THE COWLES COMMISSION AND FOUNDATION FOR RESEARCH IN ECONOMICS: BRINGING MATHEMATICAL ECONOMICS AND ECONOMETRICS FROM THE FRINGES OF ECONOMICS TO THE MAINSTREAM

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The Cowles Commission and Foundation for Research in Economics:

Bringing Mathematical Economics and Econometrics from the Fringes of Economics to the Mainstream

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Abstract: Founded in 1932 by a newspaper heir disillusioned by the failure of forecasters to predict the Great Crash, the Cowles Commission promoted the use of formal mathematical and statistical methods in economics, initially through summer research conferences in Colorado and through support of the Econometric Society (of which Alfred Cowles was secretary-treasurer for decades). After moving to the University of Chicago in 1939, the Cowles Commission sponsored works, many later honored with Nobel Prizes but at the time out of the mainstream of economics, by Haavelmo, Hurwicz and Koopmans on econometrics, Arrow and Debreu on general equilibrium, Yntema and Mosak on general equilibrium in international trade theory, Arrow on social choice, Koopmans on activity analysis, Klein on macroeconometric modelling, Lange, Marschak and Patinkin on macroeconomic theory, and Markowitz on portfolio choice, but came into intense methodological, ideological and personal conflict with the emerging "Chicago school." This conflict led the Cowles Commission to move to Yale in 1955 as the Cowles Foundation, directed by James Tobin (who had declined to move to Chicago to direct it). The Cowles Foundation remained a leader in the more technical areas of economics, notably with Tobin's "Yale school" of monetary theory, Scarf's computable general equilibrium, Shubik in game theory, and later Phillips and Andrews in econometric theory but as formal methods in economic theory and econometrics pervaded the discipline of economics, Cowles (like the Econometric Society) became less distinct from the rest of economics.

This paper, which will be published as the *New Palgrave* entry on Cowles, is an overview of an archivally-based history of the Cowles Commission and Foundation commissioned by the Cowles Foundation.

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INTRODUCTION

The American research center the Cowles Commission for Research in Economics and its successor since 1955 the Cowles Foundation have played a leading role in promoting formal economic theory and mathematical and statistical techniques in economics, closely linked, especially in its first decades, with the Econometric Society and *Econometrica*. Of the eight Cowles monographs published in the 1950s, from *Statistical Inference in Dynamic Economic Models* (Koopmans, ed., 1950) to *Theory of Value* (Debreu 1959), only one did not figure in a Nobel citation after the 1969 establishment of the Royal Bank of Sweden Prize in Economic Science in Memory of Alfred Nobel. The page listing research associates and research consultants in the Commission's 1952 report (unnumbered page preceding Christ 1952) listed nine future Nobel laureates. Yet despite such distinction, the Commission, then located in the Economics Department of the University of Chicago, was in methodological and personal conflict with another group in the same department also notable for its numerous future Nobel laureates, the emerging "Chicago school" of economics. After the move from Chicago to Yale in 1955, the Cowles Foundation continued and continues to excel in economic theory and econometrics, with several outstanding individual and group contributions, but was no longer as distinctive within economics, as characteristic approaches of the Cowles Commission from simultaneous-equations econometric models and general equilibrium to social choice, portfolio theory and activity analysis pervaded the discipline of economics.

ALFRED COWLES 3RD, THE ECONOMETRIC SOCIETY AND THE ORIGINS OF THE COWLES COMMISSION

The Cowles Commission and the journal *Econometrica* owed their existence, and the Econometric Society its prosperity, to one man's disillusionment with stock forecasts following the Wall Street crash of October 1929 (see Walter Friedman 2014, and compare the 1930 revised edition of Garfield Cox's *Appraisal of American Business Forecasts* with the 1929 first edition). Alfred (Bob) Cowles 3rd, *Chicago*

