

[Survey Article]

# The Role of the Cowles Commission and RAND Corporation in Transforming Mathematical Economics in the Mid-twentieth Century

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## I Introduction

The mathematical transformation of economics during the mid-twentieth century happened through the work of a small group of scholars. To be specific, this was the period when new fields, such as econometrics, general competitive equilibrium, and game theory were developed by scholars working in the Cowles Commission and RAND Corporation. In addition, the influence of the work done by these organizations contributed to the invention of the IS–LM model and the Solow growth model. The existing literature has already clarified the decisive role played by the Cowles Commission and the RAND Corporation from various points of view, and this has become common knowledge, at least, for some historians of economics. This article will offer a survey of this recent literature.

The Cowles Commission was founded in Colorado, United States, in 1932. To promote basic research for systematic economic forecasting, a businessman named Alfred Cowles generously donated a fund to the Econometric Society, which had been launched in 1930. A part of this fund went into founding a research center called the Cowles Commission. The commission provided a workplace for young mathematical economists active in the Econometric Society's network. In 1939, the University of Chicago offered to support the commission, which moved to the university's campus. In 1943, Jacob Marschak became the commission's director and started the research that eventually led to the establishment of econometrics. In 1948, Tjalling Koopmans succeeded him and shifted the commission's research focus toward

mathematical optimization theory, which included linear programming, and stimulated the formulation of the general competitive equilibrium models in the early 1950s and the Solow growth model in 1956.

The RAND Corporation, on the other hand, originated from the research department of an aircraft company called Douglas Aircraft. This department was created immediately after the end of the Second World War to conduct research on military technology under the support of U. S. Air Force. Initially called the RAND Project by taking the initial letter of the first and last words of “Research and Development” and the first two words of the middle word, it became independent in 1948 and was reorganized as the RAND Corporation. The corporation had employed many mathematicians since the days of the Project, and von Neumann played a major role in setting the organization’s research agenda. Princeton mathematicians, such as Albert Tucker and his students, John Nash, Lloyd Shapley, and David Gale, who had interests similar to those of von Neumann, developed game theory, among other subjects, at the RAND Corporation.

The following sections will discuss how these two organizations affected the development of mathematical economics in the mid-twentieth century, or, more specifically, econometrics, game theory, general competitive equilibrium models, the IS–LM model, and the growth model. The author of the present paper has published several essays on these issues in Japanese (Takami 2017; Takami 2017–2018) and the remaining part of this essay is a summary of the earlier essays.

## II Econometrics

The literature on the history of econometrics is rich and varied. In addition to the classic studies by Epstein (1987), Morgan (1990), and Qin (1993), there are more recent ones by Aldrich (2010), Bjerkholt (2005, 2007, 2015), and Qin (2013).

Modern statistics was established around the turn of the twentieth century by English biometrical researchers committed to Darwinism and eugenics. Francis Galton, Karl Pearson, and others presented their notions of correlation coefficient and probability distributions. American economist Henry Ludwell Moore regarded Pearson highly and started statistical studies by using their ideas and the least square method, which had been developed in the early nineteenth century to smooth out measurement errors. Henry Schultz, Moore’s pupil at Columbia University, followed in his teacher’s footsteps and worked on the estimation of the demand curves of agricultural products.

Norwegian economist Ragnar Frisch started his career by quantitatively

estimating economic ideas, such as marginal utility, by using a method similar to the one suggested by Irving Fisher. Like Fisher, Frisch was keen to create an empirical foundation for economics, rather than solely depend on the logical/deductive method; to achieve this, he turned to mathematical statistics and worked on ways to adapt it to economic statistics. His research interests included the concept of dividing business cycles into shocks and structural dumping (“impulse and propagation”) and an estimation method in which one can mechanically calculate the least square estimators for models with different sets of variables (“confluence analysis and bunch maps”).

In order to promote mathematical economics, the Econometric Society was founded by its three original initiators—Frisch, Fisher, and the mathematician Charles Roos—and the scholars who accepted their invitation to join it. Immediately after its foundation, Alfred Cowles, who ran an investment consulting company and was a member of a wealthy family, offered financial support to the Society for research on scientific economic forecasts. Cowles’s money was spent to launch the Society’s in-house journal, *Econometrica*, and establish a research institute called the Cowles Commission.

