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The interaction between Leontief and Sraffa.

No meeting, no citation, no attention?

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1. Introduction

A few years ago MIT Press published the final two volumes, numbers 6 and 7, of *The Collected Scientific Papers of Paul A. Samuelson*. Because he wrote on many and widely different topics, Samuelson has often been considered the last generalist in economics, but it is remarkable how large a proportion of his final two volumes is devoted to linear systems of the input-output type, often called Leontief-Sraffa systems. In many of these writings Samuelson showed his special admiration for the works of Wassily Leontief and Piero Sraffa. In his influential article on Marx in the *Journal of Economic Literature*, Samuelson (1971, p. 400) even coined the expression “this age of Leontief and Sraffa”.¹ However, in various other publications, Samuelson regretted that Leontief and Sraffa never cited each other, that they provided too few bibliographical details about their precursors, and failed to pay attention to each other’s work.

Already in the early years of their career, independently of each other, Leontief and Sraffa tried to construct linear systems of simultaneous equations that describe the general interdependence between the different sectors of the economy. Samuelson pointed out that citations by Leontief or Sraffa to each other were completely absent during all the decades of their long lifetimes:

As far as I can remember, neither of the two has ever referred to publications of the other and I suspect that this is an honest reflection of what each has felt to be the need to know about the other’s work. Mine is a different philosophy. With the Germans I say of their two Works: “Herring is good. Chocolate is good. How good must be chocolate and herring.” (Samuelson 1988, p. 327)

If Wassily did not know Piero in 1928, Piero did not know Wassily. What is more interesting – and it tells us much about the two personalities – in the half century that followed neither one seems ever to have referred explicitly by name to the other. (Samuelson 1991, p. 177)²

¹ At the start of my ESHET conference presentation in Rome, I introduced the following quiz. Guess the name of X, an important 20th century economist. X grew up in an intellectual and wealthy family. X was an only child. His father was a professor; his mother came from a Jewish family. In his early career (in the 1920s) X translated a book on monetary economics into his native language. In the same period he had problems with the authorities of his non-democratic home country, and he emigrated. This was a good decision; he spent many decades at an Anglo-Saxon top university. In the 1920s X was less enthusiastic about partial equilibrium models than most of his colleagues, and wanted to create a general system that expressed the interdependence between all sectors of the economy, with special emphasis on the circular nature of production. To handle this circularity, he constructed a system of simultaneous equations, which he published only much later after unexpected delays. X was an early member of the Econometric Society, but later he wrote a letter to express his disappointment. X had read widely about the history of economics, but he presented his own system with few bibliographical references (but with a conspicuous reference to Quesnay). X had some unpleasant experiences with some security services. The reports of his security investigators contained some bizarre blunders, for example, exaggerating his list of published books. At the ESHET conference a Russian colleague then guessed X was Leontief; I suppose all the Italians thought of Sraffa. In point of fact, both solutions were correct, and remained so even after I added the very specific information that the birthday of X was 5 August. Sraffa (1898-1983) was exactly seven years older than Leontief (1905-1999).

² A detailed comparison of the early works of Leontief and Sraffa is provided by Kurz and Salvadori (2006).

During their long lifetimes Leontief and Sraffa, as far as I can learn, never once referred to each other – even though in the period 1960-1983 well-informed readers were aware of the major overlaps between their systems. This is hardly to the credit of these two justly admired scholars. (Samuelson 2004b, p. 155)

Samuelson's strongest statement is the following:

I have mentioned in print that neither Wassily Leontief nor Piero Sraffa has seemed ever to cite the other's work in print. That makes things even? No, it is two warts on the face of science. (Samuelson 2000a, p. 114)³

On 14 April 1997 Leontief was interviewed by Duncan Foley, who wondered whether Leontief did "ever have any personal or scientific contact with Piero Sraffa, the Anglo-Italian who worked on linear models". Leontief answered:

No. I never met him. But I think he was a very interesting man. His vision was interesting. In general, I think the input-output analysis is not necessarily linear. I would interpret it as an outgrowth of neoclassical theory. Sraffa was interested in something slightly different, the indirect relationships. I don't insist on linear relationships, only I'm conscious of the fact that dealing with nonlinear systems is terribly complicated; and even in computations, what do mathematicians do? Linearize the system in pieces, and then put it together. This is the way most of us use mathematics in a field in which data is important. (Leontief interview of 1997, published by Foley 1998, p. 129)

It is unfortunate that, a few seconds after Foley's pertinent question on the personal contacts between Leontief and Sraffa, the interview diverted away from Sraffa to the problem of linearity or nonlinearity.

Hundreds of publications have been devoted to the works of Leontief or Sraffa, emphasising the similarities or the differences in their approaches, their connections to the tradition of the classical economists (most comprehensively in the book by Kurz and Salvadori, 1995), or their compatibility with the general supply and demand framework of conventional economic theory (see the many contributions in the collected papers of Samuelson, 2011). My paper wants to avoid duplicating these stories, or entering into controversies on classical-marxian versus neoclassical approaches. I want to concentrate on one interesting part of the Leontief-Sraffa story that has been neglected or misrepresented in the economic literature: the personal interaction (meetings, citations, attention) between Leontief and Sraffa.⁴

³ Elsewhere it is called "venial mistakes": see the memorial paper 'A portrait of the master as a young man' (Samuelson 2004a, p. 7). An earlier conference version (Samuelson 2000b) contained a nearly identical text, but used a different title: 'Our Wassily: W.W. Leontief (1905-1999)'.

⁴ One of the referees correctly mentioned that most of the 'oddity' seems to stem from Sraffa. This is one of the reasons why my paper has to pay special attention to Sraffa's side of the interaction.

As far as I know, Samuelson is correct when pointing to zero *explicit* citations in publications by Leontief and Sraffa to each other.⁵ However, Samuelson's suggestion of their zero need to know about the other's work, and Leontief's statement about zero personal meetings with Sraffa, need some revision in the light of some published and unpublished evidence. Archival evidence reveals that on various occasions Leontief and Sraffa met in Cambridge, U.K. Moreover, despite the zero citations, Leontief and Sraffa discreetly paid attention to each other's work, and sometimes in a surprising way.

2. Leontief visits Stone in Cambridge (U.K.) in 1950.

Supported by Keynes, Sraffa was able to work at the University of Cambridge, from 1927 on. He retained his Italian nationality, and regularly went back to his native country, usually many weeks per year. Sraffa never travelled to the U.S., but received many foreign economists in Cambridge. His diaries show that Leontief in 1950 was one of them.

Leontief had emigrated in 1925 from Russia to Germany (Berlin) and in 1931 from Germany (Kiel) to the U.S., where, supported by Schumpeter, he was appointed at Harvard in 1932. America remained Leontief's academic base for the rest of his career (Harvard until 1975, then New York University). Leontief travelled widely, making numerous academic visits to many European and other countries.

In the last three months of 1950, Leontief spent part of his sabbatical in Cambridge (U.K.), together with his family. John Hicks had tried to attract Leontief to Oxford, but he understood that Leontief had preferred the invitation of Richard Stone and his Department of Applied Economics in Cambridge, which took care of all practical matters, including high-quality secretarial support for Wassily Leontief and an agreeable school for his daughter.⁶ Moreover, Stone had an excellent knowledge of econometric demand studies, national income accounting, empirical input-output analysis, and related topics. Just like Leontief in the U.S., Stone in the U.K. faced the scepticism of some more theoretically oriented colleagues.