Tribune heir turned Colorado Springs investment counsellor, assembled evidence that stock market forecasters (himself included) were no better than chance in predicting stock price changes (Cowles 1931, revised as Cowles 1933). As his Colorado Springs neighbor Robert Rhea remarked in one of his *Dow Theory Comments* (reprinted in Dimand and Veloce 2010), Cowles had been a forecaster "but now pitches for the other team." To use multiple correlation analysis in his study, Cowles turned for assistance to Harold T. Davis, an Indiana University mathematics professor and Colorado College alumnus who summered in Colorado Springs. Davis told Cowles about the Econometric Society, founded at the end of December 1930, with Irving Fisher of Yale as its president, to promote "the advancement of economic theory in relations to statistics and mathematics." Cowles, a Yale graduate (class of 1913) wrote to Fisher in August 1931, offering to fund both a journal and a research organization, promising ample resources and complete academic freedom for both. Fisher delightedly read the letter over the telephone to Charles F. Roos, a mathematician who secretary-treasurer of the Econometric Society and permanent secretary of the American Association for the Advancement of Science. Roos understandably asked whether it was a crank letter, but Fisher was able to reassure him: Fisher did not know Cowles but had known Cowles's father and uncle when they and Fisher were Yale undergraduates in the 1880s. Perhaps more importantly, Alfred Cowles, Jr. and 3rd and Fisher had all been tapped for the same Yale senior society, Skull and Bones (see Christ 1952, Bjerkholt 2017, Dimand 2019), and Alfred Cowles 3rd had joined with others in his family to endow the Cowles Foundation for the Study of Government at Yale University, which supported a Yale chair in political science named in memory of their grandfather (the founding treasurer and business manager of the *Chicago Tribune*). A further bond between Cowles and Fisher was that both had survived tuberculosis. Cowles's tact was such that he was able to pursue research showing the failure of stock forecasts without offending Fisher, notorious to the world beyond economics as the man who had declared in October 1929 that stock prices appeared to have reached a permanently high plateau – and who went to his grave believing that he had a formula for predicting stock price movements (Sasulty 1947, Dimand 2019).

In a letter to Fisher, written at Fisher's home in New Haven on October 18, 1931, Cowles promised an initial $12,000 a year for the Cowles Commission, to be increased if the project flourished, and pledged "to make up any deficit in the proposed journal, 'Econometrica,' including all the expenses of editing, printing, etc." and suggested the Norwegian econometrician Ragnar Frisch as editor (Bjerkholt 1998). Since Cowles had never met Frisch, Fisher and Roos undoubtedly put forward the name of Frisch, the future co-winner of the first Nobel Prize in economics in 1969 and the driving force behind the creation of the Econometric Society during his year as a visiting professor at Yale (see Bjerkholt 1998, 2017, Frisch 2010). European members of the council of the Econometric Society, notably François Divisia, were skeptical of Cowles's motives and delegated Frisch to investigate. A week with Cowles in Colorado Springs persuaded Frisch that Cowles was sincere in his intention to support research without infringing the academic freedom of researchers or trying to promote his own interests, financial or intellectual. In addition to being president of the Cowles Commission, Cowles was treasurer of the Econometric Society from 1932 (and secretary from 1937) and business manager of *Econometrica*. Until Cowles made his offer, the Econometric Society was dependent on membership due of $2 a year for members in the United States and $1 a year for members elsewhere. Except for agricultural research, the US Government spent little on scientific research before World War II, so Cowles played a role as a private benefactor of research in economic theory, mathematical economics and econometrics in the United States in the 1930s comparable to Alfred Loomis in American physics in the same era (see Conant 2002). After the Cowles Commission's first decade, Alfred Cowles's annual grant was no longer its sole source of funding. Thus, the acknowledgements to Kenneth Arrow's Cowles Monograph *Social Choice and Individual Values* (1951, p. ix) stated that his research was supported partly by a grant from the Rockefeller Foundation for the Cowles Commission's general research program and partly by a contract between the RAND Corporation (which conducted research for the US Air Force) and the Cowles Commission for the study of resource allocation, while the contract with RAND funded the conference on activity analysis published as Koopmans (ed., 1951) and the research of all the Cowles Commission staff members contributing to it (except for Clifford Hildreth, who had a grant from the Rockefeller Foundation). In July 1951, the Office of Naval Research began funding Cowles Commission research on choice under uncertainty.

