# MACROECONOMIC DYNAMICS AT THE COWLES COMMISSION FROM THE 1930S TO THE 1950S

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**Macroeconomic Dynamics at the Cowles Commission from the 1930s to the 1950s**

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**Abstract:** This paper explores the development of dynamic modelling of macroeconomic fluctuations at the Cowles Commission from Roos, *Dynamic Economics* (Cowles Monograph No. 1, 1934) and Davis, *Analysis of Economic Time* Series (Cowles Monograph No. 6, 1941) to Koopmans, ed., *Statistical Inference in Dynamic Economic Models* (Cowles Monograph No. 10, 1950) and Klein's *Economic Fluctuations in the United States, 1921-1941* (Cowles Monograph No. 11, 1950), emphasizing the emergence of a distinctive Cowles Commission approach to structural modelling of macroeconomic fluctuations influenced by Cowles Commission work on structural estimation of simulation equations models, as advanced by Haavelmo ("A Probability Approach to Econometrics," Cowles Commission Paper No. 4, 1944) and in Cowles Monographs Nos. 10 and 14.

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**Introduction**

The application of mathematical and statistical techniques to analyze macroeconomic dynamics has been central to the research agenda of the Cowles Commission for Research in Economics at the University of Chicago and its successor the Cowles Foundation at Yale University, as shown in the titles of Cowles Monograph from the first in the series, *Dynamic Economics: Theoretical and Statistical Studies of Demand, Production and Prices* by the first director of the Cowles Commission, Charles Roos (1934), to Monograph No. 27, Katsuhito Iwai's *Disequilibrium Dynamics: A Theoretical Analysis of Inflation and Unemployment* (1981). The most influential of these works on dynamics, establishing the Cowles Commission approach to structural econometric time-series models of fluctuations, were the tenth and eleventh: *Statistical Inference in Dynamic Economic Models*, edited by Tjalling Koopmans (1950) and Lawrence Klein's *Economic Fluctuations in the United States, 1921-1941* (1950), works that contributed to Koopmans and Klein becoming Nobel laureates. The Cowles Commission approach to dynamic macroeconometrics outlined in those monographs, and in the fourteenth monograph *Studies in Econometric Method* (Hood and Koopmans, eds., 1953), shaped macroeconomic modelling for decades (see Bodkin, Klein and Marwah 1991 and Welfe 2013, and Boumans and Garcia Duarte, eds., 2019, especially Pinzon-Fuchs 2019 on Klein) and has been continued at the Cowles Foundation by Ray Fair (1984, 1994, 2004) but attracted critiques from, among other, Guy Orcutt (1952) and Ta-Chung Liu (1960) and later, more influentially and from two quite different theoretical standpoints, Robert Lucas (1976) and Christopher Sims (1980).

**The First Cowles Approach to Macroeconomic Dynamics: Roos, Davis and Dresch**

Charles F. Roos, the first research director of the Cowles Commission and the first secretary-treasurer of the Econometric Society (succeeded by Alfred Cowles 3rd as treasurer in 1932 and as secretary in 1937), was a mathematician who had studied with Griffith Evans at Rice University who came to

mathematical economics through an interest in difference and differential equations (Roos 1927, 1930), sharing with Evans a concern with modelling economic fluctuations and crises (Evans 1930, Weintraub 1998). Roos (1934, p. xiii) recalled trying to public a 65 page paper on "A Mathematical Theory of Price and Production Fluctuations and Economics Crises": the editor of a mathematical journal offered to publish the mathematics if Roos would omit the economics, a statistical journal was willing to publish the economics and statistics if he would delete the mathematics, and finally the *Journal of Political Economy* agreed to publish a much-shortened abstract of the whole paper as Roos (1930). Roos (1934) had chapters on, among other topics, demand for consumer goods, automotive demand for gasoline, demand for agricultural products, demand for capital goods, factors influencing residential building, and growth and decline of industry, using curve-fitting to estimate equations for the time-derivatives of demand for each good. From the standpoint of the second, Marschak-Koopmans generation of Cowles econometricians, Roos (1934) and Davis (1941a, 1941b) neglected the identification problem, so that it was unclear whether Roos was estimating a demand function or some linear combination of demand and supply functions, and they used single-equation techniques in situations where variables were simultaneously determined. In 1937, Roos left the Cowles Commission to establish a for-profits Econometrics Institute, initially providing demand forecasts to General Motors. Although he served as president of the Econometric Society in 1948, Roos moved away from academic econometrics and towards the right of the political spectrum, collaborating with Waddill Catchings, the former head of Goldman Sachs who was the surviving half of the underconsumptionist monetary heretics Foster and Catchings (Roos 1957, Catchings and Roos 1958, Dimand and Veloce 2007).