The creation of a Department of Applied Economics in Cambridge in 1939 had been stimulated by Keynes. In its first years, it was directed by a Committee of Management. Sraffa himself, who was a member of the Committee, had written to Stone in 1944 to ask him if he was interested in the new position of Department Director (Marcuzzo 2005, pp. 437-8). Stone accepted the offer with enthusiasm. In 1945 he became the first Director, and

⁵ The Leontief Papers at Harvard include reading lists of Leontief's courses. These lists contain many books and articles on input-output theory and empiry, but again nothing by Sraffa.

⁶ Both the academic and the family conditions were relevant. The Kaldor Papers contain several letters (from February, March and April 1950) by Leontief's wife, Estelle Marks, asking help from Kaldor's wife, to find a suitable school for her only child Svetlana Leontief. This teenage daughter wanted no boarding school, but a day school; not a rigid old fashioned institution, but a modern and agreeable one (Nicholas Kaldor Papers, Modern Archive Centre, King's College, Cambridge, NK/3/30/136/3-8).

quickly turned the Department into a prestigious center of excellence. Deaton (1987, p. 510) emphasises that many future Nobelists (Leontief, Tobin, Samuelson, Frisch, Koopmans, Klein) visited Stone's Department in its early days, and that later Stone was manoeuvred out of the directorship of the Department by the Cambridge 'Keynesians' in the mid-1950s. In this context Pesaran and Harcourt (2000, p. 157) point to Richard Kahn's and Joan Robinson's active hostility to econometrics.

3. Personal contacts between Leontief and Sraffa in the 1950s

When Leontief arrived in England in the fall of 1950, the Cambridge Faculty of Economics was divided into different factions in a rather complicated way. Leontief seemed to have contacts not only with Stone and his collaborators, but with nearly all important Cambridge economists, and his seminars were attended by members of different groups.

Note the difference between the human geography of economics at the University of Cambridge, and that of many modern Faculties of Economics elsewhere. During his stay in Cambridge in 1950, Leontief belonged to the Department of Applied Economics in Downing Street, more than half a mile away from Sraffa's rooms in Trinity College, where Sraffa had daily contacts with fellows of his own college, nearly all of them being non-economists. Most of the social life of academics and students in Cambridge revolved around the splendid colleges, not around poorly equipped faculties. For example, John Hicks, who was a fellow of Gonville and Caius College in Cambridge from 1935 to 1938, wrote to Ursula Webb that ten days after his arrival he at last saw some economists (Marcuzzo et al., 2008, p. 576).

3.1. On counting the number of contacts in Sraffa's diaries

Before studying the personal contacts between Leontief and Sraffa, a general remark is in order. When asking the question "Did Sraffa ever meet X?" it should be noted that the number of entries on X in Sraffa's small Cambridge Pocket Diaries allows us to estimate a lower bound for the actual number of contacts with X, because many were not recorded by Sraffa. Consider, for example, Sraffa's discussions with Henry Schultz in 1933. Recent research by Olav Bjerkholt (2014b) used the detailed diary Schultz kept during his visit to Europe in 1933-34. It clearly reveals that Schultz enjoyed several meetings with Sraffa in November 1933, first in Oxford, then on the train back from Oxford to London, and a few days later in Cambridge. Schultz found Sraffa exceedingly keen and competent. It was not easy to get anything out of him, but when Sraffa did say something, Schultz found it generally to the point (Bjerkholt 2014b, p. 12). Apparently, Sraffa 'opened up' when he talked about his Ricardo edition and the problems of Jacob Hollander's imperfect communication on Ricardo.⁷ However, there is no trace of discussions about Sraffa's own

⁷ I am indebted to Olav Bjerkholt for additional information on Schultz and Sraffa in 1933, and I refer to Gehrke and Kurz (2002) for a well-documented study on Sraffa's difficulties with Hollander.

work on systems of general interdependence, although Schultz had just published on marginal productivity and general equilibrium. A copy of one of these papers (Schultz 1929) is heavily annotated in Sraffa's Library [reference: Sraffa 4698].⁸ While Sraffa surely met Schultz on 18, 19 and 25 November 1933, there is not a single entry on these contacts in Sraffa's diaries. This is just one example of the obvious principle that an explicit mention of X in Sraffa's small diaries is not a necessary condition to prove contacts between X and Sraffa. The Sraffa-Schultz story also illustrates the well-known reluctance of Sraffa to reveal something about his own research that, after more than three decades, would culminate into his classic *Production of commodities by means of commodities* (Sraffa 1960), without citing Leontief's (1941) seminal *The structure of American economy*, or any other Leontief publication.

3.2. October-November 1950

The existence of personal meetings between Sraffa and Leontief needs no indirect proof; it is directly evident from various entries in Sraffa's own diaries.⁹ On Wednesday 4 October 1950 Austin Robinson and Richard Stone had an appointment with Sraffa, probably discussing the visit of their eminent visitor from Harvard. On Friday 6 October Leontief himself came to see Sraffa in his office.¹⁰ They met again on Sunday 8 October "7.30 Leontieff (Trin)", probably in the Hall of Trinity College, and also on Saturday 21 October at "Austin's Party in Sidney (Leontieff, Haley)".¹¹ On Thursday 9 November the name Leontief is crossed out in Sraffa's diary. On Saturday 11 November the diary records a seminar presented by Leontief, and on Tuesday 14 November there is an entry on another seminar: "8.30 Kahn's Seminar (Leontieff)". Participation in Kahn's 'Secret Seminar' was by invitation only. It met in Kahn's room, and sometimes distinguished visitors were invited to present a paper.

In Cambridge Leontief also read the work of one of the brightest students of Sraffa's research seminar: Jan de V. Graaff, whose Cambridge doctoral dissertation of 1950 ultimately resulted in his classic *Theoretical welfare economics* (Graaff 1957); its preface mentioned the constant help and advice of Richard Kahn. The Kaldor archives (NK/3/30/136/2) reveal that the jury of Graaff's oral exam in Cambridge involved both Leontief and Sraffa. In a letter of 8 November 1950, sent from Stone's Department of Applied Economics, Leontief wrote to Kaldor:

How are you getting along with de Graaf's magnum opus? I have just sent in my report to Sraffa and he tells me that de Graaf will arrive here on the 14th [. . .] we will have to set the oral examination for some date between Monday 20th and Thursday 23rd . . .

⁸ Items in Sraffa's Library (now conserved in Trinity College) are indicated by the name Sraffa and a number.

⁹ I have not found any Leontief diaries at Harvard.

¹⁰ Sraffa's diaries nearly always used the spelling "Leontieff" instead of "Leontief"; Dobb's diary of 1950 used three different spellings in one month. Leontief wrote "Graaf" instead of the more official "Graaff", etc. I always try to quote literally.

¹¹ This refers to Austin Robinson's party in Sidney Sussex College, in honour of two American visitors: Wassily Leontief from Harvard, and Bernard F. Haley from Stanford.

There is not a single Leontief letter in the Sraffa archives, or vice versa, but Sraffa's diary shows he and Leontief performed their common task on 22 November ("Graaff oral exam"). After examining Graaff's dissertation, Leontief made a trip to the Continent from 24 November to 14 December, and Sraffa spent his Christmas holiday in Italy, as usual. His 1950-51 diary mentions no further contacts with Leontief.