THE COLORADO YEARS

From 1935 through 1940, the Cowles Commission hosted annual month-long summer research conferences on economics and statistics in Colorado Springs, bringing leading mathematical economists, economic theorists and economic statisticians from around the world, and published volumes of summaries of the papers. The month-long format of two papers a day (plus a few public lectures) allowed for extended and intensive discussion, far beyond what was possible at an Econometric Society meeting, held over a single weekend with simultaneous multi-paper sessions. For example, the morning of July 12, 1940, was devoted to Wassily Leontief on "Some Results of an Empirical Study of the General Equilibrium," the afternoon to Paul Samuelson (a year before his doctorate) on "The Stability of Equilibrium." At a time when mathematical approaches to theoretical and empirical economics were distinctly a minority taste, encountered considerable resistance, the Cowles Commission created a sympathetic, knowledgeable forum for such research.

Alfred Cowles continued his own research on the failures of stock forecasters[1] without pressing other researchers at the Cowles Commission or its conferences to work on that topic but did involve the

[1] See, e.g., the 1960 *Econometrica* exchange between Cowles and Holbrook Working reprinted in Cootner (ed., 1964), a collection that places Cowles's work in the context of the emergence of the concept of efficient financial markets.

Commission in the compilation of an invaluable database of common stock prices going back to 1871 (Cowles and Associates 1938). The first research directors of the commission, Charles Roos (1934) and Harold Davis (1941a, 1941b), along with Gerhard Tintner (1940), engaged in a line of econometric research that stressed curve-fitting and the use of periodograms (an early form of spectral analysis) to decompose fluctuations in economic time series into numerous cycles differing in periodicity and amplitude, an approach that was sept away at Cowles (and later elsewhere) by the probabilistic revolution in econometrics initiated by Haavelmo (1941) (see Epstein 1987, Morgan 1990, Quin 1991, Hoover 2014).

With the death of his father in 1939, Alfred Cowles 3rd felt obliged to move back to Chicago to oversee his family's business interests and took the Cowles Commission with him. The University of Chicago took the Cowles Commission into affiliation with its Department of Economics, filling the gap left by the death in a traffic accident the previous year of the university's sole econometrician, Henry Schultz (1938) (see Lange, McIntyre and Yntema 1942, essays in Schultz's memory). Theodore Yntema, an international trade theorist who taught accounting and statistics at the University of Chicago, became research director of the Cowles Commission (1939 to 1942) but his interests strayed beyond academia, and he eventually joined the Ford Motor Company as vice-president for finance. The next director, who left a much deeper imprint on the Cowles Commission, was Jacob (Jascha) Marschak, a mathematical economist, monetary theorist and econometrician who had studied with Evgenii Slutsky in Kiev, taken a doctorate in Heidelberg, and directed the Institute of Statistics at Oxford University. Marschak, director from 1943 to 1948, and his handpicked successor Tjalling Koopmans, director from 1948 to 1955, recruited a team of outstanding researchers, including many future Nobel laureates, who kept the Cowles Commission at the forefront of the more technical developments in economics (except game theory, which flourished in Princeton).