The next research director of Cowles Commission, Northwestern University mathematician Harold Thayer Davis (1941a), applied harmonic analysis to decompose economic time series into trend, cycles and erratic movements, finding the superimposition of many cycles necessary to explain observed fluctuations. The conclusion of his Cowles Monograph on *The Analysis of Economic Time Series* reported

on the probability evidence supporting a forty-month cycle (1941a, pp. 546-50), ten- and twenty-year cycle (pp. 550-52) and a fifty-year war cycle (pp. 550-57, see Tarascio 1989). He also reported on "The Theory of Jevons and Its Present Status" (1941a, pp. 561-71), that is, W. Stanley Jevons's sunspot theory of the trade cycle, concluding that "The theory, however, is suggestive enough to warrant further study. It is to be hoped that we may have in time more adequate data regarding, first, the variation of ultraviolet in the sun throughout a wider range of frequencies, and, second, a more thorough understanding of the effect that this may have on human behavior" (Davis 1941b, p. 571, see also W. S. Jevons 1884, H. S. Jevons 1909, 1933, Garcia-Mata and Shaffner 1934). In contrast to his serious consideration of Jevons's sunspot theory, Davis (1941a, p. 330n1a) dismissed Keynes's *General Theory* (1936) in a footnote: "Unfortunately the arguments are not formulated in such a way that they can be tested by statistical data."[1] Alfred Cowles 3rd, whose came to establish the Cowles Commission and fund *Econometrica* as a byproduct of his own study denying that stock market forecasters, and particularly the Dow Theory, could forecast the stock market (Cowles 1933, Dimand and Veloce 2010), must have been bemused by Davis's respectful exposition of "The Dow Theory of Forecasting" (Davis 1941a, pp. 538-44), which made no mention of Cowles's critique (which Davis had cited on p. 502). Davis's approach to cycles was long continued by Edward R. Dewey's Foundation for the Study of Cycles, publishers of the quarterly *Journal of Cycle Research* and monthly *Cycles* (see Dewey and Dakin 1947 and the bibliography by Louise Wilson 1964), outside mainstream economics but with Wesley Mitchell on the Foundation's board of directors until his death in 1948. Even though Davis (1941a, 1941b) repeatedly cited Ragnar Frisch (1933), Michal Kalecki (1935) and Jan Tinbergen (1935), technically- and theoretically-sophisticated participants in the Econometric Society and in the emergence of modern macroeconomics and econometrics, his work remained rooted in the earlier tradition of cycle analysis

[1] Davis (1941b, p. 286) mentioned that "There is one school of economic thought, led by J. M. Keynes, which believes that a higher general economy is possible under low rather than under high interest rates."

that explained fluctuations as the summation of cycles, each with a given periodicity and amplitude, as many cycles as needed for *ex post* explanation of observed changes, so that Jevons on sunspots resonated with him but he could not see anything of interest in Keynes. The first generation of Cowles econometrics has been largely forgotten or ignored: neither Clifford Hildreth (1986) nor Carl Christ (1994) cite Davis (1941a, 1941b) although their titles indicate coverage of the Cowles Commission in Chicago from 1939 to 1955 and Davis's involvement ended not with the commission's move from Colorado in 1939 but with Marschak's appointment to succeed Yntema in January 1943 (Davis taught mathematics at Northwestern University in the Chicago suburb of Evanston, and remained an associate editor of *Econometrica* for mathematics throughout the journal's first 26 years).

Davis (1941a, pp. 14, 28, 44, 47, 60, 307, 312-16, 563) repeatedly cited the periodogram analysis of Sir William Beveridge (1921, 1922), who used an early form of spectral analysis to decompose a time-series for wheat prices in Western Europe into nineteen superimposed cycles of varying amplitude, with periodicities ranging from 2.735 years to 68 years (see Dimand 1999 on Beveridge on cycles, Cargill 1973 on early use of spectral or harmonic analysis). The need to use so many different cycles to explain the data caused Harvard epidemiologist E. B. Wilson (1934a, 1934b) to doubt that the data was truly cyclical, since any time-series whatsoever could be represented as the summation of a sufficiently large number of cycles (see Carvajalino 2019 on Wilson). Davis (1941a, pp. 27, 32, 300-304) cited Wilson's skepticism about a nine-year cycle but resisted Wilson's general argument that the whole periodogram enterprise was fruitless: "With all these conclusions the author is not in agreement … very far from admitting that the observed periods and the observed energies are fortuitous" (Davis 1941a, p. 304).