After the late 1930s, many mathematical economists fled from the political turmoil in Europe and immigrated to the United States. The Cowles Commission provided them with employment, and the influx of these European scholars transformed the commission into a major powerhouse in economic research. Jacob Marschak, director of the commission from 1943 onward, focused its efforts on basic research to estimate simultaneous equation models that used macroeconomic statistics. Statistical work by Frisch and Jan Tinbergen prior to 1940 did not fully use the modern probabilistic statistics, but Abraham Wald and Trygve Haavelmo, who were working closely with Marschak, had started to apply the probabilistic framework to economic statistics. Building upon their contribution, the Cowles Commission developed a method of estimating simultaneous equation models—called the Limited Information Maximum Likelihood method—that could avoid estimation biases. This method was applied to the macroeconometric models designed by Lawrence Klein, a former fellow at the Commission, and others.

### III Game Theory

The history of game theory is still a relatively new field. Poundstone (1993) is a rather popular account of game theory and its history; Mirowski (2001) and Giocoli (2003) each mentioned game theory only indirectly in their general studies of the cognitive turn in science and the rationalization of social sciences, respectively; however, Leonard’s work (2010) is a definitive

treatment of the subject up to 1960 and this book is an authoritative study in this field.

The *Theory of Games and Economic Behavior*, a book that introduced game theory to economists, was written by John von Neumann and Oskar Morgenstern in 1944. von Neumann was a Hungary-born mathematician who studied axiomatic mathematics under David Hilbert at the University of Göttingen. In the early 1920s, the mathematicians close to von Neumann were working on a mathematical analysis of board games, such as chess; this inspired him to publish a paper on the same topic in 1928. The paper consists of a highly formalized mathematical expression of games. In this paper, he proved the so-called Minimax theorem, which states that the payoff of a game is the same, regardless of who plays first, when players decide strategies stochastically.

Morgenstern, the other author, grew up in Austria and studied economics at the University of Vienna. He attended lectures by Ludwig von Mises and acquired critical views against mainstream economics. One manifestation of such views was his 1928 essay, in which he criticized the American statistical research by Warren Persons and Wesley Clair Mitchell and claimed that economic forecasts are, in principle, impossible. Morgenstern worked alongside Karl Menger, a mathematician and son of the economist Carl Menger, and other mathematicians close to Menger. Morgenstern was deeply attracted by their mathematical analyses of social interactions, different from the existing theoretical frameworks in economics. In 1938, in the aftermath of the German annexation of Austria (the Anschluss), he emigrated to the United States and began teaching at Princeton University.

von Neumann was working at the Institute for Advanced Studies, which was adjacent to Princeton University, and came to know Morgenstern after the latter moved there. von Neumann was intrigued by the geopolitical strategic relationships in Europe, and Morgenstern was taken up by mathematical social analyses that took into consideration the expectations about others' behavior. The wide overlap in their interests resulted in the publication of *Theory of Games and Economic Behavior*.

The research on game theory was continued at the RAND Corporation. von Neumann's influence was highly pronounced at the RAND Corporation, and game theory, his creation, was viewed as a means to support the construction of military strategies. Albert Tucker, a Princeton mathematician, and his students participated in the research going on at the corporation. Among these researchers was John Nash. In a series of articles published in the early 1950s, Nash extended the Minimax theorem and proved that  $n$ -person non-cooperative games always have an equilibrium of mixed strategies. In

addition, many types of games were tested by experiments using human subjects at the RAND Corporation. In the experiments in which Nash was involved, it was observed that subjects' actions did not accord with theory.

#### IV General Competitive Equilibrium

Two pieces of Weintraub's work (1985, 2002) are the pioneering studies on the history of the general competitive equilibrium theory; and D uppe and Weintraub (2014) is an authoritative text on this subject.<sup>1</sup> Weintraub wrote the latter with D uppe, who worked independently on the cooperation between Arrow and Debreu.

