How Mathematical Economics Became (Simply) Economics: The Mathematical Training of Economists during the 1940s, 1950s, and 1960s in the United States

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Abstract

Before the use of mathematics in economics was generalized, mathematical and non-mathematically trained economist lived together. This paper studies this period of cohabitation. By focusing on the communication challenges between these two groups during the 1940s, 1950s and 1960s, a watershed moment, this paper analyzes the entrance of mathematics into economists' training. The paper explores the development of teaching material specific for the mathematical training of social scientists, the entrance of mathematics to economics curriculum and the role of the Social Science Research Council in this delivered process. All these elements are integral to understand how the mathematical methods and tools introduced by a small group of economists during the mid-Twentieth Century come to be adopted by the entire discipline within a couple of decades and thus effected a permanent transformation of economics.

Keywords

Mathematical training of social scientists, mathematical economics, Social Science Research Council, Jacob Marschak

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> The current level of mathematical training for social scientists in this country [the United States] was not quickly achieved, nor did it grow by itself through natural evolution; instead, it has come about through a long, fairly deliberate process that has depended upon the ideas and contributions of a great many people and organizations.
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> — Frederick Mosteller, *The Role of the Social Science Research Council in the Advance of Mathematics in The Social Sciences* (1974)

In 1947, during the dinner meeting of the American Economic Association, John Maurice Clark (1884 –1963) gave an address entitled "Some Cleavages among Economists". The same year an expansion of one section of the address was published in *Econometrica* under the title "Mathematical Economists and Others: A Plea for Communicability". There Clark presented "mathematical economists" as "a growing and able sect, using an esoteric method and a special language, which makes their results increasingly inaccessible to the rest of us ["generalist economists"]" (Clark 1947, 75). The note illustrates both a cleavage between "mathematical economist" and "generalist economists", and a recent transformation in the balance of forces between the two groups. Indeed, Clark started by characterizing his "standpoint" by the "distinctly rudimentary" level of his mathematical equipment measured by the "present standards". He insisted on his "tremendous respect for the accomplishments of the mathematical students" and expressed his desire to make "as much use of them as possible" or, at least, "to see them utilized as fast as necessary" (Clark 1947, 75). Ten years later Clark's plea for communicability remained a hot topic. As Robert Solow expressed it in 1957: "Next to the desire for salary increases, the desire most frequently expressed by economists is for a translation of some of the more recondite results of recent mathematical economics for the use of the profession at large" (Solow 1958, 178).

Before the use of mathematics in economics was generalized, in other words, before *mathematical economics* became *economics*, there was a period during which mathematical and non-mathematical economist lived together. This paper studies this period of cohabitation, and more concretely, the communication challenges that mathematical and non-mathematical

economist confronted during a watershed moment in the process of extending the use of mathematics in economics, the 1940s, 1950s and 1960s.

Important research has been done on the mathematization of economics in the United States from the interwar to the postwar period. The importance European emigrants[2], World War II's interdisciplinary teamwork[3] and military funding[4] have been extensively studied. The role of individuals[5], institutions[6] and learned societies[7] in the introduction of mathematical tools in US economics have also been the object of significant scholarly work. Nevertheless, we still know very little about the more general diffusion of mathematical training in economics. In other words, a key question remains open: *how did the mathematical methods and tools introduced by a small group of economists during the mid-Twentieth Century come to be adopted by the entire discipline within a couple of decades and so effected a permanent transformation of economics?* By focusing on the challenges linked to communication between mathematically

[2] See for example Grubel and Scott (1967), Craver (1986), Scherer (2000), Hagemann (2005, 2011), Backhouse and Medema (2009) and Akhabbar (2010).

[3] See for example Erickson, et al. (2015).

[4] See for example Mirowski (2002b).

[5] The list of individuals includes, within others, Paul Samuelson (see for example Backhouse (2017)), Kenneth Arrow (see for example Weintraub and Gayer (2001), Düppe (2012) and Düppe and Weintraub (2014a)), Gerard Debreu (see for example Mirowski and Weintraub (1994), Düppe (2010, 2012)), Jacob Marschak (see for example Cherrier (2010)), Lawrence Klein (see for example Pinzón-Fuchs (2019)) and Robert Solow (see for example Halsmayer (2014)).

[6] Here are of particular importance the Cowles Commission (see for example Mirowski (2002a), Düppe and Weintraub (2014b) and Dimand (2019)) and MIT's economics department (see for example Weintraub, ed (2014)).

[7] Of particular importance is here the Econometric Society (see Bjerkholt (2015, 2017) and Morgan (1992)).

and non-mathematically trained economists, this paper analyzes the entrance of mathematics into economists' training. The Social Science Research Council played an important role in this process giving economists and other social scientists a platform to develop the foundations to train future generations of social scientists in mathematics.

The generalization and thus the entrenchment of the use of mathematics in economics was not an exclusive result of the entrance of a relatively small group mathematicians and physicists into the discipline, or of World War II, nor was it a creation stimulated solely by the development of new methods and tools. While these processes are all fundamental to understand the *mathematization of economics* during the mid-twentieth century, the development of systematic training in mathematics for students of economics is integral to the explanation of the long-term reach of this transformation. This paper will show that extending the use of mathematics in economics was a deliberate process that depended upon the development of a curriculum and teaching materials for economics students that made mathematical training central to becoming an economist.

1. NON-MATHEMATICALLY TRAINED ECONOMISTS: BETWEEN APPEALING FOR COMMUNICABILITY AND TURNING BACK

When in 1947 the former president of the American Economic Association and future Francis A. Walker medalist John Maurice Clark addressed his audience, he was at the top of the discipline.[8] Yet he, like many other economists from his own and even the younger generation, found himself in the very uncomfortable position of not being able to understand important parts of the research produced at that time. That said, he did not discount the importance of this work. Instead, he accepted that a part of the new research was beyond his grasp and asked general economists "to be content to leave verification of algebraic process to the mathematical jury" and "trust specialists" to catch the slips (Clark 1947, 76). However,

[8] Clark was President of the AEA in 1935 and was recognized with that organization's highest award, the Francis A. Walker Medal, in 1952.

mathematical economists did not have (yet) the upper hand. It was Ragnar Frisch, a founding member of the Econometric Society and the first editor of *Econometrica*, who asked both Clark and the editor of the *Proceedings* of the *American Economic Review* for authorization "to bring to the attention of the readers of *Econometrica*" —a.k.a. mathematical economists— "Professor Clark's important message" (Clark 1947, 75). Indeed, by the standards of the time mathematical economists were not, in the minds of many, fully trained economists. For Clark, mathematical economics students spent most of their time "in mastering and manipulation of high-powered techniques" and did not take the time to acquire the knowledge necessary to verify the "resemblance to reality" of their concepts, premises and results (Clark 1947, 76). In other words, in 1947 an economist poorly endowed in mathematical capital like Clark was still in a position to feel entitled to "fairly ask" mathematical economists "in the interest of their own *influence* and *acceptance*, to do their part towards making such verification possible" (Clark 1947, 76).[9] This was the only way, he thought, in which mathematical economists could safeguard their "reasoning against nonsense" (Clark 1947, 77). For Clark, what was needed "[was] not a reduction of difficulty for the uninitiated by elision of steps in the reasoning; rather the contrary, it is greater attention to certain steps which the specialists tend to elide, when they are talking, as they usually must, to one another" (Clark 1947, 77).

Clark's plea was highlighted that same year by Jacob Marschak in his review of William L. Crum and Joseph A. Schumpeter's "Rudimentary Mathematics for Economists and Statisticians" (1946).[10] Marschak was at that time head of the Cowles Commission, one of the centers of mathematical economics production during the 1940s and 1950s (Cherrier 2010; Dimand and Hagemann 2019). He entitled his review "On Mathematics in Economics" (1947), a title which itself illustrates the tentative status of these methods in economics. Marschak did two things in this review that are important for understanding how mathematical economists addressed

[9] The emphasis is mine.

[10] The book was an expansion by Schumpeter of a text by Crum's originally published as a supplement to the *Quarterly Journal of Economics* (1938).