Just like in the case of Schultz and other foreign visitors (and Cambridge economists), Sraffa in 1950 did not reveal to Leontief anything about his own research on linear systems. Most probably Sraffa emphasised he had reached the final stages of producing the first volumes of his Ricardo edition. In 1950 he spent numerous hours with Maurice Dobb, working intensively on the soon to be published volumes 1 and 2, which would appear on Friday 13 July 1951.

Dobb's diaries show Leontief met Dobb on Wednesday 18 October 1950 ("2.30 Leontieff Dept. of App. Econs."), on Friday 20 October, on Saturday 21 October for Austin Robinson's "sherry party" (also mentioned in Sraffa's diary). Finally, on Wednesday 8 November Dobb records "Leontiev chez Postan".¹²

Leontief surely must have been interested in news about the Sraffa-Dobb collaboration on Ricardo. In various interviews Leontief claimed that as a young student he enjoyed spending long days and evenings in the public library in Leningrad, reading all the classical economists from beginning to end:

I still think classical economics is a magnificent structure.¹³

I read systematically all economists beginning with the seventeenth century. I just read and read, so I had a pretty good background in the history of economic thought.¹⁴

3.3. Sraffa's similar discretion when meeting Morgenstern

Most probably Sraffa's meetings with Leontief in 1950 were very similar to his personal contacts with Oskar Morgenstern, involving conversations about Sraffa's work on Ricardo, but not on his secret research on linear models, related to those of Leontief, or those of Morgenstern's favourite colleague at Princeton, namely John von Neumann. After he visited Cambridge on 2 September 1947, Morgenstern's diary describes that he spent the day in Cambridge with Sraffa, "affable, promising the collected works of Ricardo soon, as always" (Leonard 2010, p. 308). There is no mention of a discussion on the economic growth model

¹² Michael Postan was a professor of economic history in Cambridge, member of Peterhouse College, an anti-communist emigrant from the USSR, but even the marxist students were attracted by his unusually fascinating lectures (Hobsbawm 2002, Chapter 17).

¹³ Leontief interview by Silk (1976, p. 155)

¹⁴ Leontief interview by Foley (1998, p. 118)

of von Neumann (1937), although both Sraffa and Morgenstern were highly interested in this sort of economic topics.¹⁵

Perhaps it is not widely realised that Morgenstern already in 1941 drew special attention to the paper by von Neumann (1937), in a long and critical book review (33 pages) of *Value and Capital* by John Hicks (1939). In his Hicks critique, which he had discussed with von Neumann himself, Morgenstern (1941, p. 369) regretted that, several years after von Neumann (1937) had done “decisive work”, Hicks and other mathematical economists still seemed to be unaware of it. They were still comparing the number of equations and the number of unknowns. Such a primitive procedure can assure neither the existence nor the positivity of the solution of an economic system. In a later autobiographical article on his collaboration with von Neumann, Morgenstern (1976) describes not only his famous joint research with von Neumann on game theory, but also his immediate interest in the linear economics of von Neumann (1937). According to Morgenstern (1976, p. 810) this was “another area of thought which occupied him and that he studied very carefully”. Morgenstern “was immediately convinced of its extraordinary significance” and dismayed at the total lack of interest of his Princeton colleagues in the following years, and disappointed by the complete bypassing in the literature of his own critique of Hicks, “perhaps due to the war conditions, perhaps due to its irreverent nature” (Morgenstern 1976, p. 810).

In England, in 1945, the *Review of Economic Studies* published an English translation of the paper by von Neumann (1937), thanks to an initiative from its editor Nicholas Kaldor, a personal friend of von Neumann (both emanated from Hungary). Kaldor asked David Champernowne to write an accessible commentary to the translated article. From archival research by Kurz and Salvadori (2001b) we know that the commentary by Champernowne (1945) was significantly influenced by Sraffa, who had already spent a lot of discreet research on similar topics, without any visible output and without using the sophisticated mathematics of von Neumann, of course.¹⁶

Hence, due to Sraffa’s secrecy in 1947, it was only much later (when he received a complimentary copy of Sraffa’s (1960) book) that Morgenstern became aware that Sraffa had been working on joint production and some other problems that also had interested himself and von Neumann.

¹⁵ For many details on Sraffa and von Neumann, see also Kurz and Salvadori (2001a, 2001b).

¹⁶ Ironically, Hicks already had an opportunity to learn about von Neumann’s economic system, when he met von Neumann in 1933: “I know, from personal recollection, that he had these things in mind in September 1933, when I met him with Kaldor in Budapest. Of course I did not understand what he was saying!” (Hicks 1960, p. 676). Many years after the Hicks critique by Morgenstern (1941), the importance of the von Neumann system was explained by Hicks himself in his survey of linear theory (Hicks 1960). Moreover, after he received a copy of Sraffa’s (1960) book, Hicks sent a long letter to Sraffa with several remarks on similarities between von Neumann and Sraffa. This long letter of 3 September 1960 is reproduced in full by Kurz and Salvadori (2001b, pp. 177-8).

4. Leontief, Sraffa, and Cambridge students

In 1950 Sraffa no longer offered any lectures, but he was responsible for the research students of economics in Cambridge, being an *Assistant Director of Research*. Besides Graaff (see above), several other young foreign economists went to Cambridge. Burgess Cameron from Australia, for example, was intensely interested in linear systems of general interdependence, and quickly managed to publish various papers on input-output analysis in prestigious journals, including a paper in the *Economic Journal*, entitled *The Labour Theory of Value in Leontief Models* (Cameron 1952). Interesting archival material used by Alex Millmow (2014, pp. 10-11) draws attention to Cameron's mixed feelings about Cambridge in 1950. From Cameron's letters to Wilfred Prest and Heinz Arndt, it becomes clear that Cameron preferred Leontief over Sraffa. On the one hand, Cameron was "extremely disappointed in Sraffa and his research seminar", judging it to have poor standards and inefficient conduct. On the other hand, Cameron benefited a lot from Leontief's stay in Cambridge: "I had a number of long talks with Leontief before he returned to the States. His presence was particularly good for my morale as none else in Cambridge is working in this field!"¹⁷ Cameron in the 1950s had not the slightest idea about Sraffa's secret research on similar topics. Leontief too left England at the end of 1950 without realising that Sraffa was heavily interested in models of the input-output type.

The strong impression Leontief made on students in Cambridge was also referred to in the Leontief obituary by Tam Dalyell (1999):

My first memory of Leontief was when I and other Cambridge undergraduates were told by our supervisor, the late Harry Johnson, to attend a lecture by one of the most innovative economists of the day. It was not just the undergraduates who went. There sat Nicholas Kaldor and Richard Kahn, Dick Stone and Sir Dennis Robertson, Piero Sraffa, Austin Robinson and Joan Robinson. Later in the week, at Robertson's political economy club, the students had the benefit of the glittering conversation between Robertson, some of his colleagues and Leontief.

