	14.2	4.6	18.8	81.2	100	56.9	43.1
1973-76	539	74	14	88	451	533	274	259
\$ (000)								
%	100	13.7	2.5	16.2	83.8	100	51.4	48.6

tical Science and the Schools of Law and of Organization and Management. Non-tenured staff numbered eight to ten. Both permanent and younger staff devoted one-quarter to one-half of their professional effort during the academic year and up to two full months in the summer to their research and to seminars and discussions with their colleagues.

Research at Cowles is facilitated by a small library in the building which makes materials readily available to the staff and supplements the technical economics and statistics collections of other libraries on the Yale campus (it is open during the week to all faculty and students associated with Yale). The collection includes about 6,000 books and Government documents, 178 journals, reprints from 22 research organizations and a rotating collection of recent unpublished working papers. The collection is oriented towards the research needs of the staff and emphasizes economic theory and monetary theory, mathematics and mathematical economics, statistical and econometric studies and methods and, recently, energy and natural resources.

The research staff was also supported by the services of five secretaries and a manuscript typist under the supervision of Miss Althea Strauss, administrative assistant at Cowles since the Foundation was established at Yale. The end of the period of this report marked the end of her full-time services to Cowles as ill health forced her retirement. Her efficient and loyal service is remembered with appreciation by all who are or have been associated with the Cowles Foundation.

## MONOGRAPHS

1934 – 1976\*

The monographs of the Cowles Commission (Nos. 1-15) and Cowles Foundation (Nos. 16-25) 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. 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. (Out of print.)

No. 4. *Silver Money*, by DICKSON H. LEAVENS. 1939. Evanston, Ill.: Principia Press. 439 pages. (Out of print.)

No. 5. *The Variate Difference Method*, by GERHARD TINTNER. 1940. Evanston, Ill.: Principia Press. 175 pages. (Out of print.)

No. 6. *The Analysis of Economic Time Series*, by HAROLD T. DAVIS. 1941. Evanston, Ill.: Principia Press. 620 pages. (Out of print.)

No. 7. *General-Equilibrium Theory in International Trade*, by JACOB L. MOSAK. 1944. Evanston, Ill.: Principia Press. 187 pages. (Out of print.)

No. 8. *Price Flexibility and Employment*, by OSCAR LANGE. 1944. Evanston, Ill.: Principia Press. 114 pages. (Out of print.)

No. 9. *Price Control and Business*, by GEORGE KATONA. 1945. Evanston, Ill.: Principia Press. 246 pages. (Out of print.)

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. (Out of print.)

No. 11. *Economic Fluctuations in the United States. 1921-1941*, by LAWRENCE R. KLEIN. 1950. New York: John Wiley and Sons. 174 pages. (Out of print.)

\*Orders for Monographs 12, 13, 14, 16, 17, 21, 22, 23, 24, and 25 should be sent to Yale University Press, 92A Yale Station, New Haven, Connecticut 06520. Orders for, or inquiries concerning, all other Monographs should be sent to the Cowles Foundation for Research in Economics at Yale University, Box 2125 Yale Station, New Haven, Connecticut 06520.

No. 12. *Social Choice and Individual Values*, by KENNETH J. ARROW. Second Edition, 1963. New Haven: Yale University Press. 124 pages. 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. 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 Haven: Yale University Press. 324 pages. 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. 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 Investment*, by HARRY M. MARKOWITZ. 1959. New Haven: Yale University Press. 344 pages. 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 returns.

No. 17. *Theory of Value, An Axiomatic Analysis of Economic Equilibrium*, by GERARD DEBREU. 1959. New Haven: Yale University Press. 114 pages. 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. New York: John Wiley and Sons. 427 pages. (Out of print.)

No. 19. *Risk Aversion and Portfolio Choice*, edited by DONALD D. HESTER and JAMES TOBIN. 1967. New York: John Wiley and Sons. 180 pages. (Out of print.)

No. 20. *Studies in Portfolio Behavior*, edited by DONALD D. HESTER and JAMES TOBIN. 1967. New York: John Wiley and Sons. 258 pages. (Out of print.)

No. 21. *Financial Markets and Economic Activity*, edited by DONALD D. HESTER and JAMES TOBIN. 1967. New Haven: Yale University Press. 256 pages. (Out of print.)