Clark's plea for communicability, and more broadly, how the use of mathematical tools in economics was generalized. On the one hand, Marschak presented Clark's plea as a request for *translation* of mathematical results into a language intelligible to the broader community of economists. On the other hand, Marschak advocated combining the translation approach with a long-term strategy: *learning* the foreign language. Marschak presented Crum and Schumpeter's book as a step in this direction. Their approaches, then, had very district implications for the path forward. From Clark's point of view, his plea for communicability was a step towards an efficient *division of labor* and *collaboration*. Marschak in contrast, wanted to move the entire profession toward the methods used by mathematical economists. The terms in which Marschak presented the issue —translation in the short-term and training as long-term strategy— are key to understanding how mathematical economists responded to the challenge of forging an accommodation in the post war environment while still in the minority.[11]

As we will see in sections 2 and 3, Jacob Marschak remain engaged with the mathematical training of economists and of social scientists in general throughout his academic life. However, as one of the earliest mathematical economists in the United States, a fellow of the Econometric Society from its beginnings (1935) and one of its early presidents (1946), Marschak also knew well the importance in the short-term of communication with non-mathematically trained economists who made up the majority of the profession. He stressed this point in 1955 when recommending Lawrence Klein for a position at the University of Manchester:

> Lawrence Klein has an internationally recognised position in the field of econometrics, owing to his two outstanding qualities. He has the understanding, the courage, and the energy needed to apply new and untried statistical methods to test economic theories by using a great variety of data; and he is able to express himself with force and clarity, and thus to acquaint a wide audience of students and of practical workers with results of current advanced research work. Although there are several men of his age who are

[11] This paper focuses on the development of a specific training in mathematics for economists. Elsewhere I study mathematical economists' *translation* efforts, in particular Tjalling Koopman's *Three Essays on the State of Economic Science.*

> both more original and more profound than Klein, hardly any one of these can rival Klein in the two qualities which I have mentioned. Without Klein's work, the aims and the uses of mathematical and statistical methods in economics would be less known and less understood than they actually are at present. This also implies that Klein is competent as a general economist and is able to communicate successfully with the members of the economic profession as well as with statisticians. (Letter from Marschak to W. A. Lewis, February 16, 1955, Jacob Marschak Papers, Box 92, Folder Klein, Lawrence)

As Marschak's letter makes clear, Klein's ability to successfully communicate mathematical results to economists with little or no training in mathematics was very valuable and certainly a not widespread feature within the group of mathematical economists.

Signs of communication problems between differently trained economists continued to crop up through the early 1950s. Yet, generalist economists were not all alike. If the aim of Clark's plea for communicability was to foster collaboration between mathematical and generalist economists, not all economists poorly endowed with mathematical capital adopted the same compromising attitude. David Novick's (1906 – 1991) note published in *The Review of Economics and Statistics* in 1954 provides an illustration of a different and more belligerent approach. As sociologists know well, there exists a correspondence between social structures and mental structures. The position that agents occupy in a field informs their responses — their strategies— even when these are not the result of systematic and intentional calculation (Bourdieu 2004, 55–70; Bourdieu and Wacquant 1992, 12–25). Unlike Clark, Novick was not at the top of the discipline, and his field —cost analysis and Planning, Programming, and Budgeting Systems— was within those areas of economics where highly sophisticated mathematical methods were being heavily used and bearing great fruit. Novick did acquire some recognition for his work at RAND, where he worked as an economist for more than 40 years heading the Cost Analysis Department from 1950 to 1970. Nevertheless, the influence of his work could not be compared with that of Kenneth Arrow or Tjalling Koopmans, who also developed research at RAND in similar areas and later received the Nobel Prize (in 1972 and 1975 respectively).

In his plea for communicability Clark's main worries were the "tragic consequences" of excluding "the type of economists fitted for realistic verification of premises from access to the most powerful theoretical analysis [produced by mathematical economists]" (Clark 1947, 78). Novick, though, was deeply concerned about what he saw as "the unfortunate results of the increasing use of mathematics as an expository device" (Novick 1954, 357). For Novick "the use of mathematics as a form of communication provides no greater *virility* to the ideas than the verbalization which heretofore has been more typical of the social sciences" (Novick 1954, 358).[12] Whereas verbal statements of ideas and their interpretation permitted general reading and discussion, Novick claimed that "the present trend to mathematics as a language has cut off a large part of the *fraternity* from an ability either to read or understand much of the new thinking" (Novick 1954, 358).[13] Moreover, this new thinking was for Novick just a set of interesting efforts written in a specific language that "cowed", in his terms, those with limited training and experience in mathematics.

Seymour Harris (1897 – 1974), editor of *The Review of Economics and Statistics*, realized that Novick's note reflected an important widely felt set of concerns and so elected both to publish it and solicit a set of responses from other economists, to be published in the same issue. Out of the eleven economists Harris invited to respond, nine accepted the offer: Jan Tinbergen (1903 – 1994), Tjalling C. Koopmans (1910 – 1985), David G. Champernowne (1912 –2000), Paul Samuelson (1915 – 2009), Robert Dorfman (1916 – 1999), James S. Duesenberry (1918 – 2009), Lawrence Klein (1920 – 2013), Robert Solow (1924 –) and John S. Chipman (1926 –). It would be a mistake to assume that these nine economists were representative of the discipline. Nevertheless, its composition illustrates that while the cleavage among economists described by Clark nicely captures the transformation in the discipline that was taking place during the late 1940s and early 1950s, it does not capture the fact that neither of these groups was a monolith. That Koopmans, Samuelson, Dorfman, Klein, Solow and Chipman had credentials as

[12] The emphasis is mine.

[13] The emphasis is mine.

mathematical economists is very difficult to question. Nevertheless, their differences in terms of tools and their conception of the role of mathematics in economics are significant. The age gap between them rules out a strictly generational explanation. Duesenberry and Champernowne can be characterized as "literary economists", to use Harris's terms, yet their approaches were significantly different. It is worth noticing that, like Clark (and also Harris), they were well established economists whose individual legitimacy was not being directly contested. Tinbergen was a category apart, presenting himself as "a mathematician of only modest knowledge" often experiencing "considerable difficulties when reading Cowles Commission stuff" (Tinbergen in Samuelson et al. 1954, 67).

Harris invited Samuelson to edit the symposium, or as Samuelson put it, gave him "the fun of acting Master of Ceremonies for the slugfest set off by David Novick's blast against mathematical economists" (Samuelson et al. 1954, 359). The symposium illustrates two important points. First, collaboration with their non-mathematical counterparts was not the main concern for mathematical economists when communicating their contributions to the rest of the discipline. And second, they were well aware of the limits of translation as a means for communication between mathematical and literary economists and thus emphasized the importance of training as a long-term strategy.

Communication as a means for publication for mathematical economists

As Harris noted with some regret in the postscript that accompanies the symposium, Novick received hardly any support. All the participants were certain of the accomplishments of the mathematical methods and shared a great faith in the potency of mathematics as a tool to be used in economics. When, as in Harris's case, they were unlearned in mathematics, they were "impressed by the contributions that can be made [in economics] by the use of mathematics. (Harris in Samuelson et al. 1954, 382). Little to nothing was mentioned regarding any potential

superiority of literary methods in specific matters.[14] Certainty, Duesenberry and Champernowne, but also Tinbergen and Chipman, recognized the possibility of accomplishing important theoretical results in economics through non-mathematical methods. Nevertheless, only Champernowne and Duesenberry (and to a certain extent Tinbergen with his detailed description of his econometric method) included a reflection on how mathematical economists could concretely use the work of their non-mathematical colleagues. While there were not communication problems in this direction, since in principle mathematical economists could read and understand non-mathematical economic research, the fact that the issue was only tangentially raised is telling as to why mathematical economists were interested in communicating their results to their non-mathematically trained colleagues.[15] One of these reasons is related to the possibility of publishing the results of their work.

Harris's motivation in organizing the symposium was very practical. In his job as editor of *The Review of Economics and Statistics* Harris was "torn between a desire to publish contributions to knowledge even though he [did] not understand them and a compulsion to hold on to his subscribers, the vast majority of whom cannot read mathematical economics" (Harris in Samuelson et al. 1954, 382). Seymour Harris was not the only editor of an economic journal facing this practical problem. During the early 1950's editors of other journals (and in other countries) were confronted with challenges raised by a heterogeneously trained audience. In a notice published in 1954, the editors of *The Economic Journal*, Roy F. Harrod, Austin Robinson and R. C. O. Matthews regretted "the increasing growth of a linguistic barrier" between authors

[14] Duesenberry highlighted the superiority "verbal logic" compare to "mathematical analysis" without mentioning examples (Duesenberry in Samuelson et al. 1954, 361).

[15] Tinbergen mentioned two elements of econometric research where mathematics has no function: the enumeration of phenomena to be included in the analysis and the formulation of hypothesis (or "economic principles") (Tinbergen in Samuelson et al. 1954, 366). Nevertheless, as all the other participants to the symposium, he does not mention how exactly exchanges between differently trained economists could be developed.

who “present their work and results with the added precision that mathematical arguments affords […] and many of their readers” (Harrod, Robinson, and Matthews 1954, 1–2). The notice started by stressing the unprecedented growth in the number of those engaged in teaching and research in economics and the corresponding rise in the number of articles for publication reaching the editors of all journals. In this context, Harrod, Robinson and Matthews claimed, editors of economics journals “must take account of the size of the audience that a particular article can hope to reach, and give some preference in each issue to those authors whose writing is intelligible to a reasonable proportion of our readers” (p.2). They urged authors reduce the use of advanced mathematics as much as possible and, in all cases, state the assumptions, the conclusions and, whenever possible, the main stages of their arguments in “ordinary economic language” (p. 2).