Dalyell does not mention the exact timing of these Leontief lectures, but they must refer to a shorter visit by Leontief in the mid-1950s. The recently published autobiography by Dalyell (2012) shows he came up to King's College in Cambridge in 1952, after finishing his national service in the army. First Dalyell obtained a degree in history, and then, stimulated by Harry Johnson, he switched to Part 2 of the Cambridge Economics Tripos in the mid-1950s. He left Cambridge in 1956, and managed to have a remarkable political career in Britain, with an exceptionally long service of more than four decades as Member of Parliament. His autobiography, which describes many notorious conflicts in British politics, contains some

¹⁷ Cameron's letters are quoted in the very informative paper by Millmow (2014, pp. 10-11). Amartya Sen's many personal contacts with Sraffa for all his undergraduate years were much more productive: "I ended up learning a great deal from him on a large variety of economic, political and philosophical issues", and Sen also called Sraffa "an exceptionally stimulating educator who left a lasting mark on a great many students in Cambridge" (Sen 2004, p. 26). For more comprehensive studies on Cambridge as a *place* in economics, see Marcuzzo *et al.* (2008); Johnson and Johnson (1977).

strong remarks on the Cambridge Faculty of Economics. On the one hand, Dalyell remembered the unusual brilliance of several Cambridge economists; on the other hand, he stresses: “No divisions in politics in which I participated were as cantankerous as those in the Cambridge University Economic Faculty of 1955/56” (Dalyell 2012, p. 62).

5. Only a coffee in 1970

Leontief must have been surprised when in 1960 he received a complimentary copy of Sraffa’s book.¹⁸ Even a quick glance at the text must have been sufficient for Leontief to realise that for decades Sraffa had been silently interested in similar topics as he. Leontief never cited Sraffa’s book; the closest he came to it was his citing of *Lectures on the Theory of Production* by Pasinetti (1977). When Leontief (1986a, p.392) cited Pasinetti, he drew attention to the contrast between the pleasant, smooth work of the theorists and the ‘back-breaking’ empirical work he had done himself.

In the 1960s the reputation of Leontief’s input-output publications was still growing, leading to a Nobel Prize in 1973, and in some intellectual communities Sraffa became the legendary figure behind the scenes of the Cambridge capital controversies. In the meantime, the linear systems of Leontief and Sraffa were discussed in numerous articles and textbooks. When Leontief visited Cambridge again in 1970, the personal interaction between the two eponyms of ‘this age of Leontief and Sraffa’ seemed to be limited to a cup of coffee on Wednesday 27 May 1970, when Sraffa’s diary notes:

“ M.L. solo caffè Leontieff + Goodwin”,

a rather short contact in the Marshall Library with Leontief and his former Harvard colleague Richard Goodwin, who now worked at the University of Cambridge since 1951.

It is interesting to draw attention to Goodwin’s special position. When Goodwin’s career ran into problems in the U.S., because he could not get tenure at Harvard, and because his left-wing past was not an asset in the American university system, he was happy to consider working in Europe. Stone, who had met Goodwin at the 1950 Driebergen conference on input-output, supported Goodwin’s appointment at the University of Cambridge. “By careful discretion, I was able to have a long and happy relation with both Stone and the Kahn-Robinson group by diplomatic separation of the two groups in relations with each separately.” (Goodwin 1995, p. 18). Keeping good relations with different factions was facilitated by Goodwin’s preference to work on his own.

¹⁸ Sraffa sent out a large number of complimentary copies; see the long lists in the Sraffa Papers, D3/12/113. In this file some of the handwritten drafts appear in reverse chronological order, and reveal that Sraffa first had put a question mark after the names “Leontieff” (p. 69) and “Goodwin” (p. 67), but ultimately he included both in the more polished final list (p. 65).

Goodwin had been a colleague of Leontief at Harvard in the 1940s, and had published innovating papers on mathematical economics, including economic dynamics and theoretical input-output, even using the Perron-Frobenius theorem on nonnegative matrices already in 1950. The Perron-Frobenius matrices provided the crucial tools to solve many mathematical problems in Sraffa's linear model, but neither Sraffa nor his mathematical friends Watson and Besicovitch paid attention to Perron-Frobenius, and Sraffa never asked Goodwin's help in this context in the 1950s (Parys 2013).

After the coffee with Goodwin and Leontief, the rest of Sraffa's Wednesday 27 May 1970 was spent on the Ricardo Index in the afternoon, on his favourite bike ride to Coton, and on three other appointments (Krishna Bharadwaj, Thomas Gold, and Luigi Pasinetti). The next day Sraffa telephoned British European Airways to book a flight to Italy, and he left Cambridge from 4 June till 17 June 1970.

6. Attending one lecture in 1971

Unlike in 1950, the main purpose of Leontief's stay in England in May 1970 was not a sabbatical in Cambridge, but a business seminar at the *Royal Lancaster Hotel* in London, on *Business planning through input-output analysis*. Its participants were not academic economists, but marketing managers, directors, etc. Leontief repeated this seminar at the same hotel in May 1971. Because he stayed in the U.K. for a couple of weeks, many British universities tried to invite him for a lecture. In his letter of 28 April 1971 to Thelma Liesner, Leontief accepted to present a seminar in Cambridge on *The use of mathematics in economics* on Tuesday 18 May 1971, and he referred Liesner to Goodwin for more information about his whereabouts after arriving in Britain.¹⁹

Sraffa's diary mentions this seminar of 18 May 1971 "2.30 Leontieff (Marshall Room) on Maths. in Ec." Sraffa adds a reference to "A.E.R. March 71", which refers to Leontief's critical presidential address at the December 1970 meeting of the American Economic Association (Leontief 1971), on the large gap between the economic reality and the mathematical and statistical tools used by many economists. Apart from the 18 May reference, Sraffa's 1971 diary shows no further trace of Leontief.

7. Never at the same conference

Sraffa preferred to construct the fundamentals of his theories on his own. Leontief's temperament was partly similar, partly different. In an interview of 5 April 1997 by

¹⁹ The business seminars of 1970 and 1971 in London are mentioned in the Leontief Papers, HUG 4517.6, Box 11, Folder 'London Seminar May 18-19' and HUG 4517.6, Box 13, Folder 'England'. The latter folder contains the letter to Liesner.

DeBresson (2004: 146), Leontief said: “I think very separately from my friends and colleagues”. His wife added: “When Wassily’s mind is at work, he puts a wall around himself”.²⁰ The classic books by Leontief (1941, 1951) and Sraffa (1960) contain hardly any modern bibliographical reference. However, unlike Sraffa, Leontief wanted to combine theory and large-scale empiry, and needed a lot of assistants, research funds and sophisticated machinery for this. Moreover, after his results had been established, Leontief often propagated his findings throughout the world, and actively participated in numerous conferences during his long career. Sraffa’s participation in academic conferences was extremely limited, and never did he present material related to his 1960 book. To show that they never met at a conference, the shortest method is to examine the few conferences attended by Sraffa. It turns out that Leontief and Sraffa never appeared at the same conference, although in 1931 it nearly happened.

7.1. *Econometric Society Conferences*

On 22 September 1931 Sraffa presented a paper on the slightly mathematical monetary theory of Henry Lloyd, in the very first *European Meeting of the Econometric Society* at the University of Lausanne. The paper drew no questions from the audience, and is not extant. In the week of the conference, Sraffa’s diary contains only two words: *Che barba* (“How boring”), written on that special day of 22 September.²¹

Leontief had been invited to the same Lausanne meeting by François Divisia in a letter of 16 August 1931, but he regretted he could not attend, because he emigrated to New York a few weeks before the start of the Lausanne conference.²² Leontief often attended the *American Meetings* of the *Econometric Society*, and also the *First World Congress* in Rome (9-14 September 1965). Sraffa, after the ‘boring’ experience in Lausanne, never travelled to an *Econometric Society* conference again, not even to Rome, even though he very often visited his native country, for example, in the last two weeks of September 1965, thus arriving in Italy one week after the end of the *World Congress*.