After L eon Walras formulated the general equilibrium in the 1870s, Knut Wicksell, Gustav Cassel, and others contributed to the subject. However, the theory took off in a new direction in Vienna in the 1930s. Abraham Wald, who also made a contribution to econometrics, wrote a series of articles when he was a student of Karl Menger. Wald avoided the possibility of prices turning negative by adding free goods—goods that have no price because their supply is too large compared to their demand—in the model. von Neumann also submitted a paper that discussed a mathematical model of the economy to Karl Menger's journal in the 1930s. von Neumann's model was not exactly a market equilibrium model, but the succinct mathematical expression and the use of a fixed-point theorem substantially influenced the literature on the subject in the early 1950s.

The most well-known work in that literature is probably the essay co-authored by Kenneth Arrow and Gerald Debreu, who were both fellows at the Cowles Commission at a certain point in their careers. Arrow studied statistics under Harold Hotelling at Columbia University; in 1947, he became a fellow at the commission on the recommendation of Hotelling and Wald. The latter was teaching at Columbia after an escape from Europe and a brief stay at the Cowles Commission. During the two-year fellowship, he actively participated in the discussions during seminars and impressed upon Marschak, Koopmans, and others his competence as a mathematical economist. In the summer of 1948, he visited the RAND Corporation through a personal connection, and there he conceived social choice theory, which established his reputation as theoretical economist.

Debreu, on the other hand, was born in France, and after spending a

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<sup>1</sup> Japanese mathematicians, especially Kakutani and Nikaido, contributed significantly to the general equilibrium theory; on this topic, Ikeo (2006, 2014) are informative. However, it has little relevance to this survey article, and is not discussed in the text.

solitary childhood owing to family misfortune, he had fateful contact with Bourbakism at the *École Normale Supérieure* in Paris. Bourbakism was a movement in which young French mathematicians endeavored to reconstruct the entire mathematical system on the basis of the generality of the mathematical structure. Debreu retained a high regard for structural generality for the rest of his career. After the war, he became interested in economics through the work of Maurice Allais; von Neumann and Morgenstern's book on game theory also made him realize that axiomatic mathematics could contribute to economics. When he was staying in the United States on a fellowship by the Rockefeller Foundation, he gave a presentation at the Cowles Commission, and this presentation was impressive enough for the commission to offer him a fellowship. Debreu worked at the commission from 1950 to 1960.

Lionel McKenzie, who published a general equilibrium model using a fixed-point theorem independently of, and earlier than, Arrow and Debreu, also worked closely to the network of the Cowles economists. After studying at Princeton and Oxford, McKenzie taught at Duke University. After two years, the university allowed him to stay in the University of Chicago to get trained in mathematical economics. Instead of the lectures given at the Economics Department, McKenzie attended the ones by the Cowles economists, such as Marschak and Koopmans, and also studied topology at the Mathematics department.

In 1948, Koopmans replaced Marschak as the director of the Cowles Commission, and its research focus shifted from econometrics to linear programming. In January 1949, the commission extended its network to include applied mathematicians by reaching an agreement with the RAND Corporation for research cooperation on mathematical optimization. A conference was organized in the same year to discuss linear programming, Wassily Leontief's input-output analysis, game theory, and so on. This conference helped disseminate new mathematical expressions of economic transactions and convexity analysis to economists working in, and closely allied to, the Cowles Commission. All of the three economists mentioned above later acknowledged that the 1949 conference was crucial for the construction of their general competitive equilibrium models.

It was through the Cowles Commission that Arrow and Debreu came to write a joint paper. Arrow built a competitive equilibrium model using a fixed-point theorem in the fall of 1951 and submitted it to the Commission. When Debreu reported to the director Koopmans that he was interested in similar problems, Koopmans handed Arrow's working paper to him. Debreu then wrote to Arrow, who, in turn, suggested that they write a joint paper.

## V IS–LM Model

The creation of the IS–LM model is not directly relevant to the present essay's purpose because it is related not to the Cowles Commission, but to the Econometric Society. However, the importance of the IS–LM model in the history of economics and the organizational ties between the Commission and the Society justifies its discussion here. Young (1987) is a classical study on the formation of the model. This book describes how Roy Harrod, James Meade, and John Hicks made presentations that mathematically explained Keynes's theory at a session of the 1936 Econometric Society conference held at the University of Oxford. However, Young does not answer the question why these three English scholars made presentations neither at the Royal Economic Society conference nor some other English domestic conference, but at the conference of the Econometric Society, with which they were not closely involved.