In a context in which *ordinary economic language* was not (yet) mathematics, communicating mathematical results in English was a step towards publication, at least for the majority of mathematical economists. Some privileged ones, like Robert Solow, had more interesting things to do (“other research, books to read, children to bring up”) than “phrasing complicated mathematical arguments in readable English” (Solow in Samuelson et al. 1954, 373). Champernowne’s contribution to the symposium offers a list of concrete recommendations to those mathematical economists who were having more difficulties than Solow getting their work published. For Champernowne, economists with mathematical training should provide in their articles numerical examples, translate into prose axioms and results but make only minor concessions to non-mathematical readers in the exposition of the proof itself. By so doing, Champernowne claimed that the mathematical economist could respond to the demands of the editors worried by the increasing growth of a linguistic barrier in the discipline. But, they could also enjoy non-mathematical economists’ “qualifications to judge the relevance of mathematical models to the real world” (Champernowne in Samuelson et al. 1954, 371). For Champernowne, the ability to judge the relevance of an economic theory and its conclusions to the real world was but rarely associated with the ability to understand advanced mathematics. His interest in the division of labor made mathematical economists’ silence on collaboration

even more evident. When the question of "selective translation" is raised, as in Koopman's case, the emphasis is on the potential problem for the development of mathematical economics of non-mathematical economists' "language difficulty". For Koopmans, "rather than being impressed, the discerning economist may tend to overlook the significance of contributions made by mathematical analysis in economics, because he has no real opportunity for absorbing and evaluating their contents" (Koopmans in Samuelson et al. 1954, 379).

The limits of translating mathematical analysis to literary form

The question of the precise degree to which contributions made by mathematical analysis in economics could be translated to literary form was a concern for several contributors to the symposium.[16] The danger that a prose translation of a mathematical argument will render it inexact and slipshod was brought up several times (Tinbergen p. 368, Champernowne p. 370 and Dorfman p. 375). This issue was key in a context in which the legitimacy of mathematical economics was rising quickly. Paul Samuelson had already advanced the debate in this direction in an article published in 1952 entitled "Economic Theory and Mathematics – An Appraisal". For Samuelson, "any truth arrived at by way of mathematical manipulation must be translatable into words" (Samuelson 1952, 60).[17] Yet, while translation was possible, in terms of convenience languages were not equal: "There are still some girls' seminaries where literary logic rules the roost; but no sensible man expects that in the centuries ahead the field of logic

[16] The equivalence of mathematical symbols and words and the logical possibility of translation opened is an important philosophical debate in the nature of mathematics and mathematics as a language. Here we rather focus as a practical of communication between two differently trained groups of economists. Roy Weintraub (2002) deals with this question in the chapter "Negotiating at the boundary" where he analyses the correspondence between economist Don Patinkin and mathematician Cecil Phipps during the late 1940s and early 1950s.

[17] Samuelson was following here his professor of advanced mathematical and statistical economics Edwin B. Wilson and his adviser at Harvard Josiah Willard Gibbs. On this point see Carvajalino (2018).

will be deloused of mathematics" (Samuelson 1952, 63).[18] Samuelson did not put economic theory on the same level as logic regarding the convenience of mathematics: in 1952 it was still possible to be a theorist without knowing mathematics. But he did warn his reader of the superiority of mathematics to handle deductive inferences: "you can become a great theorist without knowing mathematics. Yet it is fair to say that you will have to be that much more clever and brilliant" (Samuelson 1952, 65).

Samuelson's intention in arguing for an equivalence between mathematical symbols and a literary words was "to slightly debunk [the use of mathematics] in economics" in a moment where mathematical economists was "flying high"(Samuelson 1952, 56). Paradoxically (or not), by so doing Samuelson was also justifying the substitution of reading knowledge of a foreign language for reading knowledge of mathematics as a requirement for graduate students of economics, as he explicitly suggested (p. 56-57). This idea of training economists in mathematics was central to several of the symposium essays and was perhaps must clearly expressed by Robert Dorfman:

> Practitioners of mathematical economics already [had] their hands full coping with some of the toughest problems which the science offers and it is unfair to impose on them the special problems of literary lucidity. Mathematical and literary talents do not always dwell in the same man. […] The ultimate answer lies with the professional reader, who must equip himself to read what he wishes to understand (p. 376).

[18] Samuelson's association between literary-feminine and mathematical-masculine illustrates a phenomenon well known by historians of science using *gender as a category of historical analysis* (Scott 1896). For instance, Margaret Rossiter (1997) relates the increase use of mathematics in the US American social sciences since the 1940s to a strategy aiming to increase their "prestige" by making these disciplines "harder". Mary Cookingham (1987) studies the elimination of "social economics" at Berkeley in the 1950s within these movement toward greater "hardness" and masculinization of economics. For an analysis of the tension between Paul Samuelson's analytical awareness of the problem of discrimination against women and his deprecatory remarks about female economists see Backhouse and Cherrier (2019).

However, during the mid 1950s getting the necessary mathematical equipment Dorfman refers to was very difficult for both undergraduate and graduate students of economics. Raising the level of mathematical training of economists in the United States, and of social scientists generally, was a long-term process that came about only over an extended period and through deliberate actions. Using new archival evidence from the Jacob Marschak Papers, sections 2 and 3 describe the active role played by economists in the development of mathematical training specific to social scientists. Section 2 focuses on the development of textbooks, while section 3 examines the role of a key institution: The Social Science Research Council.

2. THE MATHEMATICAL TRAINING OF ECONOMISTS: TEXTBOOKS

During the war and the immediate postwar years, insufficient availability of mathematical training was a general concern for students and professors of economics. For instance, when in 1949 undergraduate economics students were asked by a committee of the American Economic Association chaired by Horace Taylor what particular courses they would include if they were to do their under-graduate work over again, mathematics placed first (Taylor 1950, 146). Six years later when graduate students were asked by a similar committee chaired by Howard. R. Bowen about inadequacies in their earlier training, more mentioned mathematics than any other subject (Bowen 1953, 135). In this same report the inadequacy of mathematical training was highlighted as an important concern for graduate professors, and in 1950 only 2% believed that the ability of doctoral candidates to use mathematics for economic analysis was good (Bowen 1953, 135). This is not surprising given that, during the mid-forties, none of the 71 institutions studied by the undergraduate committee required courses in mathematics for majors in economics and only 8 accepted courses on this subject for their majors (Taylor 1950, 100). Signs of change were starting to appear, however. During the early 1950s already nearly a fourth of the institutions offering graduate degrees in economics permitted doctoral candidates to substitute mathematics for (proficiency) in a foreign language as a research tool, and several others imposed mathematical requirements in addition to the foreign language requirement

(Bowen 1953, 125–35).[19] But this was just the beginning, and the opportunities for economics students to receive training in mathematics were very scarce.

A lack of textbooks to train economist in mathematics was an important element in this context. In his 1947 review of Crum and Schumpeter's book, Jacob Marschak emphasized the need for two different types of textbooks. On was textbooks on *mathematics for economists*, i.e. books containing elementary mathematics illustrated with economic examples. The other was textbooks on *mathematical economics*, i.e. systematic accounts of the *present state* of mathematical economics where economic problems are discussed "for their own sake and in their own logical order, rather than as illustrations for mathematical theorems and techniques" (Marschak 1947, 273). While the main concern of textbooks on *mathematics for economists* was to train economists in mathematical methods, textbooks on *mathematical economics* required a mathematically educated audience. During the late 1940s economics in the United States was not quite there. The development of *mathematics for economists'* textbooks was a necessary prior step, but during the 1940s only a few such books were available in English: Allen's *Mathematical Analysis for Economists* (1938)[20] and Crum's *Rudimentary Mathematics*

[19] The committee to study the teaching of undergraduate economics was appointed in 1944 and its report was published in 1950. The committee on the study of graduate education was appointed in 1949 and its report was published in 1953. During the 1950s the AEA appointed two other committees to evaluate economics education, the Committee on Economics in Teacher Education and the Committee on Education.