No. 22. *Economic Theory of Teams*, by JACOB MARSCHAK and ROY RADNER. 1971. New Haven: Yale University Press. This monograph emphasizes the informational aspect of the problem of designing efficient

organizations. After an introduction to decision-making under uncertainty and to the economics of information, a wide variety of models is treated within a unifying conceptual framework.

No. 23. *Efficient Estimation with A Priori Information*, by THOMAS J. ROTHENBERG. 1973. New Haven: Yale University Press. A unified theory of estimation in the presence of prior information is developed. How valuable is prior information in increasing the precision of parameter estimation and what are efficient methods of incorporating this information into estimation procedures are the two basic questions investigated.

No. 24. *The Computation of Economic Equilibria*, by HERBERT E. SCARF. 1973. New Haven: Yale University Press. The first general method for the explicit numerical solution of the price system and economic equilibrium is presented. An important connection between computational methods and economic theory is made which promises to be of use as a practical tool for the evaluation of economic policy.

No. 25. *Bank Management and Portfolio Behavior*, by DONALD D. HESTER and JAMES L. PIERCE. 1975. New Haven: Yale University Press. This monograph provides a microeconomic analysis of portfolio behavior and earnings by commercial and mutual savings banks using time series of cross-section data for individual banks. The results are shown to be of value in constructing an aggregate model of a system of banks.

#### *Special Publication*

*A Model of Macroeconomic Activity, Volume II: The Empirical Model*, by RAY C. FAIR, Ballinger Publishing Company, 1976.

## COWLES FOUNDATION PAPERS

July 1, 1973 – June 30, 1976

No. 401. WILLIAM D. NORDHAUS, "The Allocation of Energy Resources," *Brookings Papers on Economic Activity*, 3:1973.

No. 402. G. S. MADDALA and A. S. RAO, "Tests for Serial Correlation in Regression Models with Lagged Dependent Variables and Serially Correlated Errors," *Econometrica*, Vol. 41, No. 4, 1973.

No. 403. RONALD G. BODKIN, "Additively Consistent Relationships for Personal Savings and the Categories of Consumption Expenditures, U.S.A., 1949-1963," *Eastern Economic Journal*, Vol. 1, No. 1, 1974.

No. 404. PARTHA DASGUPTA and JOSEPH E. STIGLITZ, "Benefit-Cost Analysis and Trade Policies," *Journal of Political Economy*, Vol. 82, No. 1, 1974.

No. 405. TJALLING C. KOOPMANS, "Is the Theory of Competitive Equilibrium With It?" *The American Economic Review*, Vol. 64, No. 2, 1974.

No. 406. WILLIAM D. NORDHAUS, "Resources as a Constraint on Growth," *The American Economic Review*, Vol. 64, No. 2, 1974.

No. 407. MARTIN SHUBIK, "The Core of a Market Game with Exogenous Risk and Insurance," *New Zealand Economic Papers*, Vol. 7, 1973.

No. 408. WILLIAM D. NORDHAUS, "The Falling Share of Profits," *Brookings Papers on Economic Activity*, 1:1974.

No. 409. SUSAN J. LEPPER, "Voting Behavior and Aggregate Policy Targets," *Public Choice*, Vol. 18, 1974.

No. 410. JOSEPH E. STIGLITZ, "The Cambridge-Cambridge Controversy in the Theory of Capital; A View from New Haven: A Review Article," *Journal of Political Economy*, Vol. 4, 1974.

No. 411. JOSEPH E. STIGLITZ, "Alternative Theories of Wage Determination and Unemployment in LDC's: The Labor Turnover Model," *The Quarterly Journal of Economics*, Vol. 88, 1974.

No. 412. ROSS M. STARR, "The Price of Money in a Pure Exchange Monetary Economy with Taxation," *Econometrica*, Vol. 42, 1974.

No. 413. JOSEPH E. STIGLITZ, "Incentives and Risk Sharing in Sharecropping," *Review of Economic Studies*, Vol. XLI, 1974.

No. 414. PETER A. DIAMOND and JOSEPH E. STIGLITZ, "Increases in Risk and in Risk Aversion," *Journal of Economic Theory*, Vol. 8, 1974.