Davis (1941a, pp. 38, 54, 57, 283) also cited, but also missed the point of, another article that challenged his approach to modeling economic dynamics by decomposing time series into multiple cycles. Eugene Slutsky[2] ([1927] 1937) showed, by taking a moving average of a series that was purely

[2] Slutsky had been Marschak's first teacher of economics and statistics, in Kiev (Kyiv) before World War I.

random by construction (the last three digits of winning lottery numbers), that the summation and smoothing used by cycle analysts would generate apparent cycles even if none were truly present in the data. Instead of grasping that Slutsky, like Wilson, had found a reason why the results of cycle analysts like Davis might well be spurious[3], Davis thought that Slutsky was offering a reason why the economy was cyclical (Dimand and Veloce 2007).

In the same volume of *Econometrica* in which Slutsky ([1927] 1937) was translated, Alfred Cowles, writing with Cowles Commission staff member Herbert Jones (Cowles and Jones 1937), reversed the findings of Cowles (1933) on stock market forecasting, the very study that had led Cowles to finance the creation of the Cowles Commission and of *Econometrica*. Cowles (1933) found that stock market forecasters did not no better than chance in predicting stock price movements, but Cowles and Jones (1937) reported structure in stock price movements that would allow profitable prediction. Unfortunately, as Holbrook Working (1960) and Cowles (1960) agreed decades later, the surprising results of Cowles and Jones (1937) were spurious, the consequence of just the kind of averaging that Slutsky showed would produce the appearance of cycles and did not justify Cowles's reversal of the conclusions of his 1933 study (see Dimand and Veloce 2010). The first Cowles Commission approach to economic dynamics, that of Davis, Roos and Cowles and Jones (1937), like the attempts by H. S. Jevons (1933) and Garcia-Mata and Shaffner (1934) to revive the sunspot theory of the trade cycle[4], floundered in the face of statistical findings such as those of Slutsky and Wilson.

Francis W. Dresch, an instructor in mathematics at the University of California at Berkeley, spoke at prewar Cowles summer conferences on his efforts to construct a dynamic model of US economic

[3] Irving Fisher, who was involved in the creation of the Cowles Commission and served on its advisory council, had long insisted that "the so-called business cycle" was not really a cycle or a summation of cycles, but rather a "dance of the dollar" driven by monetary shocks (see Dimand 2003).

[4] Harold Wilson, giving the first Beveridge Memorial Lecture to the Institute of Statisticians in 1966 (while Prime Minister), recalled his "frantic and ultimately successful attempts" as Beveridge's research assistant in 1940 to dissuade Beveridge from endorsing the sunspot theory of the trade cycle in print (Dimand 199, p. 40).

fluctuations, inspired by the simplified but dynamic version of general equilibrium presented by Berkeley mathematician Griffith C. Evans[5] (Dresch 1939, 1940, see also Evans 1930, 1937, Dresch 1938, Dimand 1990, Malinvaud in Arrow et al. 1991, p. 55, Weintraub 1998, Dimand and Veloce 2007). Dresch (1940) reported that he had a system of fifteen equations (some involving time derivatives) with fifteen independent variables such as national income and price and production indices for capital and consumption goods, subject to twenty three empirical constraints: "Given a set of values for these 23 parameters, it would be possible, save for exceptional cases, to solve for each of the 15 variables as a function of time. On the other hand, being given the appropriate time series for the variables, it would be possible to estimate the parameters and to test the model for consistency. Unfortunately it is very difficult to obtain data for the complete set of 15 series" (Dresch 1940, p. 67). Extended summaries of Dresch's papers appeared in the conference volumes of abstracts (and Davis 1941b, p. 418, cited Dresch 1940), but the full papers, including Dresch's system of simultaneous equations, were never published.

**The Cowles Commission Approach: Monographs 10 and 14**

Charles Roos (1934) and Harold Davis (1941a, 1941b[6]), mathematicians who were the research directors of the Cowles Commission before the commission moved from Colorado Springs to the University of Chicago in 1939, emphasized curve-fitting and the use periodogram analysis (a precursor of spectral analysis) to decompose economic time series into trend, multiple superimposed cycles of differing periodicity and amplitude, and erratic movements (Dimand and Veloce 2007). After Jacob

[5] Although, as E. Roy Weintraub (1998) shows, Evans (like Davis and Roos) disappeared from postwar mathematical economics and econometrics (despite Evans's prominence in applied mathematics, as president of the American Mathematical Society in 1939-40), Evans was one of only three speakers presenting more than once at the 1937 Cowles conference, with Evans speaking on July 12, 13 and 14, Ragnar Frisch on July 14, 21, 22 and 23, Jacob Marschak (then director of Oxford's Institute of Statistics) on July 16 and 20 (there were morning and afternoon sessions each day, each with one paper).