In August 1952 Richard Stone had brought the *European Meeting of the Econometric Society* to Cambridge, but at that moment Sraffa had to stay in an Oslo hospital, due to a severe accident on holiday in the Norwegian mountains. He returned from Oslo to England by air, on stretcher, only on Tuesday 16 September 1952.

²⁰ The confidential appraisal of Leontief’s doctoral dissertation (Leontief 1928) contained a similar remark about the young Leontief: “... the candidate received no guidance whatsoever from his academic teachers. He arrived at his present position quite independently, one might say, despite them. It is very likely that he will maintain this scientific point of view also in the future.” This appraisal was written by Ladislaus von Bortkiewicz and much later published by Leontief (1991).

²¹ See Parys (2013) for more details. The improvised closing speech of 24 September 1931 by Ragnar Frisch (quoted by Bjerkholt 2015, p. 1164) implicitly referred to Sraffa’s talk on Lloyd. In his speech Frisch ironically remarked: “I know that there is a theory of price none of us shall forget: the price theory of Monsieur Lloyd!”. Most probably Sraffa already had left Lausanne earlier. (I thank Nerio Naldi for details on an Italian police report which shows that Sraffa’s car crossed the Italian border on 24 September 1931).

²² Leontief Papers, Accession 12255, Box 10, Folder ‘Ancient Correspondence 1930-32’

In September 1970 the *Econometric Society* visited Cambridge again, now for its big *Second World Congress*. Sraffa's library has a copy of the conference's *Program and abstracts of papers*, but his diary mentions only the invited lecture by Joan Robinson on the capital controversy, presented in the morning of Friday 11 September. The rest of Sraffa's Friday was spent on his Ricardo Index, his usual bike ride to Coton, and meeting Bertram Schefold. The congress included several papers on input-output analysis, but Leontief himself was not there.²³

7.2. Other conferences attended by Sraffa

Sraffa was reluctant to attend conferences or to accept scholarly awards. Apparently, Gunnar Myrdal could overcome his hesitations on a few occasions. It is well-known that Myrdal was instrumental in making Sraffa accept the prestigious Söderström Gold Medal in Sweden in 1961 (a sort of pre-1969 forerunner of the Nobel Prize in Economics). Earlier, in the late 1940s, Sraffa also accepted some invitations from the *United Nations Economic Commission for Europe* (UN-ECE), which had nominated Myrdal as its first executive secretary. For example, Sraffa attended part of the "second session of the UN-EEC", which lasted from 5 to 16 July 1947.²⁴ In September 1949 Myrdal organised a more "scholarly" UN-ECE conference of about thirty prominent economists, again in Geneva, on problems of European and international economic reconstruction and development after the war. The British delegation of ten included Sraffa. The only two participants from the U.S. were Chamberlin and Haberler, two Harvard colleagues of Leontief (who was not in Geneva). One of the reasons why Sraffa accepted Myrdal's invitations was that they did not imply the presentation of a paper.²⁵

In April 1952 Sraffa attended an international economic conference in Moscow, as a member of the Italian and not the British delegation (the latter included Joan Robinson, Maurice Dobb, etc.). There was no Leontief, no economic theory, no Sraffa paper, but a lot of discussions on the trade between the East and the West (Cairncross 1952).

After a long visit to China, organised by the *Associazione Italia-Cina* in the autumn of 1954, Sraffa contributed a paper for a symposium in Milan in 1955, on the trade between China and Britain (Sraffa 1955).²⁶

The *Istituto Gramsci* has organised various conferences in Italy on the life and the ideas of Antonio Gramsci, and related political questions. Sraffa attended such a conference in January 1958. Given Sraffa's special role in helping Gramsci during his prison years, and in

²³ See the complete program and the abstracts of the papers in the *Econometrica* issue of July 1971.

²⁴ The Sraffa Papers (A/1/8:18) contain a United Nations admission card with a stamp, dated 5 July 1947, of the "2nd Session of Economic Commission for Europe", and Sraffa's diary on the same day mentions "Apertura conferenza". However, this 'conference' can hardly be qualified as a purely scholarly one; it had to take care of many practical political problems, as the UN-ECE included both Western and Eastern European countries.

²⁵ See Speich Chassé (2014, pp. 203-4) for a list of all the participants. .

²⁶ I thank Nerio Naldi for providing a copy of Sraffa's paper.

preserving Gramsci's prison writings, Sraffa was a sort of guest of honour here; he delivered no paper or discussions. The other participants and the topics had no immediate relation to Leontief-Sraffa economics (Istituto Gramsci 1958).

A much more prestigious forum for economists was the famous Round Table Conference on the Theory of Capital, on the Island of Corfu, from 4 to 11 September 1958, organised by the *International Economic Association*. It is well-known that Sraffa delivered no paper, but he made a few interventions during the discussions of papers by John Hicks and by William Fellner (Lutz and Hague 1961, pp. 305-6, 325). Later Samuelson (2000a, p. 113) wrote that Sraffa informally told him at Corfu that he was working on the final drafts of a forthcoming book on capital theory. Leontief was not at Corfu.

Maybe some 'nonacademic' conferences are missing in the above list, but we can safely conclude that the interaction between Leontief and Sraffa through conferences was zero.

8. Sraffa's attention to Leontief's writings

Contrary to the impression created by the Samuelson quotations at the start of my paper, contrary to the zero citations by Sraffa to Leontief, contrary to the limited number of personal contacts when Leontief visited Cambridge, the Sraffa Library (donated to Trinity College after his death) shows a genuine interest in Leontief's work. It contains several writings by Leontief, and the presence of certain items is not a matter of trivial routine.

8.1. Leontief articles in the Sraffa library

A few Leontief items in the library are not annotated, for example, two early articles in German, from the 1930s, on demand and supply analysis; or Leontief (1938) on the significance of Marx for modern economics; or the Italian translation of Leontief (1960), on the decline and rise of economic science in the Soviet Union. Jacob Marschak had sent Sraffa the final three articles on the controversy on 'pitfalls' in supply and demand curve analysis, an unusually bad tempered controversy, involving Leontief on one side, Frisch at the opposite, and Marschak as the mediator, but Sraffa did not annotate these articles.²⁷

Sraffa paid more attention to an article by Leontief (1934), entitled *Interest on capital and distribution: a problem in the theory of marginal productivity*, which discussed some theoretical parts of the influential book *The Theory of Wages* by Paul Douglas (1934). The copy in the Sraffa Library [reference: Sraffa 4704] has a few lines in the margins, for example, with respect to Leontief's remarks on the vague foundations of Douglas's theory of capital and interest.

²⁷ The Sraffa Library contains no copy of Leontief's important doctoral dissertation, which was published in the *Archiv für Sozialwissenschaft und Sozialpolitik* (Leontief 1928).

8.2. Sraffa's interest in Leontief's classic 1941 book

Many pioneers of input-output models were invisible in Sraffa's library, for example, Isnard, Mühlpfordt, Charasoff, Potron, Remak, etc. Furthermore, Sraffa read Bortkiewicz's important papers for the first time in the 1940s, more than three decades after they were published (Gehrke and Kurz 2006), and he acquired a copy of the important 1904 book by Dmitriev only in the 1960s (de Vivo 2014, pp. xxxix, 138).