[20] Allen's book was based on a series of lectures given at the London School of Economics annually since 1931. The list of persons Allen acknowledges includes Jacob Marschak, who spent time during the 1930s in the England before emigrating to the United States. In Allen's book every mathematical method introduced was used in the elucidation of problems of economic theory and all chapters included examples with economical content. The idea was to get the reader familiar with both the mathematical tools and with their applications to concrete economic problems.

for Economists and Statisticians (1938) (and its later the extension by Schumpeter). From the 1930s mathematical economists were conscious of the importance of developing this kind of material for raising the level of mathematical training in the discipline.

In 1939 Fritz Machlup (1902 - 1983) approached Oskar Lange (1904 - 1965) looking for an economists competent to write a "little book" which was to be titled *Mathematical Economics for Non-mathematical Economists* and would be published by Blakiston Company. Machlup thought that the book should be a short textbook, with "much less pretention than Allen but much more versatile than Crum".[21] Lange "had other plans" but suggested that Machlup to get in touch with Marschak. Three years later, in 1942, Machlup did so, and Marschak was indeed interested in the offer. Moreover, he indicated that he "[had] been thinking of the matter for the last year or two and in fact [had] some plans jointly with David A. Kosh" [22], a "pupil" who helped him at the New School by giving tutorials classes in mathematical economics.[23] At the New School Marschak taught "Elementary Mathematical Economics", a graduate course offered by the Faculty of Political and Social Sciences.[24] From this experience Marschak knew that the usual textbooks on calculus were not designed for economists. Because they were designed for other audiences (mostly future engineers, chemists and physicists), the organisation of both materials and exercises did not suit economists' particular needs. On the other hand, while Crum's book was specifically designed for students of economics it had an important lacuna: the absence of exercises. Allen's book did include exercises, but Marschak believed that he could improve upon the *status quo* in two ways. First, by preparing a text on *mathematical economics* rather than *mathematics for economists*. Second, by filling important

[21] Letter from Machlup to Marschak, January 12, 1942, Jacob Marschak Papers, box 100, folder Kosh and Machlup. Library Special Collections, Charles E. Young Research Library (UCLA).

[22] During the early 1940s David Kosh was working in Washington for the government.

[23] Letter from Marschak to Machlup, January 20, 1943, Jacob Marschak Papers, box 100, folder Kosh and Machlup.

[24] Syllabus. Jacob Marschak Papers, box 103, folder Oscar Lange.

gaps, particularly those which had arisen because of his implying too much knowledge at the beginning. For instance, Allen's book did not include the simple algebra of linear equations.

For Marschak the second option was the priority. His teaching experience in mathematical economics had shown him "that any serious worker gains much more by learning the tools systematically in the beginning, rather than by starting to apply those tools haphazardly and without proper understanding". For this reason, Marschak thought exercises "should be classified not by economic chapters but in mathematical chapters, arranged in the order of increasing difficulty and complication". The idea was to start with very elementary questions in which the students were required, for example to formulate a simple functional relationship.[25]

In a letter that Marschak sent to Kosh in April 8, 1943 he announced the book's working title: "Mathematical Primer for Economists" and included a twelve-section tentative outline: I. Dimensions and Notations; II. Geometric and Other Models; III. Simple Operations; IV. Linear Equations: two variables; V. Linear Equations: n variables; VI. Simple Algebraic Functions and Equations; VII. General Functions; VIII. Differentiation of Functions; IX. Application to Maxims and Minims; X. Exponential and Logarithm and their Differentiation; elasticities; XI. Partial Derivatives; XII. Implicit Functions. To construct the outline of the book Marschak used as an example the program of the mathematics for economists course that he was teaching to University of Chicago graduate students in economics. From this experience Marschak knew that it was important to start at a very elementary level. His students at Chicago, even those with some mathematical background, were having difficulties, "in spite of the appearances". Nevertheless, he was satisfied with the results to that point, in particular for the "pure" economics students. In the letter Marschak highlighted that "it has seemed useful for ["pure" economists] to give precision to their rather vague framework of concepts". Indeed, Marschak's emphasis had been on "developing the capacity to formulate economic concepts and

[25] Letter from Marschak to Machlup, January 20, 1943, Jacob Marschak Papers, box 100, folder Kosh and Machlup.

relationships. And he concluded: “These are almost more like problems in physics rather than in mathematics”. Marschak sent a copy of the letter to Fritz Machlup “whose reactions will be those of an experienced teacher and will help us much"[26]. Throughout the back-and-forth correspondence that followed over the next several months the emphasis on exercises became more urgent and the provisional tittle of the book was changed to “Elementary Mathematical Problems for Economists”.[27]

In October 1943 the publisher sent a copy of the contract to Marschak and Kosh. After long hesitation, in December 1943, Marschak finally told the publisher that he would not sign the contract, saying, “I must not sign a contract which I may be unable to execute”. Since Kosh was still interested in pursuing the project alone, Marschak inquired about this possibility, mentioning that he had suggested that Kosh invite Franco Modigliani (1918 - 2003), who had succeeded Kosh at the New School as Marschak’s teaching assistant, to join him as a co-author.[28] While this never happened, and David Kosh never published “Elementary Mathematical Problems for Economists”, this episode sheds light on three elements that are key understanding the communication challenges that mathematical and non-mathematical economist confronted during the process of extending the use of mathematics in economics: the absence of materials for training economics students in mathematical methods, students’ very modest level of proficiency, and the simultaneously rising importance of mathematical methods in the discipline.

[26] Letter from Marschak to Kosh, April 8, 1943, Jacob Marschak Papers, box 100, folder Kosh and Machlup.

[27] Letter from Marschak to Kosh, May 28, 1943, Jacob Marschak Papers, box 100, folder Kosh and Machlup.

[28] Letter from Marschak to publisher, December 10, 1943, Jacob Marschak Papers, box 100, folder Kosh and Machlup.

By the end of the 1940s economists were not the only social scientists in this situation. The letter that the interdisciplinary scholar Gregory Bateson addressed to Jacob Marschak in 1947 shows the *paradoxical position* in which many social scientists found themselves during the late 1940s and early 1950s. If Clark's plea was intended to foster collaboration and Novick's was principally concerned with the unfortunate results of the increasing use of mathematics in economics, others such as Bateson, found themselves advocating for more mathematics without mastering the tools. In his letter Bateson confessed to Marschak that

> [T]he Cowles Commission materials, at least in abstract form, are too difficult for me at present. I look forward, therefore, to the appearance of the book in which I hope that there will be a sufficient admixture of words so that the weaker brethren may get a pretty clear idea of what the mathematics is about. Can you suggest to me any good introductory text which might help? I find myself in a rather ironic position of advocating a more mathematical approach, but myself only just able to get the gist of, e.g. Von Neumann, who puts in plenty of straight prose (Letter from Bateson to Marschak, January 8, 1947, Jacob Marschak Papers, box 97, folder No name.[29]

Scholar such as Bateson were the target of "Mathematical Thinking in the Social Sciences", a book edited by the sociologist Paul Lazarsfeld and published in 1954. The book was advertised by its publisher, The Free Press, as "the only general introduction to the use of advanced mathematical thinking in the social sciences". It was the product of a symposium that Lazarsfeld organized at Columbia University 1952, where he invited leading figures to join him in "the effort to introduce mathematical thinking into the social sciences".[30] Marschak was an important part of this effort, contributing a chapter where he used basic ideas about probability in connection with pay-off matrices. The aim of the chapter, which Marschak presented as an introduction to problems of linear programming and general operational analysis, was to

[29] When Bateson wrote the letter to Marschak he was at Institute for Intercultural Studies in New York City. He was later founding and core member of the Macy conferences in Cybernetics.

[30] Handbill, Jacob Marschak Papers, box 92, folder F Lazarsfeld.

elucidate the links between subjective utilities and subjective estimates of the probability of events.[31]

As with Harris and the editors of the *Economic Journal*, Lazarsfeld dealt with the issue of making mathematical analysis accessible to scholars in the social sciences limited by his own modest knowledge of mathematics. In a letter addressed to Marschak on September 23th 1952, Lazarsfeld offered a series of concrete remarks intending to make Marschak's contribution "as understandable as possible to a large number of readers". For Lazarsfeld there were a variety of ways in which that could be done. He advised Marschak to "explain more fully in advance what [he] intend to do, what [he] d[id] and why", but in some cases, this was not enough. Even with considerable expansion, some mathematic proofs, Lazarsfeld thought, could not be really understandable for the readers he had in mind. In those cases, he wondered if "it might not be a better idea to leave out the mathematics, substituting a general argument that explained the whole idea of this tie-up without giving any proofs at all".[32] The exchange between Lazarsfeld and Marschak makes clear the distance between the contributors and the targeted audience and thus the limits of this kind of introductory book in a context where training in mathematical methods was not part of the social scientists' curriculum. As Harris put it in 1951 "even with the greater interest in mathematics of today it is going to be a long time before one half of the economists are competent to understand the economics published in (say) *Econometrica*" (Harris in Samuelson et al. 1954, 383).