THE COWLES APPROACH TO SIMULTANEOUS-EQUATIONS ECONOMETRIC MODELS

The Cowles Commission approach to identification and estimation of structural simultaneous-equations time-series models, and to the use of such models for prediction and for policy evaluation, was presented in Cowles Commission Monographs on *Statistical Inference in Dynamic Economic Models* (Koopmans, ed., 1950, resulting from a January 1945 conference) and *Studies in Econometric Method* (Hood and Koopmans, eds., 1953), volumes which included notable contributions by, among others, Koopmans, Marschak, Jean Bronfenbrenner, Leonid Hurwicz, Trygve Haavelmo, Herbert Simon and mathematical statisticians T. W. Anderson and Abraham Wald (see Hildreth 1986, Epstein 1987, Morgan 1990, Quin 1993, Christ 1994, Hendry and Morgan, eds., 1995). Lawrence Klein's Cowles Monograph on *Economic Fluctuations in the United States, 1921-1941* (1950) provided an empirical counterpart to these methodological volumes, marking the beginning of Klein's leadership in macroeconometric modeling that eventually modelled the world economy by combining national models in Project Link (see Klein 1991, Bodkin, Klein and Marwah 1991, Welfe 2013). These developments had roots in Koopmans's dissertation on *Linear Regression Analysis of Economic Time Series* (1937), in the League of Nations study on *Statistical Testing of Business Cycle Theories* by Koopmans's teacher Jan Tinbergen (1939), in work by Frisch (see Haavelmo's chapter on Frisch in Koopmans, ed., 1950), in earlier *Econometrica* articles by Marschak (see Marschak 1949), and especially in Haavelmo's dissertation and *Econometrica* supplement on the "Probability Approach to Econometrics" (1941, reprinted as a Cowles Commission Paper, see Hoover 2014).

Enormously influential, the Cowles Commission approach to structural econometric modelling was also controversial. Ta-Chung Liu (1960) doubted that there were enough truly exogenous variables to identify the equations of large macroeconomic model. Robert Lucas's celebrated "Lucas critique" of econometric policy evaluation denied that models estimated with data observed under a given policy regime could predict what would happen if policy changed, because the coefficients would change unless the models were derived directly from individual optimization (articles collected in Lucas 1981). Christopher Sims (1980) questioned whether *a priori* economic theory could provide adequate insight to justify the exclusionary restrictions on coefficients needed to identify structural models, and advocated a vector autoregression approach that revived, with more modern statistical techniques, the atheoretical statistical approach to economic time-series of Burns and Mitchell (1946), which Koopmans (1947) had decried as "measurement without theory." Such critiques, and movements in macroeconomics away from the Keynesian economics associated with Klein and other structural modelers, led to a turn away from academic research on Cowles-style structural macroeconometric models (with the notable exception of Ray Fair 1984, 1994, 2004 at the Cowles Foundation), yet such models remained widely used in central banks, governments and the private sector.

ACTIVITY ANALYSIS, SOCIAL CHOICE AND GENERAL EQUILIBRIUM

Of the twelve Cowles Monograph from number 10 in 1950 on *Statistical Inference in Dynamic Models* (Koopmans, ed., 1950) through numbers 19, 20 and 21 on portfolio choice and financial markets, edited by Donald Hester and James Tobin in 1967 (see Tobin's contributions reprinted in Tobin 1971-96), eleven were written or edited or co-edited by a future Nobel laureate (and three other future Nobel laureates contributed at least two chapters each), and the citations for their Nobel Memorial Prizes stressed their work in those Cowles Monographs. These awards recognize the pivotal rule of the work done at the Cowles Commission and Foundation in shaping, in addition to structural econometric modeling and the portfolio choice approach to money and finance, key areas of microeconomic theory (see Christ 1952, Hildreth 1986, Mirowski 2002, Düppe and Weintraub 2014a, 2014b, Herfeld 2017, 2018): activity analysis (linear and nonlinear programming), social choice and general equilibrium analysis (but, despite early expressions of interest, not game theory).