It was less difficult for Sraffa to discover the existence of the first edition of the classic *The Structure of American Economy* by Leontief (1941). For many years, Leontief already enjoyed a high reputation among the Cambridge economists. As early as 1933, during his long stay in the U.S., Richard Kahn had drawn Sraffa's attention to the special position of Leontief at Harvard:

Scarcely anyone seems to go in for pure theory (except for Schumpeter, Chamberlin, and Leontieff - a very brilliant young Russian, about whom a lot will be heard before he is much older: he is about my age).²⁸

Being written by a distinguished Harvard economist, the book by Leontief (1941) was reviewed not only in American journals, but also in Britain, in the *Economic Journal* by Erwin Rothbarth (1943). The review mentions that the original price is 14 shillings; the same price is also indicated in Sraffa's copy [his library reference: Sraffa 2035]. Sraffa was very interested in Leontief's book, but most other economists apparently were not eager to buy it. In 1941 Harvard University Press had printed only 614 copies of the first edition, and it took six years to dispose of them (Hall 1986, p. 79). Taking into account that many university libraries routinely bought it, the number of individual buyers of the 1941 edition must have been disappointingly low, in sharp contrast with the commercial success of *The Theory of Monopolistic Competition* by Leontief's Harvard colleague Edward Chamberlin (1933). In his letter of 24 August 1981 to Max Hall, Leontief pointed out that Harvard University Press had refused the second enlarged version of the book, because the monograph was "obsolete and of little scientific interest". According to Leontief, Oxford University Press then bought the copyright for one dollar, and published the second enlarged edition in 1951.²⁹

The preface of Leontief (1941) contains the following announcement:

Only a small part of the explanatory notes on statistical sources and methods of computation are included in Appendix III of this volume. Additional material is available in the form of a mimeographed supplement. It will be sent to the readers of this volume upon request addressed to the Harvard Committee on Research in the Social Sciences, G-52 Littauer Center, Cambridge, Massachusetts.³⁰

²⁸ Both Kahn and Leontief were born in August 1905. Kahn's long letter to Sraffa was sent from New York, 17 February 1933 (Sraffa Papers, C 150).

²⁹ Leontief Papers, Accession 12255, Box 4, Folder 'Cambridge (sic) University Press'.

³⁰ A similar announcement appeared at the start of Appendix II (Leontief 1941, p. 141).

The number of requests for this mimeo was even much more limited than the sales figures of the book. Very few university libraries own the mimeo. Rather surprisingly, there is a copy of it in the private library of Piero Sraffa [reference number: Sraffa 2029].

The first two parts of Leontief (1941) were not entirely new. Part 1 (pp. 11-30) updated an article from the *Review of Economic Statistics*, entitled *Quantitative input and output relations in the economic system of the United States* (Leontief 1936). This pioneering 1936 study presented the first input-output tables of the U.S. economy, but no algebra. Part 2 of Leontief's 1941 book (pp. 31-65), called *The theoretical scheme*, contained material from a 1937 article, also from the *Review of Economic Statistics*, and entitled *Interrelation of prices, output, savings, and investment* (Leontief 1937). Here Leontief published for the very first time the well-known simultaneous equations of his closed input-output system. There are no offprints of these 1936 and 1937 articles in Sraffa's library.

The lines in the margins in Sraffa's copy of Leontief (1941) are all situated in the first 30 pages of the book. Some theoretical mathematical paragraphs in the rest of the book were perhaps too tedious or too heavy for Sraffa. Some involved rather cumbersome partial derivatives in comparative static exercises, including the study of many elasticity concepts. Their purpose was to answer questions of the following type: suppose there is a 1 % decrease in all input coefficients of the industry producing commodity A, all other things remaining equal; what would be the effect on the price of commodity B? Leontief used rather lengthy arguments with partial derivatives here, just like in his earlier theoretical article (Leontief 1937).

8.3. Keynes (*Economic Journal*) rejected Leontief

The prehistory of the input-output mathematics of Leontief's 1937 paper is not entirely clear. In 1931 Leontief had informed Emil Julius Gumbel about his system of simultaneous equations and input-output, and Gumbel had referred him to similar work by Robert Remak. A few days later Leontief wrote to Remak, who lived a few miles away from him in Berlin. The rest of the Remak-Leontief story is unclear, and Leontief never presented detailed information on this (Parys 2014, pp. 1006-7).

On 2 June 1933 Leontief sent a paper entitled *Economic changes and general equilibrium* to Keynes for the *Economic Journal*, but it was rejected rather quickly. The rejection letter by Keynes and the Leontief manuscript seem to be lost, but a Leontief letter of 25 July 1933 acknowledged receipt of the manuscript returned by Keynes, and politely accepted that it did not meet the approval of Keynes (see Parys 2013, pp. 42-4).³¹

Using Frisch's editorial files of *Econometrica*, Bjerkholt (2014a, pp. 25-29) reveals that Leontief submitted a paper with the same title in November 1933 to *Econometrica*, and a

³¹ The two letters from Leontief to Keynes are conserved in the Harvard University Archives, Leontief Papers, HUG 4517.5, Box 1, Folder 'General Correspondence: 1932-1941'.

revised version in January 1934. Both texts seem to be lost, but Bjerkholt was able to trace two referee reports written by editor Frisch himself, who criticised the lack of elegance of Leontief's (often nonlinear) mathematics.

It seems that the lost 1933 paper partially overlaps with the publication in the *Review of Economic Statistics* (Leontief 1937). The 1937 publication showed us for the first time the linear input-output equations of Leontief's closed system, together with rather lengthy and tedious comparative static exercises, involving a mass of first derivatives. The hypothesis about the overlap between the 1933 and 1937 texts is also supported by the existence of a file named *Keynes Deriatives* (sic) *Theory* in the Leontief archives.³² This rather mixed file contains some comparative static derivatives that we also find in the article by Leontief (1937, pp. 119, 122) and in his book (Leontief 1941, pp. 58-9). Hence, some results in the lost 1933 paper seem to anticipate the more polished material that Leontief published in 1937 and 1941.

There are various reasons why Keynes in 1933 could have rejected Leontief's first and rather inelegant presentation of his input-output ideas. It is well-known that Keynes did not apply positive discrimination in favour of heavy or clumsy mathematical submissions, and/or emanating from America (Moggridge 1990). Moreover, Leontief's timing was unlucky, because the *Economic Journal* of 1933 had an unusually low acceptance rate. In a letter of 8 February 1933 Keynes informed his co-editor D.H. Macgregor that he had "never known such a deluge of manuscripts. They are averaging two a day..."³³

There is no evidence that Keynes informed Sraffa about Leontief's submission for the *Economic Journal*. All we know is the following: on the one hand, Keynes did not publish the equations of Leontief's cumbersome text in 1933; on the other hand, Keynes was more enthusiastic when he saw an early draft of Sraffa's first equations in 1927.³⁴

8.4. The notation with two subscripts

Pasinetti (2007, p. 178) points out that in the early 1940s Sraffa had more free research time, because of the supposed ending of the work on Ricardo, and then resumed "all of a sudden and very intensively" his research on linear systems. To what extent did the book by Leontief (1941) provide an important impetus? The answer is difficult, but the question is interesting.³⁵ One year after the appearance of Leontief (1941), a Sraffa document of 15 November 1942 (D3/12/15:7) considers the following system and notation (I reproduce it literally):

³² Leontief Papers, HUG 4517.30, Box 4.

³³ John Maynard Keynes Papers, King's College, Cambridge, JMK/EJ/1/3/313.