No. 415. KATSUHITO IWAI, "The Firm in Uncertain Markets and Its Price, Wage and Employment Adjustments," *Review of Economic Studies*, Vol. XLI, 1974.

No. 416. MARTIN SHUBIK, "The General Equilibrium Model: Barter and Trust, or Mass Markets with Money and Credit," *The Economic Record*, Vol. L, No. 130, 1974.

No. 417. GORDON H. BRADLEY and MARTIN SHUBIK, "A Note on the Shape of the Pareto Optimal Surface," *Journal of Economic Theory*, Vol. 8, No. 4, 1974.

No. 418. DONALD J. BROWN and ABRAHAM ROBINSON, "The Cores of Large Standard Exchange Economies," *Journal of Economic Theory*, Vol. 9, No. 3, 1974.

No. 419. DONALD J. BROWN, "An Approximate Solution to Arrow's Problem," *Journal of Economic Theory*, Vol. 9, No. 4, 1974.

No. 420. MARTIN SHUBIK, "Money, Trust and Equilibrium Points in Games in Extensive Form," *Zeitschrift fur Nationalokonomie*, Vol. 34, 1974.

No. 421. GERALD H. KRAMER and ALVIN K. KLEVORICK, "Existence of a 'Local' Cooperative Equilibrium in a Class of Voting Games," *Review of Economic Studies*, Vol. 61, No. 4, 1974.

No. 422. JOSEPH M. OSTROY and ROSS M. STARR, "Money and the Decentralization of Exchange," *Econometrica*, Vol. 42, No. 6, 1974.

No. 423. DONALD J. BROWN and ABRAHAM ROBINSON, "Non-standard Exchange Economies," *Econometrica*, Vol. 43, No. 1, 1975.

No. 424. ALVIN K. KLEVORICK, "Law and Economic Theory: An Economist's View," *American Economic Review*, Vol. 65, 1975.

No. 425. WILLIAM D. NORDHAUS, "The Political Business Cycle," *The Review of Economic Studies*, Vol. XLII, 1975.

No. 426. MARTIN SHUBIK, "Oligopoly Theory, Communication, and Information," *American Economic Review*, Vol. 65, 1975.

No. 427. W. C. BRAINARD and R. N. COOPER, "Empirical Monetary Macroeconomics: What Have We Learned in the Last 25 Years?" *American Economic Review*, Vol. 65, 1975.

No. 428. JAMES TOBIN, "Keynesian Models of Recession and Depression," *American Economic Review*, Vol. 65, 1975.

No. 429. GARY SMITH, "Pitfalls in Financial Model Building: A Clarification," *American Economic Review*, Vol. 65, No. 3, 1975.

No. 430. MARTIN SHUBIK, "On the Eight Basic Units of a Dynamic Economy Controlled by Financial Institutions," *Review of Income and Wealth*, Ser. 21, No. 2, 1975.



## COWLES FOUNDATION DISCUSSION PAPERS

*July 1, 1973 – June 30, 1976*

- No. 362. H. LELAND, Regulation of Natural Monopolies and the Fair Rate of Return.
363. M. SHUBIK, A Theory of Money and Financial Institutions, Part XI: Trade with Fiat Money but No Individual Trust – A Preliminary Stage Towards Banking.
364. M. SHUBIK, A Theory of Money and Financial Institutions, Part XII: A Dynamic Economy with Fiat Money Without Banking and With and Without Production Goods.
365. M. SHUBIK, The General Equilibrium Model is the Wrong Model and a Noncooperative Strategic Process Model is a Satisfactory Model for the Reconciliation of Micro and Macroeconomic Theory.
366. M. SHUBIK, A Theory of Money and Financial Institutions, Part XIII: Trade with Spot Markets, Fiat Money and International Banking.
367. M. SHUBIK, A Theory of Money and Financial Institutions, Part XVII: On the Eight Basic Units of a Dynamic Economy with Spot and Futures Markets.
368. M. SHUBIK, A Theory of Money and Financial Institutions, Part XV: A Trading Model to Avoid Tatonnement Metaphysics.
369. K. IWAI, Towards Keynesian Micro-Dynamics of Price, Wage, Sales and Employment.
370. J. D. SARGAN, The Moments of the 3SLS Estimates of the Structural Coefficients of a Simultaneous Equation Model.
371. M. SHUBIK, On the Role of Numbers and Information in Competition.
372. R. M. STARR, Transactions Technology and the Use of Intermediary Agents.
373. J. VOS and M. W. VOS, The Walrasian and Von Neumann Equilibria: A Comparison.
374. M. SHUBIK, A Theory of Money and Financial Institutions, Part XVIII: A Noncooperative Model of a Closed Economy with Many Traders and Two Bankers.
375. J. E. STIGLITZ, Equilibrium Wage Distributions.
376. S. J. LEPPER, Fiscal Capacity, Equalization and Public Expenditure for Education.
377. M. SHUBIK, A Theory of Money and Financial Institutions, Part XVI: Mathematical Models for a Theory of Money and Financial Institutions.