One possible answer to this question lies in Louçã (2007). Keynes had passed very harsh remarks on mathematical economics in *The General Theory*: “It is a great fault of symbolic pseudo-mathematical methods of formalising a system of economic analysis . . . that they expressly assume strict independence between the factors involved and lose all their cogency and authority if this hypothesis is disallowed; whereas, in ordinary discourse, where we are not blindly manipulating but know all the time what we are doing and what the words mean, we can keep ‘at the back of our heads’ the necessary reserves and qualifications and the adjustments which we shall have to make later on. . . .” (Keynes 1936, 297).

According to Louçã (2007), key members of the Econometric Society felt threatened by this remark. In the same month that *The General Theory* was published (February 1936), Marschak wrote a letter to Frisch, in which he suggested that young economists close to Keynes should be asked to mathematically explain the content of *The General Theory*. The same letter refers to the abovementioned remark by Keynes: “On pp. 297–98 of his new book Keynes makes some nasty and unfounded remarks against mathematical economics. Owing to his enormous influence, that makes our task even more urgent” (quoted in Louçã 2007, p. 193). This clearly shows that the Econometric Society's intention to neutralize Keynes's criticism of mathematical economics was a key factor in the creation of the IS–LM model.

## VI Growth Theory

Although there is no book-length historical treatment of Solow's growth theory yet, historians did produce essays on the subject; those worth mentioning include Boianovsky and Hoover (2014), Halsmayer (2014), and Mata and Louçã (2009).

Solow himself never belonged to the Cowles Commission, but he was strongly influenced by the commission's research on linear programming. As a graduate student at Harvard University, he participated in Wassily Leontief's applied research on input–output analysis, and simultaneously followed closely the latest trends in mathematical economics. In 1950, Solow was employed by the Massachusetts Institute of Technology; this marked the beginning of a long collaboration with his colleague, Paul Samuelson. Samuelson had taken part in the abovementioned 1949 conference and presented a paper that reinterpreted the input–output analysis as the behavior of rational economic agents.

In a similar vein, Solow published a paper that discussed the relationship between the input–output analysis and the conventional economic theory in the early 1950s. In it, he linked the input–output analysis and Roy Harrod's growth theory and reinterpreted the latter as the dynamic optimizing behavior. However, he claimed in the same paper that Harrod's theory could not completely describe the behavior of rational agents; thus, a different growth theory would be needed. Only a couple of years later, Solow published a paper to present what is now called the Solow growth model. The above historical background suggests that this model was, at least partly, an outcome of the ongoing trend of mathematical economics, in which Samuelson and the Cowles economists attempted to reorganize economic theory in terms of optimizing behavior.

## VII Conclusion

This essay has made it clear that the Cowles Commission and the RAND Corporation had tremendous significance for mathematical economics in the mid-twentieth century. To highlight more general background, the Great Depression and the Second World War were crucial. The Great Depression made scholars trained in natural sciences, such as Jan Tinbergen and Koopmans, study economics and also prompted Alfred Cowles to donate a fund to the Econometric Society. The Second World War, on the other hand, forced many European mathematical economists to emigrate to the United



States and promoted close intellectual exchange among them. Other ramifications of the war included von Neumann's revisiting of game theory and the war logistic problems leading to the rise of linear programming as an important item on the Cowles Commission's agenda.

Behind the heightened interest among the history of economics community in the Cowles Commission and the RAND Corporation lies a shift in historiography. Recent literature in the history of economics in the United States and Europe is much more concerned about organizations and groups, or in other words, "collectives," (as opposed to "individuals") as explanatory units. This shift reflects the fact that sociological and anthropological approaches are now more dominant in humanity disciplines, such as philosophy and history of science (Hands 2001). One could also say that historians of economics now prefer objective evidence to subjective interpretation of text. In any case, the interest in collectives is not confined to the history of twentieth-century economics. We have a broader range of evidence available for the twentieth-century economics, and this has resulted in an abundance of studies on the collectives in this period. However, this fundamental interest is the same for the history of previous periods too.

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