[6] Davis (1941b) was the first book in English with econometrics in its title (Jan Tinbergen used the equivalent term in the title of a book in Dutch the same year).

Marschak replaced Theodore Yntema as research director of Cowles in January 1943, that approach to econometrics was displaced at Cowles by a concern with the statistical implications of simultaneity in systems of equations with random error terms, influenced by Trygve Haavelmo (1943, 1944) and Leonid Hurwicz (1943) (see Bjerkholt 2005 on Frisch, Bjerkholt 2015 on Haavelmo, and Haavelmo on Frisch in Koopmans, ed., 1950; Haavelmo 1944 was his Oslo doctoral dissertation supervised by Frisch, completed in 1941 while Haavelmo was at Harvard), as well as by Koopmans's 1936 dissertation with Tinbergen, published as Koopmans (1937)[7] (see Hildreth 1986, Epstein 1987, Morgan 1990, Qin 1993, Christ 1994).

*Statistical Inference in Dynamic Economic Models* (Koopmans, ed., 1950) resulted from what Edmond Malinvaud (in Arrow et al. 1991, p. 57) called "the most influential conference on statistical inference in economics ever held," in Chicago from January 27 to February 1, 1945[8]. Cowles Monograph No. 10 included pathbreaking papers on the conditions for identification of the structural coefficients of simultaneous equations, on the bias when simultaneous equations are estimated by least squares methods suitable for single equations, and on full information maximum likelihood (FIML) and limited information maximum likelihood (LIML) methods of estimating systems of simultaneous equations. Some contributions were made after the conference, the chapter on LIML by T. W. Anderson in early 1946, but the manuscript was complete by early 1947, with publication delayed by typographical and other printing issues. The precursor to the 1945 conference, before Marschak left the New School for Social Research in New York to become director of the Cowles Commission in January 1943[9] and

[7] In addition to Haavelmo studying with Frisch and to Koopmans studying with Tinbergen, the second generation of Cowles Commission researchers were also linked to pre-World War II European econometrics by Marschak's study of economic theory and statistics with Slutsky in Kiev before World War I (Marschak subsequently took his doctorate with Emil Lederer in Heidelberg). Frisch and Tinbergen, stranded in German-occupied countries, were isolated from North American developments in econometrics during World War II, while Slutsky abandoned economics for meteorology during the Soviet purges of the 1930s (ironically, turning to the study of sunspots).
[8] The long delay in publication reflected the search for a new publisher for Cowles monographs: Principia Press belonged to Harold Davis, and moved from Bloomington, Indiana (where Davis had taught mathematics at Indiana University) to San Antonio, Texas, when Davis moved from Northwestern to Trinity University of San Antonio.
[9] Marschak's involvement with the Cowles Commission predated his taking up the directorship in January 1943: while still directing Oxford's Institute of Statistics he took part in month-long Cowles summer research conferences in Colorado in 1937 and 1939. After the 1937 conference, Alfred Cowles 3rd offered Marschak the directorship of

recruited Koopmans, Haavelmo and Modigliani to the commission, was a small National Bureau of Economic Research econometrics seminar that met on weekends in New York from 1940 to 1942, led by Oskar Lange (then professor of economics at the University of Chicago and author of a 1944 Cowles Monograph and, in 1943, of the first Cowles Commission Paper) and including Marschak, Koopmans, Haavelmo, Abraham Wald and Marschak's New School doctoral student Franco Modigliani (Malinvaud in Arrow et al. 1991, p. 56, Modigliani 2001, p. 19). Marschak's "Economic Interdependence and Statistical Analysis" (in Lange, McIntyre and Yntema, eds., 1942, pp. 135-50), in a volume in memory of Henry Schultz (the econometrician whose death in a car accident inclined the University of Chicago to welcome the Cowles Commission as a replacement for him), marked the turn of econometrics at the Cowles Commission from Roos's single-equation fitting of demand and supply curves to embracing the statistical implications of simultaneity. The new direction of the Cowles Commission under the directorships of Marschak from 1943 to 1948 and then Koopmans from 1948 until Cowles moved from Chicago to Yale in 1955 was emphasized by designating the reprint series begun in 1943 as Cowles Commission Papers, New Series, even though there was no previous series.