- No. 378. S. SMALE, Global Analysis and Economics VI Geometric Analysis of Pareto Optima and Price Equilibria under Classical Hypotheses.
379. M. SHUBIK, Competitive Equilibrium Contingent Commodities and Information.
380. G. SMITH, Okun's Law Revisited.
381. G. SMITH, Further Notes on the Misuse of  $R^2$ .
382. W. C. BRAINARD and G. SMITH, The Value of A Priori Information in Estimating a Financial Model.
383. G. SMITH, Multicollinearity and Forecasting.
384. W. BUITER and J. TOBIN, Long Run Effects of Fiscal and Monetary Policy on Aggregate Demand.
385. K. IWAI, On Disequilibrium Economic Dynamics (Part I) Microfoundations of Wicksellian Disequilibrium Dynamics.
386. K. IWAI, On Disequilibrium Economic Dynamics (Part II) Wicksellian Disequilibrium Dynamics, Say's Law and the End of the Natural Rate Theory of Unemployment.
387. J. TOBIN, Keynesian Models of Recession and Depression.
388. M. SHUBIK, Oligopoly, Theory, Communication and Information.
389. C. EAVES, A Finite Algorithm for the Linear Exchange Model.
390. C. EAVES, and H. SCARF, The Solution of Systems of Piecewise Linear Equations.
391. D. J. BROWN, Acyclic Aggregation Over Finite Sets of Alternatives.
392. J. EVERS, A Duality Theory for Convex  $\infty$ -Horizon Programming.
393. D. BROWN, Collective Rationality.
394. M. SHUBIK, A Theory of Money and Financial Institutions, Part XXI: Fiat Money, Bank Money, the Float and the Money Rate of Interest.
395. M. SHUBIK, A Theory of Money and Financial Institutions, Part XXIII: Fiat Money, Bank Money, the Force of the Rate of Interest and the Vanishing Float.
396. G. KRAMER, A Dynamical Model of Political Equilibrium.
397. R. C. FAIR, On Controlling the Economy to Win Elections.
398. D. HENDRY and G. ANDERSON, Testing Dynamic Specification in Small Simultaneous Systems: An Application to a Model of Building Society Behavior in the United Kingdom.
399. D. HENDRY, The Limiting Distribution of Inconsistent Instrumental Variables Estimators in a Class of Stationary Stochastic Systems.

- No. 400. D. HENDRY and F. SRBA, A Control Variable Investigation of the Properties of Autoregressive Instrumental Variables Estimators for Dynamic Systems.
401. J. EVERS, Invariant Competitive Equilibrium in an  $\infty$ -Horizon Economy with Negotiable Shares.
402. F. CAMPBELL and G. SMITH, A Critical Analysis of Ridge Regression.
403. V. GINSBURGH and I. ZANG, Price Taking or Price Making Behavior: An Alternative to Full Cost Price Functions.
404. K. PECK, The Estimation of a Dynamic Equation Following a Preliminary Test for Autocorrelation.
405. W. NORDHAUS, The Demand for Energy: An International Perspective.
406. D. BROWN and P. LOEB, The Value of a Nonstandard Competitive Allocation.
407. G. HEAL, The Influence of Interest Rates on Resource Prices.
408. T. KOOPMANS, Examples of Production Relations Based on Microdata.
409. R. MANTEL, Implications of Microeconomic Theory for Community Excess Demand Functions.
410. P. DUBEY and M. SHUBIK, A Theory of Money and Financial Institutions, Part XXIV: Trade and Prices in a Closed Economy with Exogenous Uncertainty, Different Levels of Information, Money and No Futures Markets.
411. K. IWAI, On Disequilibrium Economic Dynamics, Part III: A Keynesian Theory of Money Wage Adjustment.
412. V. GINSBURGH and J. WAELBROECK, A General Equilibrium Model of World Trade, Part I: Full Format Computation of Economic Equilibrium.
413. V. GINSBURGH and J. WAELBROECK, A General Equilibrium Model of World Trade, Part II: The Empirical Specification.
414. P. DUBEY and M. SHUBIK, A Closed Economy with Exogenous Uncertainty, Different Levels of Information, Futures and Spot Markets.
415. W. NORDHAUS, Inflation Theory and Policy.
416. M. SHUBIK, On the Number of Types of Markets with Trade in Money.
417. M. SHUBIK, The Theory of Money and Financial Institutions, Part XXVII: Beyond General Equilibrium.
418. R. FAIR, The Effect of Economics Events on Votes for Presidents.