Marschak, in his review of Crum and Schumpeter's "Rudimentary Mathematics for Economists and Statisticians", addressed the issue in terms of "mathematical habits of thinking" (Marschak 1947, 269). Educational institutions of all levels play a major role in building these habits

[31] The other contributors are mathematical statistician T.W. Anderson, biologist Nicolas Rashevsky, sociologist James S. Coleman, psychologist Louis Guttman and Lazarsfeld.

[32] Letter from Lazarsfeld to Marschak, September 23, 1952, Jacob Marschak Papers, box 92, folder Lazarsfeld.

(Bourdieu 1980, 133–36). For Marschak, as for many other social scientists, introducing mathematics into the program of study to university social sciences students was thus essential. In a letter to Schumpeter in 1945 Marschak elaborated on this point:

> Have you seen the "Readings on Business Cycles" selected under Heberler's leadership and issued by the American Economic Association? I have just finished reviewing it, — having, I am afraid, taken again the position of a hairclothed pedant clamoring for more precision in our language and implying that, to achieve this in the future, the university curriculum should include mathematics (Letter from Marschak to Schumpeter, January 29, 1945, Jacob Marschak Papers, box 95, folder Schumpeter.

Before the 1940s were over, Marschak and other social scientist were taking action in this direction. One of the first efforts to bring mathematics into the social sciences curricula was the symposium on *Mathematical Training of Social Scientists*, organized by Marschak during the 1949 American summer meeting of the Econometric Society held in Boulder, Colorado, simultaneously with the annual meetings of the Institute of Mathematical Statistics and the Mathematical Association of America. The motion adopted by unanimous vote at the conclusion of the event announced the constitution of an *Intersociety Committee on Mathematical Training of Social Scientists*, with William G. Madow as chairperson. This effort would involve a close collaboration with the Social Science Research Council (SSRC) in developing "a better mathematical training for social scientists […] and improving the mathematical preparation of social scientists" (Intersociety Committee on the Mathematical Training of Social Scientists 1950, 193). As we will see in Session 3, the SSRC provided essential support for the efforts to create a community to develop mathematical training in the social sciences.

3. THE SOCIAL SCIENCE RESEARCH COUNCIL COMMITTEE ON MATHEMATICAL TRAINING FOR SOCIAL SCIENTISTS

During the 1950's, as a part of its interest in the improvement of training for research in the social sciences, the SSRC payed particular attention to the mathematical prerequisites for research in the social science fields. In fact, from its creation in 1923, the SSRC had carried on

programs to support individuals in developing mathematical skills and pursuing quantitative research.[33] Looking beyond the handful of individuals who would be producers of mathematical work, the SSRC developed efforts to train the large contingent of students of social sciences as competent consumers of mathematical work. For instance, in 1930 the SSRC also appointed a committee, with H. R. Tolley as chairperson, to report on the "Collegiate Mathematics Needed in the Social Sciences".[34] This report was presented in 1932, first to the SSRC, and then to the Mathematical Association of America, and appeared one year later in *Econometrica*. The idea was to think in terms of the mathematical needs of the large group of students who may take only a few courses in this field and did not need much technical proficiency. What was different about mathematics during the 1950s was that the *producer's* command was viewed as necessary both by a large contingent of students and across a broader front of the social sciences.

The first step in this direction was the organization, during the summer 1951, of an eight-week summer seminar in mathematical models for learning at Tufts College (SSRC Committee on Mathematical Training of Social Scientists 1953b7; Mosteller 1974, 19). The same year, after discussion with members of the Intersociety Committee on Mathematical Training of Social Scientists, the SSRC invited eight specialists to prepare memoranda on the minimum mathematical background required of PhD candidates in social anthropology, social psychology, and sociology. The idea was to prepare an update of the 1932 report. The eight specialists invited shared both a high degree of consensus as to topics that should be included in basic mathematics courses in the social sciences and concerns about the importance of the obstacles to the development and offering of such courses (SSRC Committee on Research Training 1952,

[33] For a brief history of the SSRC see Prewitt (n.d.).

[34] Frank L. Griffin served as a member of the committee and expended six months in 1931 under the auspices of the SSRC interviewing European economists and biologists who had been using mathematics in their writings (Intersociety Committee on the Mathematical Training of Social Scientists 1950, 194; Mosteller 1974).

35). In an effort to overcome these obstacles, in December 1952 the SSRC appointed the Committee on the Mathematical Training of Social Scientists, with funds for the committee's program provided by the Ford Foundation. William G. Madow (University of Illinois), an expert in sample survey methods, was the first chairperson of the SSRC Committee and more generally a key figure in the development of specific mathematical training for social scientists. Table 1 presents the list of members of the SSRC Committee on the Mathematical Training of Social Scientists over the years.

Table 1
Members of the SSRC Committee on the Mathematical Training of Social Scientists over the years

Name	Years	Discipline	University
William G. Madow (Chairperson)	1952-1958	Mathematics	University of Illinois
E. P. Hutchinson	1952-1958	Sociology	University of Pennsylvania
Jacob Marschak	1952-1954	Economics	University of Chicago / Cowles Commission
George A. Millet	1952-1954	Psychology	Harvard University
Frederick Mosteller	1952-1958	Mathematics	Harvard University
Robert M. Thurall	1952-1958	Mathematics and Operations research	University of Michigan
Howard Raiffa	1955-1958	Mathematical statistics and Decision analysis	Harvard University
Robert Solow	1955-1958	Economics	MIT
Robert R. Bush	1956-1958	Psychology	New York School of Social Work
Elbridge Sibley (staff)	1952-1958	Sociology	SSRC

Sources: (SSRC Committee on Mathematical Training of Social Scientists 1955, 13), (Mosteller 1974, 19–20).

During the 1950's this committee on the Mathematical Training of Social Scientists was very active carrying out its activities through two related initiatives, the development of sources materials for courses in mathematics specifically designed for social scientists and the development of a special curriculum in mathematics for social science students. The members of the Committee and other scholars directly involved in its activities were also informally

engaged in speaking at meetings of mathematical and social sciences societies on the objectives and activities of the Committee (Madow 1957, 45).

The development of sources materials for the mathematical training of social scientists

Six months before appointing its own Committee on the Mathematical Training of Social Scientists, the Council supported an initiative of the Intersociety Committee on the Mathematical Training of Social Scientists to produce a source book on the mathematical methods used in the social sciences. The book, which only reached a manuscript form and was never published, was the product of the Interuniversity Summer Research Seminar on Source Material held from June 23 to August 23 1952.[35] The idea was to produce a book containing examples in mathematics using illustrative materials drawn from the social sciences, which could then be used as resource in mathematical courses for social scientists. In addition, the participants in the seminar explained typical mathematical methods applicable to large numbers of social science problems and prepared translations of social science ideas into mathematical terms together with a list of mathematical references for social scientists.[36] Table 2 present the list of participants in the seminar.

[35] The SSRC interuniversity summer research seminars program started in 1950 with with support provided by the John and Mary R. Markle Foundation. The seminars were designed to aid outstanding social science research workers in the 30 to 40-year age group who might otherwise be financially unable to further their research interests during the summer vacation period (SSRC Committee on Research Training 1952, 7). In 1954, with support provided by the Rockefeller Foundation, the SSRC reinstituted the program (SSRC Committee on Mathematical Training of Social Scientists 1955, 16). For more information on the SSRC summer seminars program see: (SSRC Committee on Research Training 1954a, 4–6).

[36] Memorandum from Madow to the members of the Committee, August 3, 1955, Jacob Marschak Papers, box 93, folder Mathematical Training for Social Scientists.

Table 2
List of participants to the 1952 SSCR Interuniversity Summer Research Seminar on Source Material

Name	Discipline	University
William G. Madow (director)	Mathematics	University of Illinois
Samuel S. Wilks (assistant)	Mathematical statistics	Princeton University
Oswald H. Brownlee	Economics	University of Minnesota
David A. Grant	Psychology	University of Wisconsin
George A. Miller	Economics	MIT
Robert Solow	Economics	MIT
E. William Noland	Sociology	University of North Carolina
Howard Raiffa	Mathematical statistics and Decision analysis	Columbia University

Source: (SSRC Committee on Mathematical Training of Social Scientists 1952, 35).