Cowles Monograph No. 10 opened with Jacob Marschak's "Statistical Inference in Economics: An Introduction" (Koopmans, ed., 1950, pp. 1-50), which overlapped with his University of Chicago course "20 Lectures on Introduction to Econometrics" (Marschak 1949), and with Tjalling Koopmans and his graduate research assistants Herman Rubin and R. B. Leipnik on "Measuring the Equation Systems of Dynamic Economics" (Koopmans, ed., 1950, pp. 53-237). Koopmans also contributed shorter chapters on "The Equivalence of Maximum-Likelihood and Least-Squares Estimates of Regression Coefficients" in

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an expanded Cowles Commission, but failed to obtain the Rockefeller Foundation grant that would have covered Marschak's salary and the expansion of the Commission. Marschak was further connected through Lange's participation in the New York seminar and Marschak's contribution to Lange et al. (1942). In 1940 Marschak and Lange coauthored "Mr. Keynes on Statistical Verification of Business Cycle Theories" (first published in Hendry and Morgan, eds., 1995, pp. 390-98) defending Tinbergen (1939, Vol. 1) against Keynes's skeptical *Economic Journal* review (reprinted in Hendry and Morgan, eds., 1995, pp. 382-89). Keynes, as editor of the *Economic Journal*, rejected their submission.

just-identified models (pp. 301-304), “Models Involving a Continuous Time Variable” (pp. 384-89), and “When Is an Economic System Complete for Statistical Purposes?” (pp. 393-409), while Rubin, who completed his Chicago PhD in 1948 (three years after the conference), also wrote on “Consistency of Maximum-Likelihood Estimates in the Explosive Case” (pp. 356-64). Leonid Hurwicz, another Cowles Commission staff member (and future Nobel laureate), also contributed several chapters, on “Generalization of the Concept of Identification” (pp. 245-57), “Prediction and Least Squares” (pp. 266-300), and “Least-Squares Bias in Time Series” (pp. 365-83). The Columbia University statistician Abraham Wald, the founder of statistical decision theory and of sequential analysis, who did not join the staff of Cowles but had been part of the preceding New York seminar, wrote a “Note on the Identification of Economic Relations” (pp. 238-44) and “Remarks on the Estimation of Unknown Parameters in Incomplete Systems of Equations” (pp. 305-310). In a paper written a year after the conference, the statistician T. W. Anderson introduced LIML in “Estimation of the Parameters of a Single Equations by the Limited-Information Maximum-Likelihood Method” (pp. 311-322), followed by articles by Anderson and Herman Rubin in *Annals of Mathematical Statistics* in 1949 and 1950 (both in Cowles Commission Paper No. 36), a paper by Anderson and Hurwicz to the Econometric Society in 1947 (abstracted in *Econometrica* but not published in full), and a chapter by Herman Chernoff and Rubin in Hood and Koopmans, eds. (1953, pp. 200-212). Cowles Monograph No. 10 was thus not a typical conference volume, drawing varied contributors each giving a single paper, but the product of a small, close-knit community of scholars, pursuing a common research agenda on the statistical implications of simultaneity in multi-equation dynamic economic time-series models. That agenda, set out in the two chapters by Marschak and Koopmans that comprised the first 237 pages of the volume, was rooted in the earlier work of Koopmans and Marschak before they moved from the New York econometrics seminar to the Cowles Commission at the University of Chicago.

The sequel, Cowles Monograph No. 14, *Studies in Econometric Method* (Hood and Koopmans, eds., 1953), was edited jointly Koopmans with William C. Hood of the University of Toronto, then a postdoctoral fellow at Cowles and later Canada's Deputy Minister of Finance. Like Monograph 10, it opened with chapters by Marschak and Koopmans: Marschak on "Econometric Measurements for Policy and Predictions" (Hood and Koopmans, eds., 1953, pp. 1-26) and Koopmans, reprinted from *Econometrica* in 1949, on the identification problem in simultaneous-equations models (Hood and Koopmans, eds., 1953, pp. 27-48; also reprinted in 1949 as Cowles Commission Paper, New Series, No. 31), the latter paired with Herbert Simon on "Causal Ordering and Identifiability" (pp. 49-74). Drawing on the work of Anderson and Rubin on LIML but going beyond them in stepwise maximization of the likelihood function, Koopmans and Hood discussed maximum-likelihood estimation of a linear model with normally distributed errors, with emphasis on how to test the validity of identifying restrictions on such a structural model (pp. 112-99). Trygve Haavelmo contributed reprints of two 1947 journal articles, one from the *Journal of the American Statistical Association* contrasting the inconsistency of least squares with the consistency of maximum likelihood in estimating a system of equations including the consumption function and one with Meyer Girshick from *Econometrica* on maximum likelihood estimation of a system of equations for demand for and supply of food (Hood and Koopmans 1953, pp. 75-91, 93-111[10], respectively; previously reprinted in 1947 as Cowles Commission Papers, New Series, Nos. 22 and 24). In an otherwise heavily male-dominated research program, Jean Andrus Bronfenbrenner, then at the US Department of Commerce but previously on the staff of the Cowles Commission and an assistant professor of economics at the University of Illinois, examined the large-sample bias from incorrect choice of predetermined variables in estimating a two-equation model (Hood and Koopmans, ed., 1953, pp. 221-35). Like Lawrence Klein's "The Use of Econometric Models as a Guide