- No. 419. E. VILKAS, On a General Approach to Optimality in Game Theory.
420. R. FAIR, The Use of Optimal Control Techniques to Measure Economic Performance.
421. T. KOOPMANS, Concepts of Optimality and Their Uses.
422. P. DUBEY and M. SHUBIK, The Noncooperative Equilibria of a Closed Trading Economy with Market Supply and Bidding Strategies.
423. K. IWAI, On Disequilibrium Economic Dynamics, Part IV: The Theory of Long-run Phillips Curve.
424. M. SHUBIK, A Theory of Money and Financial Institutions, Part XXX: The Optimal Bankruptcy Rule in a Trading Economy Using Fiat Money.
- 424R. M. SHUBIK and C. WILSON, A Theory of Money and Financial Institutions, Part XXXI: (Revised) The Optimal Bankruptcy Rule in a Trading Economy Using Fiat Money.
425. D. BROWN and G. HEAL, Existence of a Market Equilibrium in an Economy with Increasing Returns to Scale.
426. G. SMITH and W. STARNES, A Short-run Two Commodity Macroeconomic Model.
427. W. BRAINARD and J. TOBIN, Asset Markets and the Cost of Capital (for the Fellner Festschrift).
428. R. MANTEL, The Linear Exchange Model and Induced Welfare Optima.
429. P. DUBEY and M. SHUBIK, A Closed Economic System with Production and Exchange Modelled as a Game of Strategy.
430. R. FAIR, A Model of the World Economy.
431. J. EVERS and M. SHUBIK, A Dynamic Economy with Shares, Fiat, Bank and Accounting Money.
432. C. WILSON, A Model of Insurance Markets with Asymmetric Information.

## PUBLICATIONS AND PAPERS BY STAFF MEMBERS

July 1, 1973 – June 30, 1976

This list contains papers which were published during the period and resulted from work at the Cowles Foundation, papers published while the author was a staff member, and a few other papers referred to in the text of the Report.

### BRAINARD, WILLIAM C.

Papers: CFP 427

Discussion Papers: CFDP 382, 427

Other Publications:

- A. "Tax Reform and Income Redistribution: Issues and Alternatives," presented at ASSA meetings in New York, December 1973 (with J. Tobin, J. Shoven, J. Bulow).
- B. "Estimation of the Savings Sector in a Disequilibrium Model" (with G. Smith), presented at the North American Meeting of the Econometric Society, San Francisco, December 1974.
- C. "Some Results of the American Economic Association Readership Survey," presented at the December 1975 meetings of the American Economic Association.

### BROWN, DONALD J.

Papers: CFP 418, 419, 423

Discussion Papers: CFDP 391, 393, 406, 425

Other Publications:

- A. "The Core of a Purely Competitive Economy," presented at the 1974 conference on Nonstandard Analysis at Oberwolfach, Germany.

### FAIR, RAY C.

Discussion Papers: CFDP 397, 418, 420, 430

Other Publications:

- A. *A Model of Macroeconomic Activity, Volume II: The Empirical Model*, Ballinger Publishing Company, 1976.
- B. "A Note on an Iterative Technique for Absolute Deviations Curve Fitting" (with J. K. Peck), mimeograph, November 1974.