Irving Fisher, who served on the advisory council of the Cowles Commission until that council (representing the Econometric Society) was replaced in 1943 by an advisory committee representing the University of Chicago, had independently invented general equilibrium analysis in his 1891 Yale dissertation *Mathematical Investigations in the Theory of Value and Price* (in Fisher 1997, Vol. 1), only managing to obtain books by Walras and Edgeworth when the thesis was almost ready for submission, and had gone beyond them to build a hydraulic mechanism to simulate the simultaneous determination of equilibrium prices and quantities. John von Neumann and Abraham Wald made the first rigorous treatments of the existence of general equilibrium, under stringent assumptions, in Karl Menger's mathematical colloquium in Vienna in the 1930s (see papers by Arrow and by Debreu in Arrow et al. 1991). General equilibrium analysis was extended to international trade theory in two Chicago dissertations by Theodore Yntema (1932), a student of Henry Schultz and Jacob Viner who was director of Cowles from 1939 to 1942, and by Jacob Mosak (1944), a student of Viner, Lange and Yntema whose thesis became a Cowles Monograph. Much more widely influential was the reformulation of general equilibrium at the Cowles Commission by Kenneth Arrow and Gerard Debreu, at first independently and then in a joint article (Arrow and Debreu 1954) proving the existence of general equilibrium (that is, finding a set of sufficient conditions for existence of a solution), a line of work culminating in Debreu's *Theory of Value* (1959). Lionel McKenzie (1954a) also published an existence proof for general equilibrium at the same time and in the same journal issue as Arrow and Debreu (1954), and then came to Cowles as a visitor (McKenzie 1954b), but unlike Arrow and Debreu he never became a Nobel laureate and economists more often refer to the Arrow-Debreu model of general equilibrium than to Arrow-Debreu-McKenzie (see Düppe and Weintraub 2014a on the issues of scientific credit).

After Cowles had moved to Yale, Herbert Scarf provided examples of global instability of general equilibrium, explored (with Debreu) the relationship between the core of an economy and the set of attainable competitive equilibria, and created the first fixed-point algorithm for computation of general equilibrium (Scarf with Hansen 1973). Showing how to find the solution to the system of equations characterizing a Walrasian general equilibrium, rather than just proving by contradiction that some solution must exist, Scarf with Hansen (1973) created the flourishing field variously known as computable general equilibrium, numerical general equilibrium or applied general equilibrium. Scarf's algorithm fulfilled the ambitions of Fisher's hydraulic mechanism for simulating general equilibrium, and appropriately Scarf first announced it in *Ten Economic Studies in the Tradition of Irving Fisher* (Fellner et al. 1967). Cowles remains a center of general equilibrium research (see, e.g., Bewley 2008) but general equilibrium, a distinctive Cowles Commission interest in 1954, pervades economics sixty-five years later.

While Arrow participated in proving the existence of general equilibrium, Arrow created modern social choice theory by proving the nonexistence of a social welfare function, a rule for aggregating preferences to make policy choices that would satisfy a short list of desirable criteria: "we assume a given social welfare function satisfying Conditions 1-5 and show that the assumption leads to a contradiction" (Arrow 1951, p. 51). What became known as the "Arrow impossibility theorem" not only provided the founding insight for social theory, but also testified to the scientific integrity of the research: Arrow had hoped to find the conditions for a collective rational, transitive mechanism for social choice, but logic led him to show that the goal was unattainable.

Activity Analysis of Production and Allocation: Proceedings of a Conference (Koopmans, ed., 1951) introduced linear and nonlinear programming to economic analysis (see Düppe and Weintraub 2014b). The conference brought together Koopmans and Cowles research associates and research consultants with George Dantzig's Air Force operations researchers and the Princeton game theorists (David Gale, Harold Kuhn and Albert Tucker wrote on "Linear Programming and the Theory of Games" and Oskar Morgenstern on "The Accuracy of Economic Observations") as well as other notable figures as Nicholas Georgescu-Roegen, Paul Samuelson and Robert Dorfman (that at University of California, Berkeley, soon to move to Harvard and collaborate with Samuelson and Solow at MIT on linear programming). Dantzig's

"Proof of the Equivalence of the Programming Problem" (chapter XX) showed that his simplex algorithm for solving linear programming problems could also be used to find the solution to two-person, constant-sum games. In addition to Cowles research associates, who were located at the University of Chicago, a list of future Nobel laureates at the conference is a reminder that the Cowles Commission also included research consultants affiliated with other universities: Kenneth Arrow at Stanford, Leonid Hurwicz at the University of Illinois, Herbert Simon at Carnegie Tech.