³⁴ See Naldi (1998, pp. 513-4) for letters by Keynes (to Lydia Lopokova) and by Pigou (to Sraffa) on Sraffa's first equations. See also Naldi (2005, pp. 387, 398).

³⁵ I am indebted to Jonathan Smith for raising this question.

$$a_{i1}x_1 + \dots + a_{in}x_n = C_i x_i \quad i = 1, \dots, n$$

$$\text{where } a_{11} + a_{21} + \dots + a_{n1} = C_1$$

$$a_{12} + a_{22} + \dots + a_{n2} = C_2$$

$$\cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot$$

$$a_{1n} + \dots + a_{nn} = C_n$$

where a_{i1} = quantity of commodity 1 used to produce commodity i , C_i = quantity of commodity i produced, x_i = price of commodity i .

Hence in this 1942 document Sraffa denotes, for example, the input of commodity 2 used up in the production process of commodity 1 by a_{12} . This is exactly the same notation as in the book by Leontief (1941): the first subscript indicates the number of the production process. This notation is also used in many contemporary texts on Sraffa (see, for example, Kurz and Salvadori (1995), or Bidard (2004)). In his second edition Leontief (1951) still used the same notation. A few years later, Leontief reversed the meaning of the subscripts. In this way, a_{12} in the “modern Leontief notation” indicates the input of commodity 1 into the production process of 2. This notation is found in many contemporary publications on input-output.³⁶

8.5. Sraffa’s calculations using Leontief’s input-output statistics

Given the purely theoretical content of his own *Production of commodities by means of commodities*, it is remarkable how Sraffa was interested in the empirics of Leontief’s book. The outstanding example to show this is a very surprising item in the catalogue of the Sraffa Papers: the unexpected document ‘Sraffa I61’, named *Calculations* and belonging to the Category I (“Items removed from printed books”). The catalogue of the Sraffa Papers mentions that ‘Sraffa I61’ was removed from ‘Sraffa 2035’. In plain words, the document originally was inside Sraffa’s copy of *The Structure of American Economy*, the Leontief (1941) classic!

This handwritten document ‘Sraffa I61’ presents a table of 45 rows and 7 columns, with figures extracted from Leontief’s input-output table of the 1919 U.S. economy.³⁷ Sraffa performs some patient arithmetical calculations on these Leontief data, the ultimate purpose of which is not easy to grasp.

³⁶ The story about Leontief’s notations is even more sophisticated, because in Leontief (1936) we did not find two subscripts yet, but a notation with letters like in Sraffa (1960, p. 4). And a fourth variant of notation can be found in the German dissertation by Leontief (1928).

³⁷ Every reader of Leontief (1941) can find the huge folded tables for 1919 and 1929 in the pocket at the back of the book. The 1919 table was also published in Leontief (1936).

To try to understand some of Sraffa's intentions, consider, for example, agriculture, the first sector in Leontief's table for 1919. I use Sraffa's own notation, from a to g . Sraffa extracts or calculates the following figures for agriculture:

Gross output = $a = 22\,147$ (prices in millions of dollars)

To human consumption³⁸ = $b = 2209$

From wages³⁹ = $c = 1099$

From profits⁴⁰ = $d = 9818$

From wages and profits⁴¹ = $e = c + d = 10\,917$

c reduced in proportion of a to b ($= \frac{bc}{a}$) = $f = 110$

($\frac{be}{a}$) = $g = 1090$

Sraffa considers these concepts not only for agriculture, but for all sectors, and then calculates expressions like $\frac{\sum b}{\sum g}$ and $\frac{\sum a - \sum b}{\sum e - \sum g}$, summing over all 41 sectors of Leontief's Table and he also uses some alternative summation procedures.⁴²

Using the summation over 41 sectors, he finds $\frac{\sum b}{\sum g} = 3.51$ and $\frac{\sum a - \sum b}{\sum e - \sum g} = 2.63$.

It is difficult to find detailed information on the purpose of Sraffa's patient calculations. Therefore, it might be useful to look at the special simplifying case of a one commodity economy where all physical capital is used up during the production process, and the whole net output is consumed by wage earners and profit earners. In such a case both $\frac{\sum b}{\sum g}$ and $\frac{\sum a - \sum b}{\sum e - \sum g}$ reduce to the simple ratio $\frac{a}{e}$, the ratio of 'gross output' over 'net output'. In a draft on 'subsystems' (or vertical integration), dated 10 February 1944, Sraffa (D3/12/36: 47) mentions that a gross output may be many times larger than a net output. Looking at

³⁸ Part of the gross output of American agriculture (the amount 22 147) was delivered to American human consumers (the amount 2209), a much larger amount was absorbed by agriculture itself (feed for the cows, for example), or delivered to the sector Slaughtering and Meat Packing, or to Exports, etc.

³⁹ By "From wages" Sraffa means the amount paid by the sector to wages and salaries (as computed by Leontief).

⁴⁰ Sraffa leaves the entry for d blank for all sectors, but in later computations for $e = c + d$ he uses the amount of Leontief's 'Capital and entrepreneurial services' (equal to 9818 in agriculture)

⁴¹ Sraffa implicitly takes the sum $c + d = e$, and then he explicitly defines f and g as above.

⁴² Sraffa considers also alternative summations over 42 terms, the last one using the figures of "undistributed" items like taxes etc. It is obvious that Sraffa spent a lot of time on computing all these ratios. All rows and columns were handwritten by Sraffa. His arithmetical 'technology' must have been extremely primitive, compared to Leontief's use of the most advanced machinery at Harvard; see Leontief (1948).

Sraffa's ratio's 3.51 and 2.63 above, let us assume that in our one commodity example the ratio of gross over net output equals 3.

Such a result might perhaps have interested Sraffa with respect to his famous notion of the *standard ratio* R (Sraffa 1960, Chapter 4), which equals Sraffa's *maximum rate of profits*, which is by definition the profit rate 'corresponding to a zero wage' (Sraffa 1960, p. 94). If my simple case above reveals a ratio of gross output a over net output e equal to 3, then Sraffa's maximum rate of profits R equals $1/2$. In other words, here the rate of profits cannot exceed 50 %, 'even if the workers could live on air' (Sraffa 1960, p. 94).⁴³

9. Leontief's attention to Sraffa's writings

9.1. Refereeing a paper that used Sraffian concepts

In February 1988 the *Cambridge Journal of Economics* asked Leontief to referee a paper by Jaromir Cekota, on technological change in Canada. It used a combination of Leontief's input-output analysis and some Sraffian tools. Leontief suggested dropping some "unnecessary theoretical embellishments", for example, the "very artificial" distinction between basic and non-basic commodities, which Leontief found "really not necessary". The latter is a typical Sraffian distinction, but Leontief did not mention the name Sraffa in his referee report. Leontief found most of the paper an excellent example of applied input-output analysis. He emphasised he recommended publication, even if the author would not want to follow his suggestions.⁴⁴ Despite this strongly positive review, the paper ultimately was not published in the *Cambridge Journal of Economics*, but a very similar paper by Cekota (1988) appeared in the *Canadian Journal of Economics*.