During the 1950s the Committee continued taking steps to improve the availability of appropriate materials, particularly by securing grants to support the preparation of teaching and reference books relevant to particular social sciences (Table 3). These monographs were initially used as teaching support or made available to participants in the training programs organized by the Committee (printed by photo-offsets). The Committee anticipated that in the long run the quality of some of these materials would be very high, as was the case for Gerard Debreu's work on economic problems from the algebraic and topological point of view. In the opinion of the chairperson of the Committee, Debreu did "an excellent job on the statement of the necessary mathematics, as well as on some of the economic formulations".[37] Nevertheless, in the short term these materials were conceived more as intermediate products, the first step in writing mathematical textbooks for courses given to social scientists (Bush, Abelson, and Hyman 1956). While the members of the Committee were certain that one or two years of additional work on any of the projects would result in a considerable improvement, they all

[37] Memorandum from Madow to the members of the Committee, July 7, 1955, Jacob Marschak Papers, box 93, folder Mathematical Training for Social Scientists.

agree that the contribution of the materials prepared as part of this project would be greater if they were made available in the very short term in "incomplete first draft forms".

Table 3.
List of individual grants for the preparation of teaching and reference books relevant to particular social sciences

Authors	Grant	Monograph	Summer Institute
Samuel **Goldberg** (Oberlin College)	For the completion of a monograph on social science applications of difference equations.	*Introduction to Difference Equations for Social Scientists.* Published in 1958: *Introduction to Difference Equations*: *with illustrative examples from economics, psychology, and sociology* (publisher: John Willey & Sons).	Used as part of the teaching materials in the **1955** summer institutes (photo-offset).
Robert R. **Bush** (Harvard University), Robert P. **Abelson** (Yale University) and Ray **Hyman** (Harvard University)	In 1954 to prepare a manuscript giving mathematical examples and problems for psychologists. The idea was that the manuscript will work as an adjunct to mathematics texts which not specifically prepared for psychologists.	*Mathematics for Psychologists: Examples and Problems*. Published by the SSRC in 1956.	Used as part of the teaching materials in the **1955** summer institutes (photo-offset).
Harold W. **Kuhn** (Bryn Mawr College)	To prepar a manuscript, including exercises, on applications of the theory of games and linear programming in economics.		
Gerard **Debreu** (Cowles Commission)	To developed materials for the study of certain basic economic problems from the algebraic and topological point of view.	*Theory of Values: An Axiomatic Analysis of Economic Equilibrium*. Published in1959. Publisher: John Wiley Be Sons.	Made available at both 1955 summer institutes (photo-offset).
Mathematical Association of America William. L. Duren, Jr (director, Tulane University)	To assist a group working at the University of Kansas in the summer of 1954 on the preparation of experimental text materials for a general	The resulting manuscript, *Universal Mathematics*, was divided in two parts. The first part, *Functions and Limits: A Book of Experimental Test*	

	freshman course in mathematics for students planning to enter fields other than engineering.	*Material*, was published in 1954 as a preliminary edition (photo-offset) by the University of Kansas. The second part, *Structures* in *Sets*, was also published as a preliminary edition (photo-offset) by Tulane University in 1955.	

Sources: (SSRC Committee on Mathematical Training of Social Scientists 1954b, 48), (Madow 1957, 45), (Memorandum from Madow to the members of the committee, July 7 1955, Jacob Marschak Papers, box 93, folder Mathematical Training for Social Scientists), (Mosteller 1974, 20–21).

The urgency of publication was increased by the "growing number of requests from people for copies", as chairperson Madow reported to the members of the Committee the 3rd August 1955. He concluded:

> Publication by a commercial publisher takes more time and much more work than is needed for the *materials to be useful*[38]. What is needed in a program such as the one with which we have been associated is essentially a method of publication that would provide wide distribution quickly and on paper that could be guaranteed to disappear within five or ten years. I say this not to be facetious but to emphasise that what I was taking about is a medium of publication of informal material rather than definitive works; a medium of publication suitable for quasi-rough-draft (Memorandum from Madow to the members of the Committee (Subject: Publication Policy), August 3, 1955, Jacob Marschak Papers, box 93, folder Mathematical Training for Social Scientists).

Two weeks later, the Committee officially recommended to the SSRC an "early publication policy". Concerns about the responsibility, both of the Committee and more generally of the SSRC, for publishing "nearly draft" manuscripts were addressed with the preparation of an introductory statement emphasizing that the Committee was only facilitating publication, not reviewing or judging the volumes.[39]

[38] My emphasis.

[39] Letter from the members of the committee to the SSRC (Subject: Recommendations on Publication Policy), August 22, 1955, Jacob Marschak Papers, box 93, folder Mathematical Training for Social Scientists.

The development of a special curriculum in mathematics for social science students

Beyond the preparation of teaching material for the mathematical training of social scientists, the Committee was also engaged in developing a special curriculum in mathematics for social science students, one that would be compatible with the broader educational objectives of colleges and universities and, at the same time, cognizant of the fallacy of minimizing the difficulties in mathematical training. In a policy statement initially published in 1955 in ITEMS, the SSRC's bulletin, the Committee presented its training program.[40] In the long-term, the problem of mathematical training of social scientists was for the Committee an undergraduate problem. Yet, in the short-term, opportunities had to be provided for those who did not obtain satisfactory mathematical training while in college. For the committee, in 1955 it was no longer necessary to argue whether social scientists ought to study mathematics; "demand", they noted, "already is sufficient to justify the offering of suitable courses" (SSRC Committee on Mathematical Training of Social Scientists 1955, 14). This demand, along with a widespread recognition of the deficiency of the traditional undergraduate curriculum in mathematics for providing satisfactory preparation to social scientists, was a motivation for action in the mathematical community. Indeed, in that same year the Mathematical Association of America appointed a committee to revise the undergraduate curriculum (SSRC Committee on Mathematical Training of Social Scientists 1955, 14).

The Committee was of the mind that every undergraduate envisaging a career in the social sciences should be required to take at least one year of mathematics as a freshman or sophomore. For students who decide to major in a social science, the Committee recommended a second year of mathematics. The Committee proposed a specific set of

[40] The document was later reprinted in *Econometrica* (1956) and widely distributed in 1956 during the meetings of the major social science organisations such as the American Sociological Association and the Allied Social Sciences (Memorandum from Madow to members of the committee, 13 Jul 1955 – JMP Box 93 - Folder Mathematical Training for Social Scientists).

contents and schedule for each course (Table 4). While the three courses should be given by mathematics departments, the Committee emphasized that the integration of mathematical and social science training must not be left to mathematicians alone. To facilitate this, the Committee suggested two procedures. First, social science departments should offer courses for which mathematical training would be prerequisite. Second, the offering should include interdepartmental courses or seminars on applications of mathematics in the social sciences. Even if only a very small number of students were interested in these courses, they should continue to be offered, reflecting the Committee's view that the program's value would only be realized after several years.

Table 4
Objectives and recommended and contents, courses in mathematics for undergraduate students who may later decide to concentrate in a social science. Committee on Mathematical Training of Social Scientists (1955).

Courses	Objectif	Recommended contents
Fist-year course (80 hours of lecture)	Prepare students who wish to study more mathematics	• Logic and set theory, including the algebra of sets • (10 hours). • Relations, including order relations (10 hours). • Axiom systems and the nature of mathematical models (10 hours). • Functions: linear, quadratic, polynomial, rational, trigonometric, exponential and logarithmic functions, including computations • (15 hours). • Introduction to the calculus (35 hours). • Some probability might be given during the first year by reducing the amount of time spent on other subjects.
Second-Year Course (80 hours of lecture)	Prepare students for further courses in the mathematics department (cf. with emphasis on the calculus).	• Continuation of the calculus (30 hours). • Probability (30 hours). • Matrix theory (20 hours).
If sufficient students were available, the Committee recommended to offer a course on topics from advanced calculus for social scientists.		• Finite differences. • Difference equations. • Differential equations. • Partial differentiation and multiple integration.

Source: (SSRC Committee on Mathematical Training of Social Scientists 1955, 15).

For those graduate and postdoctoral students who did not have satisfactory mathematical training as undergraduates, the Committee recommended that universities offer full-year courses in mathematics which combined the two undergraduate courses into a single special course. But the Committee highlighted also the importance of continuing to organize summer institutes for intensive training in mathematics for social scientists. The first of these summer institutes was held in 1953,[41] and their objective was twofold. First, to train social science graduate and postdoctoral students in mathematical methods, and second, to test methods of instruction adapted to the needs of both students at early stages of social sciences training and more mature social scientists whose previous mathematical training was insufficient.

These programs were designed to equip students to formulate social science problems in mathematical form, read mathematical literature in their chosen fields, and do further work in mathematics and statistics beyond the level of the calculus if they found need for this in connection with their work. The summer institutes were designed to be intensive: a minimum of six hours per day of courses with two hours of homework and reviewing subjects discussed in classes with the help of staff members. This process would repeat itself five days a week for eight weeks (SSRC Committee on Mathematical Training of Social Scientists 1953b, 8).