Leonid Hurwicz and Jacob Marschak wrote long, positive review articles (17 pages by Hurwicz in the *American Economic Review*, 19 pages by Marschak in the *Journal of Political Economy*, both reprinted in Cowles Commission Paper No. 13) welcoming von Neumann and Morgenstern's *Theory of Games and Economic Behavior* (1944), and on May 25 and 26, 1945, John von Neumann presented a two-day Cowles seminar on the book. The seven Cowles seminars from January to April 1949 were about the theory of games: Chicago's Bayesian statistician L. J. Savage on zero-sum games, Arrow on multi-person games and on applications to economics, Marschak on measurable utility, Stanford statistician Meyer A. Girshick on continuous games, Savage on applications to statistical inference, and Herbert Simon on applications to politics and administration. John Nash came from Princeton to speak about "The Extended Bargaining Problem" in October 1950. But this promising beginning of Cowles interest in game theory then petered out, except for the axiomatization of expected utility theory in an appendix to the 1947 second edition of von Neumann and Morgenstern (1944), taken up by Marschak, Arrow and Markowitz (and a 1953 AEA proceedings piece by Hurwicz on "What Has Happened to the Theory of Games?"). Game theory flourished at the Cowles Foundation only after the arrival of Martin Shubik, who had been Morgenstern's doctoral student and Nash's coauthor at Princeton, as a visitor in 1962 and faculty member in 1963 (see Shubik 1982). Yale's Department of Economics had an outstanding nonmathematical game theorist and future Nobel laureate, Thomas Schelling, from 1953 (two years before the arrival of the Cowles Foundation) until Schelling moved to Harvard in 1958.

METHODOLOGICAL CONFLICT IN CHICAGO AND THE MOVE TO YALE

While at the University of Chicago, the Cowles Commission came into methodological and personal conflict with the emerging "Chicago school" of economics. Milton Friedman (1946) wrote a scathing critique of the theorizing of Oskar Lange's Cowles Monograph on *Price Flexibility and Employment* (1944) as verbal mathematics without empirical content, although he was no better pleased when Lawrence Klein's Cowles Monograph (1950) attempted to provide empirical content to Keynesian macroeconomics with a simultaneous-equations model of the interwar US economy (Friedman had previously reviewed quite critically the second volume of Tinbergen 1939). At Columbia, Arthur Burns (who had supervised Friedman's dissertation) published a methodological critique of Keynesian macroeconomics in the 1946 annual report of the National Bureau of Economic Research (reprinted in Burns 1954). Tjalling Koopmans (1947) in turn criticized Burns and Mitchell (1946) as "Measurement without Theory," an approach to business cycle analysis through techniques of time series analysis (such as examining leads and lags to find leading indicators) instead of starting from economic theory (of which Mitchell, an institutionalist and Veblen student, was skeptical). Koopmans contrasted the atheoretical NBER approach with the Cowles method of using *a priori* economic theory to identify the equations of a simultaneous-equations model by specifying which variables would have coefficients of zero in which equations (as in Koopmans, ed., 1950, Klein 1950, Hood and Koopmans, eds. 1953). Friedman's "Wesley C. Mitchell as an economic theorist" (1950) responded implicitly to Koopmans by insisting that Mitchell's work was economic theory, just not the sort of mathematical, general equilibrium theory promoted at the Cowles Commission (see also Grayson 1948 and the exchange between Koopmans and Rutledge Vining, extensively excerpted in Hendry and Morgan, eds., 1995). Structural macroeconometric modelling was dominant in the 1960s, but more recently the Burns-Mitchell NBER approach to economic time series, utilizing statistical theory but little economic theory, is echoed in the vector autoregression (VAR) approach of Christopher Sims (1980), who spent several years with the Cowles Foundation at Yale.