[10] The computational section of Girschik and Haavelmo's article was not reprinted because Monograph 14 included a long chapter by Herman Chernoff and Nathan Divinsky on computing maximum likelihood estimates of linear structural equations, including sample computations (Hood and Koopmans, eds., 1953, pp. 236-302).

to Economic Policy" (1947c), Marschak's opening chapter made clear that the goal of constructing structural econometric models was as much to evaluate policy choices as to make forecasts, the aspect of the Cowles Commission program that was to draw the criticism of Robert Lucas (1976) and, a quarter of a century earlier, Milton Friedman's suspicion of the Cowles Commission's work as creating tools for socialist planning and activist Keynesian demand management. Friedman's suspicion was not entirely unjustified regarding the motivations of Marschak, Klein and some of their colleagues, but the subsequent development of mathematical economics and econometrics does not indicate any inherent connection to central planning or activist macroeconomic policy. That the three reprinted articles in Monograph 14 had appeared in journals and as Cowles Commission Papers before the publication of Monograph 10, in the case of Haavelmo's two chapters three years before Monograph 10, shows that the papers in the two monographs were part of a single period of intense research activity, earlier than the publication dates in book form might suggest.

**Klein on Economic Fluctuations**

Lawrence Klein's Cowles Monograph *Economic Fluctuations in the United States, 1921-1941* (1950) was the empirical counterpart to and implementation of the methodological studies in Cowles Monographs 10 and 14. While Jan Tinbergen had used single-equation least squares to estimate his multi-equation models of the Dutch economy (Tinbergen 1937) and the United States economy (Tinbergen 1939, Volume 2), advances in econometric methodology and in computational technique enabled Klein (1950) to estimate his models as systems rather than as single equations (see Tinbergen's 1951 Cowles Commission Discussion Paper reviewing Klein 1950, and more generally Charles Renfro 2009, 2011 on computational advances and the evolution of econometrics). Tinbergen was aware of simultaneity bias but had no choice but to use single-equation methods in the days when a "computer" was a person (often female and unacknowledged, see Margot Lee Shetterly 2016). James Tobin recalled

that when he was a graduate student, ordinary least squares estimation of a single equation with three variables would take three days (see Dimand 2011). Koopmans (ed., 1950) and Klein (1950) were made possible by the introduction of electronic computers. The largest model in Klein (1950), Klein's Model III, had twelve endogenous variables. As with Tinbergen's *Statistical Testing of Business Cycle Theories* (1939), Klein's *Economic Fluctuations* (1950) was concerned with modelling fluctuations, dynamic macroeconomic movements over time rather than seeking a static equilibrium. As with Monographs 10 and 14, the date of Klein (1950) reflects a delay in publication: he was at the Cowles Foundation from 1944 to 1947 (see Klein 1991b, Bjerkholt 2014, Pinzon-Fuchs 2019), publishing extensively on macroeconomics (Klein 1946, 1947b, 1947c). Indeed, one of the first appearances of the term "macroeconomics" was in the title of Klein (1946), although Frisch (1933) had used "macrodynamics." His 1944 dissertation at MIT, supervised by Paul Samuelson and submitted two years after he entered graduate school, was on *The Keynesian Revolution* (published as Klein 1947a), but already while a graduate student he was inspired to think of constructing an empirical simultaneous-equations model when Trygve Haavelmo presented an early version of Haavelmo (1943) to the MIT statistics seminar organized by Klein (see Klein 1991a for an abstract of Haavelmo's talk with comments made in the seminar by Klein and Samuelson). Klein (1950), followed by Klein and Goldberger (1955), led on to Klein's involvement in simultaneous-equation structural modeling in the Brookings and Wharton models of the US economy, in models of the British and other economies, and finally to Project LINK, bring together national macroeconomic models to model the world economy (see Bodkin, Klein and Marwah 1991, Welfe 2013 and Boumans and Garcia Duarte, eds., 2019 for the development of the field, and indeed industry, of structural macroeconometric modeling, and Ray Fair 1984, 1994, 2004 for the continuation of structural modeling at the Cowles Foundation).