Between 1953 and 1957 the SSRC sponsored five of these summer institutes (Table 5). For the first three, no previous knowledge in mathematics was required. For the last two, participants must have had at least the mathematical background taught in the previous programs, meaning that mathematical prerequisites included calculus, probability theory, matrix algebra, sets and relations. This evolution was a product of the Committee's perception that new courses offered at the undergraduate and graduate level, combined with the increasing presence of mathematical faculty members applying mathematics to the social sciences and social science

[41] On the SSRC Summer Research Training Institutes program see (SSRC Committee on Research Training 1954b, 17–18, 1956, 20).

faculty members who used mathematics sufficiently in their own research, were making less urgent the SSRC's sponsorship of further activities for social scientists with little mathematical training (Madow 1957, 45–46).

Two of the workshops held during the 1957 *Summer Institute on Application of Mathematics in the Social Sciences* were specifically address to economists. The first dealt with linear programming, at the micro and the macro levels, and was led by Robert Dorfman. The topics covered included the transportations problem, a variety of applications of linear programming to problems of economics and business planning, the relationship between problems of optimal allocation and optimal pricing (i.e., duality phenomena), parametric programming, nonlinear programming and Koopmans's work on activity analysis. Previous study of linear models of economic theories was not required. The second workshop, led by Lionel W. McKenzie, was on applications of general equilibrium to the specific subjects of international trade and taxation. This workshop reviewed material which was "found chiefly in rather inaccessible journal articles" on topics related to the analysis of patterns of specialization in trade, the effects of impediments to trade, relative factor prices and factor supplies, growth in relation to trade, optimality properties of tax systems, including tariff systems, and the incidence of excise and income taxes.[42] Consistent with the SSRC's shift from basic training to the development of substantive content, both workshops allocated time for participants to develop individual investigations applying the tools discussed in the workshop (George A. Mille 1957, 41).

[42] Handbill Summer Institute on Application of Mathematics in the Social Science Research announcement 1957, Jacob Marschak Papers, box 93, folder Mathematical Training for Social Scientists.

Table 5.
SSRC Summer Institutes on Mathematics in Social Sciences

Year	Name	Place and date	Staff	Program	No. participants and discipline	Source of Funding
1953 (*1)	*Summer Institute in Mathematics for Social Scientists*	Dartmouth College, June 22-August 14	William G. Madow (director), E. P. Hutchinson, Jacob Marschak, Paul E. Meehl, George A. Miller, Frederick Mosteller, Robert M. Thral and Paul F. Lazarsfeld (visiting lecture)	Topics studied included: sets, relations, probability, matrix theory, convex bodies, theory of games, linear programming, metric spaces, convergence, differentiation and integration. Time was as well allocated to the study of specific mathematical models in the social sciences.	43 (Psychology 50%, economics 20%, sociology 20%, others 10%) Applications: Number of applications 134	Grants from the Behavioral Sciences Division of the Ford Foundation
1955 (*2)	*Institutes in Mathematics for Social Scientists*	University of Michigan	Robert M. Thrall (Director)	For intensive post- doctoral technical or interdisciplinary training in fields related to the primary interests and experience of groups of social scientists who present suitable proposals.	32 (Divided into groups of approximately equal size on the basis of their previous training in mathematics, the distinction being whether or not they have previously studied calculus for the equivalent of one year).	
1955 (*3)	*Institutes in Mathematics for Social Scientists*	Stanford University	William Maddow (Director)	For intensive post- doctoral technical or interdisciplinary training in	32 (Divided into groups of approximately	

				fields related to the primary interests and experience of groups of social scientists who present suitable proposals	equal size on the basis of their previous training in mathematics, the distinction being whether or not they have previously studied calculus for the equivalent of one year).	
1957 (*4)	*Application of Mathematics in the social science research* (*6)	Stanford University, June 24-August 17,1957	Robert R. Bush (Director, fw: I), Robert Dorfman (Harvard University, f: II), Lionel W. McKenzie (Duke University, w: III), George A. Miller (w: IV), and Patrick Suppes (w: V)	Each participant was enrolled in one of five workshops on the construction and use of mathematical models in the fields of: Psychology of Learning (w: I), Linear Economic Models (w: II), International Trade and Taxation (w: III), Communication and Language, Decision Processes (w: IV) and Measurement Theory (w: V)	35 (no more that 7 in each workshop).	
1957 (*5)	*Mathematics in the Social Sciences for College Teachers of Mathematics* (7*)	Stanford University, June 24-August 17, 1957	Robert M. Thrall (Director). Staff: William K. Estes (Indiana University), Tjalling C. Koopmans (Yale University), R.	Lecture series on applications of mathematics in economics, psychology, sociology; and on mathematical topics such as set theory, axiomatics,	40	Co-sponsor: Mathematical Association of America

			Duncan Luce (Columbia University). Lecturers: John G. Kemeny, (Dartmouth College), Albert W. Tucker (Princeton University),	linear programming, game theory. Seminars on representative new applications of mathematics in social science. Workshops to develop problems and examples suitable for use in teaching mathematics to social science students.		

Sources:

1* (SSRC Committee on Mathematical Training of Social Scientists 1953b, 7–8, 1953a, 23–24), (Mosteller 1974, 20)
2* (SSRC Committee on Mathematical Training of Social Scientists 1954a, 36, 1954b, 48) (Memorandum from Madow to the members of the committee, July 7, 1955, Jacob Marschak Papers, box 93, folder Mathematical Training for Social Scientists).
3* (SSRC Committee on Mathematical Training of Social Scientists 1954a, 36, 1954b, 48) (Memorandum from Madow to the members of the committee, July 7, 1955, Jacob Marschak Papers, box 93, folder Mathematical Training for Social Scientists).
4* (SSRC Committee on Mathematical Training of Social Scientists 1956, 52; Madow 1957, 45)
5* (SSRC Committee on Mathematical Training of Social Scientists 1956, 52)

After the 1957 summer institutes, the focus of the Committee expanded to encompass research, as well as training, and this included assisting individual scholars with their research problems, including those related to publication (Madow 1957, 46). In recognition of this new mission, the Committee on Mathematical Training of Social Scientists was disbanded and a new one, the Committee on Mathematics in Social Science Research, with Madow as it first chairperson, was appointed in 1958. In 1960 George A. Miller took the chairpersonship (Table 6), and under his leadership the new Committee developed a two-year program with two main axes: the continuation of the summer research institutes for advanced graduate students and recent PhD recipients in the social sciences who wanted to apply mathematical models in their research, and a new type of conferences for established social scientists whose research was mathematically oriented. The idea was to gather for several week a group of senior scholars all interested in some special branch of mathematical social science and in much the same

problems. They were expected to cooperate in arriving at a concrete product, whether that be a model, a set of experiments, methods of analysis, etc. Following the suggestion of T. C. Koopmans, mathematicians and mathematical statisticians were also invited to work together with social scientists who had encountered difficult mathematical problems in their investigations (Madow 1957, 46) (Table 7).

Table 6
Member of the SSRC Committee on Mathematics in Social Science Research over the years

Name	Years	Discipline	University
William G. Madow (Chairperson)	1958-1960	Mathematics	University of Illinois
Carl F. Christ	1958-1960	Economics	University of Chicago
Sanford M.Dornbusch	1958-1960	Sociology	Stanford University
John G. Kemeny	1958-1960	Mathematics	Dartmouth Collage
James G. March	1958-1960	Sociology	Stanford University
Philip J. McCarthy	1958-1960	Statistics	Cornell University
George A. Miller	1958-1960	Psychology	Harvard University
Anatol Rapoport	1958-1960	Mathematics	Michigan University
Patrick Suppes (Chairperson)	1960-1964	Philosophy	Stanford University (director of the Institute for Mathematical Studies in the Social Sciences)
David Blackwell	1960-1964	Mathematics	University of California, Berkeley
James S. Coleman	1960-1964	Sociology	Johns Hopkins University
Clyde H. Coombs	1960-1964	Psychology	University of Michigan
Robert Dorfman	1960-1964	Economics	Harvard University
Howard Raiffa	1960-1964	Mathematical statistics and Decision analysis	Harvard University
William. K. Estes	1960-61	Psychology	Indiana University
R. Duncan Luce	1962-64	Psychology (PhD. Mathematics)	University of Pennsylvania
Elbridge Sibley (staff)	1958-60 and 1963-1964	Sociology	SSRC
Francis H. Palmer (staff)	1960-62		SSRC

Sources: (SSRC Committee on Research Training 1958, 44), (Mosteller 1974, 22)

Table 7
List of activities hold by the SSRC Committee on Mathematics in Social Science Research