Milton Friedman and what became known as the Chicago school, committed to market efficiency and limited government intervention (see Reder 1982), were suspicious of the Cowles Commission's work in mathematical economics, econometrics and Keynesian macroeconomics as creating tools for central planning and activist Keynesian demand management. "I believe that mathematicians, where pure mathematicians or economists or statisticians, tend to be favorable to central planning … When they enter a field like economics, they carry over the belief that all problems have clear-cut solutions and that they are competent to find them" wrote Friedman (in Friedman and Friedman 1998, p. 262). Friedman recalled that "I developed a reputation as something of a hair shirt since I was, and still am, a persistent critic of the approach to the analysis of economic data that became known as the Cowles approach" (Friedman and Friedman 1998, p. 197). In the next paragraph, without further mention of such friction, he speculated that the departure of the Cowles Commission to Yale in 1955 was due to "a combination of [Alfred] Cowles's ties to Yale, of which he was a graduate, and financial incentives offered by Yale that Chicago was unable to match" (1998, p. 198).

With Tjalling Koopmans scheduled to take the sabbatical during which he wrote *Three Essays on the State of Economic Science* (1957), in 1953 Marschak, Koopmans and Alfred Cowles invited James Tobin of Yale University to move to Chicago to succeed Koopmans as research director of Cowles. "Although the Cowles appointment carried with it a professorship in the University of Chicago economics department, when I asked the chairman [Theodore Schultz, department chair 1946-61 and a future Nobel laureate] if the department would have been interested in me without the Cowles connection, he said 'No'" recalled Tobin (quoted in Dimand 2014, p. 14). When Tobin then telephoned Koopmans to decline the offer, Koopmans asked whether Yale would be interested in his spending his 1954-55 sabbatical at Yale. During Koopmans's sabbatical at Yale, negotiations were concluded for the 1955 transfer of Cowles from Chicago to Yale. The Cowles Commission, funded by an annual grant from Alfred Cowles, became the Cowles Foundation for Research in Economics at Yale University, with an endowment donated by Cowles and his family – as Yale University, at the initiative of Irving Fisher's colleague and former student James Harvey Rogers, had first proposed in 1937. Tobin was the first director of the Cowles Foundation, serving from 1955 until he joined President Kennedy's Council of Economic Advisers in 1961, when Koopmans became director again.

ASSET MARKETS, PORTFOLIO CHOICE AND MONEY

Jacob Marschak, in a series of articles including Marschak (1938), followed J. R. Hicks in situating the theory of money within a theory of asset market equilibrium (see Marschak 1951), and Marschak's doctoral student Don Patinkin started on the road to *Money, Interest and Prices* (1956) with four articles published in 1948 and 1949 while he was still at the Cowles Commission before his 1949 move to the Hebrew University of Jerusalem. Dickson Leavens, a Cowles Commission staffer calculating the mean and variance of returns on twenty random portfolios that Alfred Cowles compared to results of twenty forecasters in a 1944 update of Cowles (1933), noticed that returns on more diversified portfolios had lower variance. Without then knowing of Leavens's finding (published in *Trusts and Estates*, a magazine for finance practitioners), Marschak doctoral student Harry Markowitz (1952, 1959) applied Tjalling Koopmans's linear programming technique to portfolio diversification, minimizing variance (risk) for any given level of expected return (see Roy 1952 for a similar contemporary development). Markowitz's mean-variance analysis marked the beginning of the modern theory of finance, leading on to the Capital Asset Pricing Model (CAPM) of William Sharpe and John Lintner. Markowitz was concerned with how an optimizing wealth holder should diversify his or her portfolio. In 1958, while Markowitz and Marschak were his colleagues at the Cowles Foundation at Yale, James Tobin looked at the dual of Markowitz's problem: what the money demand function and asset market equilibrium would be if investors acted as Markowitz proposed. Taking money as a riskless asset, Tobin derived a separation theorem: all investors would hold the same portfolio of risky assets with each investor's degree of risk aversion determining how that investor's wealth would be divided between money and the optimally-diversified portfolio of risky assets. Subsequently, notably in contributions to three 1967 Cowles Foundation Monographs that Tobin edited with Donald Hester, Tobin and his students (notably William Brainard) developed the "Yale School" approach to the theory of money and assets, treating money as one among many assets that are imperfect substitutes for each other. Tobin stood out among his generation of leading Keynesian economists for the emphasis he placed on asset market equilibrium and on monetary policy (Tobin 1971-96, Dimand 2014). Like the Cowles Commission under Marschak's direction, the Cowles Foundation under Tobin's leadership was associated with a Keynesian position on the need for government stabilization of the economy, contrary to Milton Friedman's monetarism and later to the New Classical economics of Robert Lucas (1981). Nonetheless there were several leading non-Keynesian macroeconomists among Tobin's colleagues, such as William Fellner and Henry Wallich from the 1950s through the early 1970s and later Christopher Sims and Xavier Sala i Martin. Tobin's style of stock-flow consistent macroeconomic modeling, with many imperfectly-substitutable assets, retains some influence, but has lost ground within finance to models of arbitrage among perfectly-substitutable assets and within macroeconomics to dynamic stochastic general equilibrium (DSGE) models that are grounded in explicit individual optimization at the cost of making the strong assumptions necessary for the existence of a representative agent (so that they are in effect single-agent models). Agent-based modeling, an alternative to representative-agent models that has attracted recent attention, has roots (not always recognized because of differences in nomenclature) in the "microanalytic simulation" modeling of Guy Orcutt, initially at the University of Wisconsin and then from 1970 at Yale, with a chair in urban studies rather than at Cowles (Orcutt et al. 1961).