**Critiques of the Cowles Approach to Dynamic Macroeconometrics: Friedman, Orcutt, Liu, Lucas, Sims**

Upholding the Cowles Commission strategy of using *a priori* economic theory to impose exclusionary restrictions to identify structural equations (by imposing coefficients of zero on some variables in an equation), Tjalling Koopmans (1947) criticized the alternative NBER approach to business cycle analysis of Arthur Burns and Wesley Mitchell (1946) as "Measurement without Theory."[11] Burns and Mitchell looked to time series analysis rather than economic theory to understand fluctuations, leading for a pattern of leads and lags that would reveal some variables as leading indicators (Mitchell, an institutionalist who had studied with Thorstein Veblen at the University of Chicago, shared Veblen's skepticism about much of classical and neoclassical theory). This led to an extended journal exchange between Koopmans and Rutledge Vining (reprinted in Gordon and Klein 1965 and excerpted at length in Hendry and Morgan 1995), with Vining maintaining that both approaches were potentially fruitful but still of unproven value (see Epstein 1987, Chapter 7). A less direct response in defense of Milton Friedman's teachers Burns and Mitchell was Friedman's "Wesley C. Mitchell as an Economic Theorist" (1950), contending that Mitchell's business cycle analysis was economic theory, but in a broader sense than the mathematical general equilibrium theorizing espoused by the Cowles Commission. A change in the official motto of the Cowles Commission to "Theory and Measurement," with implicit italics on the word "and," did nothing to improve relations in the University of Chicago's Economics Department between the Cowles Commission and the emerging "Chicago school" of economics led by Friedman.

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" (in Friedman and Friedman 1998, p. 197). "I believe," stated Friedman (in Friedman and Friedman 1998, p. 262), "that mathematicians, whether pure mathematicians or economists or

[11] At least some readers at the time, such as Benjamin Higgins (1951, p. 41), read Koopmans (1947) as a response to Burns's methodological critique of Keynesian economics ("Economic Research and the Keynesian Thinking of Our Time") in the 1946 annual report of the National Bureau of Economic Research, so perhaps Koopmans did not fire the first shot in that battle.

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." Such suspicion of mathematical economics such as the Cowles approach to dynamic structural models, as creating tools for planning and interventionist policy, was much more common when the Cowles Commission was in Chicago than now. Benjamin Higgins (1951, p. 11 n11), before proceeding to quote the consumption and investment equations of Klein (1950, p. 68), recalled that "I was once attacked by the editor of the Canadian *Chartered Accountant* for using equations in an article on tax policy, published by the *Canadian Journal of Economics and Political Science*, a professional journal. The editor felt that the use of equations necessarily implied a degree of rigidity of human behavior that could only be achieved in a totalitarian state and that some kind of revolutionary plot was hidden behind my symbols." See also Franco Modigliani (2001) on red-baiting opposition to teaching of mathematical economics at the University of Illinois, where Modigliani taught while a research associate of the Cowles Commission.

Guy Orcutt (1952) criticized Klein (1950) and Colin Clark (1949, based on a Cowles Discussion Paper, Clark 1947) for designating some variables as exogenous for convenience in identification or because of unspecified *a priori* knowledge, instead of testing for exogeneity, provoking replies from Koopmans, Tinbergen and Nicholas Georgescu (the Orcutt-Koopmans exchange is excerpted in Hendry and Morgan 1995). Orcutt, who joined Yale in 1970 (but as professor of urban studies, rather than in the Cowles Foundation), went on to develop microanalytic simulation (an overlooked forerunner of agent-based modeling) as an alternative modeling approach (Orcutt et al. 1961, 1973).

Ta-Chung Liu (1960), who in 1955 had offered a simple forecasting model as an alternative to the Cowles structural models, argued with Carl Christ, Clifford Hildreth and Lawrence Klein in a panel "Simultaneous Equation Estimation – Any Verdict Yet?" at the 1958 Econometric Society meeting in

Chicago, described by Chao and Huang (2011, p. 146) as "Liu versus three Cowles people."[12] Liu insisted that, once all relevant variables are considered, structural relations tend to be underidentified, a criticism recalling Keynes's complaint about omitted variable bias in Tinbergen (1939) and Koopmans's question "When Is an Equation System Complete for Statistical Purposes?" (the title of Chapter XVII of Koopmans, ed., 1950). If properly specified models, without unjustified *a priori* imposition of coefficients of zero on some variables, failed the order condition (and therefore also the rank condition) for identification, then single-equation least squares estimation was as appropriate as simultaneous-equations maximum-likelihood estimation. Klein insisted to the contrary that overidentification was prevalent, and, in Bodkin, Klein and Marwah (1991, p. 77), took pleasure in characterizing the model of Liu (1963), together with another model of the US economy, as "almost expanded versions of the Klein-Goldberger Model."