### KLEVORICK, ALVIN K.

Papers: CFP 421, 424

### DUBEY, PRADEEP

Discussion Papers: CFDP 410R, 422, 429

### EAVES, B. CURTIS

Discussion Papers: CFDP 389, 390

### EVERS, JOSEPH, J.M.

Discussion Papers: CFDP 392, 401, 431

### GINSBURGH, VICTOR

Discussion Papers: CFDP 403, 412, 413

HEAL, GEOFFREY

Discussion Papers: CFDP 407

HENDRY, DAVID F.

Discussion Papers: CFDP 398, 399, 400

IWAI, KATSUHIITO

Papers: CFP 415

Discussion Papers: CFDP 369, 385, 386, 411, 423

KOOPMANS, TJALLING C.

Papers: CFP 405

Discussion Papers: CFDP 408, 421

Other Publications:

- A. "Ways of Looking at Future Economic Growth, Resource and Energy Use," in *Energy: Demand, Conservation and Institutional Problems*, M. S. Macrakis, ed., MIT Press, 1974.
- B. "Proof for a Case Where Discounting Advances the Doomsday," IIASA Research Report RR-74-1 to appear in *Review of Economic Studies*.
- C. "Analytical Aspects of Policy Studies," presented at IIASA conference, May 1976.
- D. "Economics of Exhaustible Resources," to appear in *Frontiers of Quantitative Economics*, Volume III. North-Holland Publishing Company.

KRAMER, GERALD H.

Papers: CFP 421

Discussion Papers: CFDP 396

Other Publications:

- A. "Theories of Political Process," to appear in *Frontiers of Quantitative Economics*, Volume III, North-Holland Publishing Company.
- B. "Commentary," to appear with reprint of "Sophisticated Voting over Multi-Dimensional Choice Spaces," in *Social Science Yearbook, Volume 5*, Munich-Verlag.
- C. "Comment on Arcelus and Meltzer, 'The Effect of Aggregate Economic Conditions on Congressional Elections'" with Saul Goodman, *American Political Science Review*, December 1975.

LEPPER, SUSAN J.

Discussion Papers: CFDP 376

Other Publications:

- A. "Wage Indexing: Boon or Boom?" paper presented at the Econometric Society Meetings, December 1974.

MANTEL, ROLF

Discussion Papers: CFDP 409, 428

NORDHAUS, WILLIAM D.

Papers: CFP 401, 406, 408, 425

Discussion Papers: CFDP 405, 415

Other Publications:

- A. "A Technique for Decomposing Inflation" (with J. Shoven), Stanford

University Memorandum No. 181, to appear in *Volumes on Income and Wealth*.

- B. "Energy and Economic Growth," prepared for the North American Study Group "The Middle East and the Crisis in Relations Among the Industrialized States: The International Economic and Political Spinoff of the Energy Crisis."
- C. "The 1974 Report of the President's Council of Economic Advisers: Energy in the Economic Report," *The American Economic Review*, September 1974.
- D. "World Modelling from the Bottom Up," IIASA Research Memorandum RM-75-10, Austria, March 1975.
- E. "Can We Control Carbon Dioxide?" IIASA Working Paper.
- F. "Mental Maps: Without Spaghetti They are Baloney," IIASA Working Paper WP-75-44, Austria, April 1975.
- G. "The Demand for Energy: An International Perspective," prepared for Workshop on Energy Demand, May 1975.
- H. "Proceedings of the Workshop on Energy Demand," IIASA Cp-76-1, May 1975.
- I. "The Effect of Incomes Policies" (with W. A. H. Godley and K. J. Coutts).
- J. "Short-Run Shifting of Corporation Taxes" (with W. A. H. Godley and K. J. Coutts).

PECK, JON K.

Discussion Papers: CFDP 404

Other Publications:

- A. "A Note on an Iterative Technique for Absolute Deviations Curve Fitting" (with R. C. Fair), mimeograph, November 1974.

SARGAN, JOHN D.

Discussion Papers: CFDP 370

SCARF, HERBERT E.

Discussion Papers: CFDP 390

Other Publications:

- A. "The 1975 Nobel Prize in Economics: Resource Allocation," *Science*, November 1975, Volume 190, pp. 649 and 710-712.

SHUBIK, MARTIN

Papers: CFP 407, 416, 417, 420, 426, 430, 432

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