9.2. An empirical publication by Leontief himself, with some Sraffian topics in disguise⁴⁵

The most remarkable example of Leontief's interest in Sraffian topics is found in Leontief's long paper *Technological change, prices, wages, and rates of return on capital in the U.S. economy*. In November 1984 Leontief submitted a copy to the *American Economic Review*. It was rejected a few months later, most probably because a referee assessed it was just a routine exercise in input-output analysis.⁴⁶ The paper then appeared as Chapter 19 in the second edition of a collection of Leontief essays on input-output economics (see Leontief 1986a). All other essays in the collection were just reproductions of older articles, and in this

⁴³ In my one commodity example the maximum rate of profits $R = e / (a - e)$. Hence, the reciprocal of R equals $(a - e)/e = (a/e) - 1 = (3/1) - 1 = 2$, and thus $R = 1/2$.

⁴⁴ Leontief Papers, Accession 13712, Box 2, Folder 'Cambridge Journal of Economics'

⁴⁵ Robert Solow (letter to me, 22 March 2016) informed me that in all the many years he knew Leontief well, "Sraffa and his ideas never came up". With respect to my current paragraph 9.2 on Leontief (1986a), Solow mentioned: "I think that Leontief would have said that those are not 'Sraffian topics in disguise', they are perfectly straightforward topics in conventional economics".

⁴⁶ Leontief Papers, Accession 13712, Box 11, Folder 'American Economic Review'

way the new paper in Chapter 19 received little attention from other economists.⁴⁷ It did not explicitly mention Sraffa, and used a different terminology, but it contained an interesting application of Leontief's statistical and economic skills to some Sraffian questions:

1. Unlike his papers of earlier decades, Leontief now pays special attention to the tradeoff between 'the long-run rate of return on capital' and real wage rates. His empirical findings suggest that the results for the U.S. were nearly linear. In the terminology of Sraffa (1960, p. 23) this means nearly "a straight-line relation between the wage and the rate of profits".
2. The summary on the back of Sraffa's (1960) book mentions that "a series of propositions are deduced concerning the effects which changes in the division of the product between profits and wages may have on the values of individual commodities". This was a fundamental exercise in Sraffa's book. Leontief now, for the first time, considers a similar exercise, and presents empirical results for the U.S.
3. The latter exercise can also be described as an analysis of the effects of changes in the rate of interest on the prices of different commodities. This exercise plays a crucial role in the controversies on 'reswitching of techniques' and related problems in the theory of capital. Unlike in earlier publications, Leontief now pays special attention to "the switching and reswitching controversy that for many years pitted the sharpest minds of Cambridge, Massachusetts, against the brightest theoretical lights of Cambridge, England" (Leontief 1986a, p. 410). His own conclusion on reswitching was negative: "the U.S. economy actually does not, however, contain even a single instance of reswitching" (Leontief 1986a, p. 410).

Ironically, Leontief's own tables allow me to construct a 'hypothetical' reswitching example. Consider the empirical table computed by Leontief in his Appendix 19-1 (1986a, p. 412). The physical units of all 85 commodities are normalised such that at interest rate $r = 12.5\%$ the price of every commodity equals 1. When r increases from 12.5% to 15% , all prices change. In Leontief's table the prices at $r = 15\%$ range from 1.080 to 0.975, and are listed in descending order (hence, not at random). Take the very first two sectors, i.e. the sector 'electric, gas, water, and sanitary services' and the sector 'communications, except radio and TV'. I now simply call them 'commodity A' and 'commodity B'. Imagine now a luxury commodity that is nowhere used as an input in any production process, and assume it can be produced by two different, but very similar production methods, namely 'method A' and 'method B'. Imagine both methods use exactly equal quantities of all inputs, with the exception that:

⁴⁷ A footnote by Roncaglia (1990, p. 477) refers to a 1984 Leontief mimeo with the same title. Roncaglia makes a short remark on the analytical resemblance between the Leontief mimeo and Sraffa's wage-profit lines. Kurz (2011) concentrates on a very short paper (Leontief 1985) in the *Scientific American*, which also contains a few Sraffian elements, but no statistical tables. In the same period two other writings on technological change were published by Leontief (1986b) and by Leontief and Duchin (1986), but these are less relevant for the Leontief-Sraffa story.

- 'method A' requires 1 extra unit of 'commodity A'
- 'method B' requires 1.001 extra units of 'commodity B'

I formulate this theoretical example using the strategy of Sraffa's clever argument (Sraffa 1960, §48 and §92), and I fill in the empirical figures that I reproduce or easily compute from the first two rows of Leontief's Appendix 19-1 (Leontief 1986a, p. 412). Consider the interest rates equal to 12.5 %, 15 % and 21 % in Leontief's table. This leads to my following reswitching result:

Rate of interest r	$r=12.5\%$	$r=15.0\%$	$r=21.0\%$
Price of 1 unit of commodity A	1	1.080	1.259
Price of 1.001 units of commodity B	1.001	1.077	1.268
Cheapest method	A	B	A

This is a remarkable and ironical result. Leontief explicitly mentions that his tables show no example of reswitching, but his empirical figures implicitly contain the seeds of my own reswitching example.

10. Conclusion

Samuelson often showed his special admiration for Leontief and Sraffa, but was disappointed that Leontief and Sraffa never cited each other, and seemed to pay no attention to the other's work. Moreover, in the Foley interview Leontief suggested he never met Sraffa. The story of 'no meeting, no citation, no attention' needs some corrections.

From Sraffa's diaries and other sources, it is beyond doubt that Sraffa and Leontief had several personal meetings in Cambridge (England) in 1950, and at least one in 1970, but Sraffa was always discreet about his own research.

Contrary to Samuelson's impressions, Sraffa's unpublished papers and his library show a genuine interest in Leontief's work. Sraffa studied parts of the first edition of Leontief's (1941) classic book *The Structure of American Economy, 1919-1929*. Furthermore, Sraffa was one of the very few economists who owned a copy of the mimeographed *Supplement to The Structure of American Economy, 1919-1929*; this supplement was available only upon special request. Moreover and most unexpectedly, Sraffa carefully looked at Leontief's American input-output table of 1919, and patiently made a lot of extra calculations, the ultimate purpose of which is not completely clear.

Similarly, Leontief showed more interest in Sraffa's theoretical results than suggested by Samuelson. In the 1980s Leontief wrote a comprehensive paper on technological change in the U.S. economy, which included some Sraffian questions, but without citing Sraffa. This ambitious paper was rejected by the *American Economic Review*, and then ended up rather

invisibly in a compilation of papers on input-output economics. The paper's detailed statistical tables show some erratic movements in relative prices when the interest rate changes. It is possible to construct a hypothetical reswitching example, by using some theoretical inspiration from Sraffa and some empirical figures from Leontief's statistics.

Even if it is true that Leontief and Sraffa never cited the other's work, the story of 'no meeting, no citation, no attention' is more than 50 % wrong.

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Abstract

Samuelson often regretted that Leontief and Sraffa never cited each other (true), and seemed to pay no attention to the other's work (false). In the Foley interview Leontief suggested he never met Sraffa (false). Archival evidence shows that in the 1940s Sraffa studied Leontief's classic *The Structure of American Economy*; he also owned the rare mimeographed supplement, and did some calculations on Leontief's first input-output table. Leontief and Sraffa met in Cambridge (U.K.) in 1950 and later. In the 1980s Leontief wrote an ambitious

empirical paper on technological change, rejected by the AER, and not widely read. It studied some Sraffian topics without Sraffian terminology. I construct a hypothetical reswitching example using Leontief's statistics.

Keywords

Sraffa, Leontief, input-output analysis, reswitching

JEL Classification: B24, B31 and C67