Although Wesley Mitchell's NBER approach statistical approach to economic fluctuations was long overshadowed by the Cowles Commission's structural modelling approach, Christopher Sims's vector autoregression (VAR) approach to analysis of economic time series, without claiming to have enough reliable *a priori* theory for exclusionary restrictions (Sims 1980), may be viewed as a revival of Burns and Mitchell (1946) with more modern statistical techniques and greater computing power and as an acceptance of Guy Orcutt's and Ta-Chung Liu's critiques of structural econometric models (Orcutt 1952, Liu 1960), although with little mention of Burns, Mitchell or Liu (see Salazar and Otero 2019 on Sims and VAR). Sims was at the Cowles Foundation from 1990 to 1999 as Yale's Henry Ford II Professor of Economics, although he had moved to Princeton before sharing the 2011 Nobel Memorial Prize. While Marschak (in Hood and Koopmans, eds., 1953) and Klein (1947c) had celebrated structural econometric models as tools for policy choice, Lucas (1976) reminded economists that a change in policy regime

[12] Liu and Klein also debated Liu's critique at the World Bank: in a commissioned celebration of the World Bank, James Morris (1963, p. 54) recalled that "I once found a group of haggard young unfortunates discussing 'A Symposium on Simultaneous Equation Estimation, by Ta-Chung Liu and L. R. Klein'."

would change the model's coefficients in ways that could only be predicted if the model was grounded in the deep structure of rational choice by optimizing individuals, a critique that has in practice been taken as justification for representative agent models, since microfoundations of individual optimization are more tractable if there is only one agent (see Goutsmedt, Pinzon-Fuchs, Renault and Sergi 2019 on Keynesian responses to the Lucas critique). Whereas Sims urged modelers not to pretend to be able to apply much *a priori* economic theory and, like Mitchell and Burns, to take a statistical approach to analyzing economic time series, Lucas opposed the Cowles Commission approach from the opposite direction, calling for a more explicit grounding of macroeconomics in microeconomic theory.

**Conclusion**

The Cowles Commission approach to structural estimation of simultaneous-equation dynamic macroeconomic models, led by Koopmans, Marschak and Klein, inspired by Haavelmo (1943, 1944) and embodied in three Cowles Commission Monographs (Koopmans, ed., 1950, Klein 1950, Hood and Koopmans, eds., 1953), shaped the teaching of econometrics and the practice of macroeconomic model-building for decades (see Epstein 1987, Morgan 1990, Qin 1993 and Boumans, Dupont-Kieffer and Qin, eds., 2011 on the development of econometrics and Bodkin, Klein and Marwah 1991, Welfe 2013 and Boumans and Garcia Duarte, eds., 2019 on macroeconomic model-building). In a few years, from Marschak's assumption of the Cowles directorship in January 1943 to Klein's departure from Cowles in 1947, the second generation of Cowles econometricians, transferred with Oskar Lange's support from the 1940-42 New York econometrics seminar and with roots in the prewar European econometric work of Frisch (1933), Tinbergen (1937, 1939) and Slutsky, swept away the now nearly-forgotten curve-fitting and periodogram approach to dynamics of the first generation of Cowles econometricians (Roos 1934, Davis 1941a, 1941b, Dresch 1939, 1940). The 1945 conference on econometric methodology and Klein's empirical monograph were crucial to the influence of the second generation of Cowles econometricians.

But, as Malinvaud observed (in Arrow et al. 1991, p. 58), "it may seem strange that from that time on, the Cowles Commission took such a detached stand about the future evolution and progress of what had been the first major scientific achievement of the organization …Among those who had been directly associated with the simultaneous-equations work of the 1940s, only L. Klein and T. W. Anderson showed publicly some interest in the subsequent developments of the subsequent, long after they had left Cowles." Koopmans's later years are associated with the Ramsey-Cass-Koopmans model of optimal capital accumulation, Marschak's with work with Roy Radner on the economic theory of teams (organizations whose members have the same interests but not the same information). James Tobin, the first director of the Cowles Foundation at Yale, was, among other things, an econometrician in the 1950s (the Tobit estimator for limited dependent variables) but was more exclusively a Keynesian monetary economist after his 1963 return from the President's Council of Economic Advisers. Ray Fair (1984, 1994, 2004) took up the Cowles Commission approach to estimating dynamic macroeconomic models at the Cowles Foundation, but Cowles did not resume its position as a leader in econometric methodology until the arrival of Peter C. B. Phillips and later of Donald Andrews. The heyday of the Cowles Commission approach to structural estimation of dynamic models occupied only a few years at the University of Chicago but influenced the economics profession beyond Cowles for decades and continued to shape the practice of model-building even after the critiques of Lucas and Sims gained traction.

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