Another approach to finance associated with the Cowles Foundation has been the work of Robert Shiller (1989, 2000) on behavioral finance and behavioral economics, beginning with his studies showing that movements of asset prices were too volatile to be explained by changes in fundamentals. The efficiency of financial markets has also been challenged, a few doors down Hillhouse Avenue from the Cowles Foundation, by Benoit Mandelbrot (1997) in Yale's Mathematics Department, whose work on fat-tailed distributions parallels Shiller's on excess volatility. Behavioral economics, with its recognition of the possibility of "irrational exuberance" (the title of Shiller 2000) and its linkage of economics and psychology, had made an earlier appearance at the Cowles Commission in the work of George Katona (1945). Truman Bewley (1999) studied downward rigidity of nominal wages in recession by going out and asking questions of wage-setters, an innovative strategy for an economist (unlike other social scientists) but made respectable by his eminence in the most technical aspects of general equilibrium theory (Bewley 2008).

THE COWLES FOUNDATION AT YALE

Although no longer as closely identified with advocacy of Keynesian macroeconomics as it was in Tobin's day, the Cowles Foundation at Yale remains a leading center of research in econometrics, economic theory and mathematical economics (including game theory, unlike the Cowles Commission). For a time, Cowles lost its focus on econometrics: Tobin, an active econometrician in the 1950s (with the Tobit estimator for limited dependent variables), kept largely to monetary economics after his 1963 return from the President's Council of Economic Advisers, while Koopmans turned from econometrics to optimal growth theory (the Ramsey-Cass-Koopmans approach to optimal capital accumulation). Cowles regained its prominence in econometrics with the arrival of Peter C. B. Phillips and then of Donald Andrews. Recent Cowles winners of the Nobel Memorial Prize have been Robert Shiller in 2013 for his work in behavioral finance, and William Nordhaus in 2018 for his pioneering study of the economics of global climate change (see also his Cowles Monograph on energy, Nordhaus 1979, and his early work with Tobin on “green accounting”). But, distinguished and productive as the Cowles Foundation’s researchers are, it no longer has the unique position that the Cowles Commission occupied in the 1950s as the clear center of mathematical economics and econometrics: general equilibrium, social choice, econometrics, linear programming, all advanced in Cowles Monographs and Cowles Papers in the 1950s, are now studied throughout the discipline of economics and are no longer concentrated in a single localized community of scholars.

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