Activity	Year	Place	Participants	Funding source
Conference on the use of mathematics in undergraduate courses in psychology. Chairperson: George A. Miller	1959	Center for Advanced Study in the Behavioral Sciences	The 21 participants were psychologists who had either taught introductory psychology in mathematical terms or planned to do so.	
Exploratory project to identify areas of political science where mathematical models would be most profitably developed. Head: James G. March	1960			
Exploratory project to consider the applicability of mathematical models to research on the behavior of small groups. Heads: Bernard P. Cohen (Social Psychology, UC Berkeley), Joseph Berger (Sociology, Stanford University), and J. Laurie Snell (Mathematics, Dartmouth College)	1960	Dartmouth College		
Summer research institute on two-person interactions. Chairperson: Cletus Burke (Statistics, Cal State East Bay)	1962	Stanford University	41 participants plus 4 assistants.	National Science Foundation
Summer research institute on models of social decision-making mechanisms and their implications for political science and welfare economics. Chairperson: John C. Harsanyi (Economics, Wayne State University)	1962	Princeton University	41 participants plus 4 assistants.	National Science Foundation
Summer research institute on bargaining, negotiation, and conflict Chairperson: Harold W. Kuhn (Mathematics-game theory, Princeton University)	1962	Princeton University	41 participants plus 4 assistants.	National Science Foundation
Summer research institute on psychology of choice and decision. Chairperson: Frank Restle (Psychology, Indiana University)	1962	Stanford University	41 participants plus 4 assistants.	National Science Foundation

Summer research institute on measurement and data analysis. Chairperson: Lincoln Moses (Statistics, Stanford University - Department of Health Research and Policy)	1963	Stanford	26 scholars	National Science Foundation
Summer research institute on mathematical models of social structure Chairperson: James M. Beshers (Sociologist, MIT)	1963	University of Wisconsin	26 scholars	National Science Foundation
Summer research institute on mathematics for political scientists and sociologists Chairmen: Anatol Rapoport and Julian H. Blau (Economics, Mathematics Association American)	1964	Stanford	25 participants	National Science Foundation
Sequence of senior conferences on learning theory and measurement and choice theory	1962	Stanford	13 psychological research workers attended	National Science Foundation
Senior conferences on psychophysics Director: R. Duncan Luce (Mathematics and Psychology, University of Pennsylvania)	1963	Stanford		National Science Foundation
Senior conferences on learning theory Directors: William K. Estes and Patrick Suppes	1963	Stanford		National Science Foundation
Senior conferences on mathematical learning theory (eight weeks) Director: Robert R. Bush and R. Duncan Luce	1964	Stanford	6 participants	Science Foundation
Senior conferences on mathematical models of economic growth (six weeks) Director: Lionel McKenzie (Economics, University of Rochester)	1964	University of Rochester	13 participants	Science Foundation

Source: (Mosteller 1974, 22–23)

In 1964, six years after its creation, the Committee on Mathematics in Social Science Research was disbanded and with this a 12-year program came to an end, giving way to the creation of a

more permanent organization, the Mathematical Social Science Board[43]. The Divisions of Social Sciences of the National Science Foundation provided the initial funds ($500,000) to set up the new organization. Physiologist Henry W. Riecken, who had been a student member of the first SSRC summer training institute in mathematics (1953), was the director of the Divisions of Social Sciences at this time and a strong supporter of this effort. The process had come full circle for, as Frederick Mosteller put it in an official historical account of the role of the SSRC in the advance of mathematics in the social sciences in 1974, "the people involved in the future development were beginning to include scholars who had received some idea of the program by actual participation" (Mosteller 1974, 23).[44]

During the period from 1964 through 1972, the Mathematical Social Science Board held 85 events, including training institutes, conferences, research seminars and workshops with total attendance numbering nearly 2,000 people. Fields more newly concerned with applications of

[43] During the early 1960s the members of the successive committees were also meeting also outside the SSRC. In 1959 the Department of Social Sciences at UNESCO voted a modest sum to start a program on the application of mathematics to the social sciences. The idea was to organize an international four-week seminar in Paris as an explanatory first step towards an UNESCO long-range international cooperation program. Paul Lazarsfeld was responsible for organizing "the American group". The list of invited US scholar included a large number of scholars associated with the SSRC committees: Jacob Marschak, K. Arrow, Patrick Suppes, James Savage, Anatole Rapaport, Herbet Simon, Howard Raiffa, J. Marschak, Robert Bush, Duncan Luce, James Coleman, Samuel Goldberg, Willam Baumal, George Muller, Fred Mosteller, Robet Solow and Paul Samuelson + Participation of approximately fifteen young European social scientists who already have a good background in mathematics. (Letter from Lazarsfeld to Marschak, April 21, 1959, Jacob Marschak Papers, box 177, folder Contents of a box file).

[44] The Mathematical Social Science Board was initially under the wing of the Center for Advanced Study in the Behavioral Science.

mathematics such as anthropology, history, linguistics, and political science were now developing activities. These involved both advanced mathematics and particular techniques and models that had grown up in one area of social science but appeared to be transferable to another, one example of which was the use of econometric models being made in history (Cliometrics). Psychology, economics, and sociology remained well represented, but with a new emphasis in training in specialized techniques and models rather than elementary mathematics. In 1973 the support provided for these efforts by the National Science Foundation was at the level of $220,000 per year (Mosteller 1974, 24).

As the first SSRC Committee on Mathematical Training of Social Scientists expected, by the mid-1970s mathematical training of social scient had largely become the responsibility of the colleges and universities. The curriculum in mathematics for social scientists was much better developed than in 1951 and source materials for mathematical courses for social scientists were readily available. In his note of the role of the SSRC in the advancing mathematics in the social sciences, Mosteller gave a very positive appraisal of these efforts: “Without becoming a mathematician, a social scientist today can get a reasonable mathematical education to equip him for his research” (Mosteller 1974, 18).

Three important elements are worth mentioning before we conclude. First, the relationship between the SSRC committees and the Mathematical Association of America was especially valuable. This relationship provided an outlet for the committee's recommendations on the mathematical curriculum for social science students. Members of the committee spoke about these training needs at a great variety of meetings of mathematicians and applied mathematicians, and mathematicians became aware of mathematical problems in social science. Courses designed especially for social science students were beginning to be offered in a few mathematics departments by the mid-1970s, with Dartmouth College, the University of Michigan and Harvard being among the leaders (Mosteller 1974, 21).

Second, from the early 1950s the SSRC’s committees on the mathematical training were never concerned with improving the statistical training of social scientists. Multiple reasons for

maintaining this arrangement were given over the years. Some were of a practical nature —for example, that the teaching of statistics in colleges and universities was thought to be better than that with respect to mathematics, a desire to avoid the tendency to confuse statistics and mathematics, and time restrictions during the summer institutes. Others, though, were more fundamental going to whether the mathematical training should be primarily abstract and theorem-proving or empirical and thus statistically-oriented (Mosteller 1974, 19–20).[45] Third, the Ford Foundation and the National Science Foundation played a key role in mathematical research in the social sciences, providing funds for the preparation of materials, the summer training institutes, and the research projects carried out under the SSRC's auspices.

CONCLUSIONS: WHAT DID ECONOMICS LOSE WITH THE DEMISE OF GENERALIST ECONOMIST?

John Maurice Clark's plea for communicability, David Novick's belligerent note and Gregory Bateson's paradoxical position illustrate the tension that mathematical economists had to confront during the 1940s and 1950s. On the one hand, the popularity of mathematical methods was rising in the discipline, and in the social sciences more generally. On the other hand, the community of mathematical economists was small and insolated from the rest of the discipline. Generalizing the use of mathematical methods, and thus training students in economics in mathematical methods, was an important step to overcome the tension. By focusing on the challenges linked to communication between mathematically and non-mathematically trained economists, this paper examined the active role played by mathematical economists in the process of developing programs to train economists in mathematical methods, in creating teaching materials, and training individuals to educate future generations. Individual efforts can hardly produce changes at the scale of an entire discipline and the creation of professional instruments to facilitate these efforts along with the support of the SSRC was key to assure a durable transformation of the discipline.

[45] This might reflect a perceived higher status of theory, and thus of the type of mathematics necessary for theorizing.

Decades have passed since the categories "mathematical economist" and "generalist economists" cessed to be appropriated descriptors of the situation in the discipline. Economics today is mathematical economics. There is nothing intrinsically wrong with the use of mathematical methods, and thus with training students to master them; after all mathematics is a powerful tool which has largely proved it efficacy both, in the natural and social sciences. Nevertheless, it is worth asking: what did economics lose with the demise of Clark's "generalist economist"? By showing that the generalization of the use of mathematics in economics was a deliberate long-term process that depended upon real people and real institutions who worked to produce a desired outcome, this paper has shed some light on the answer of this question.

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