David Hawkins and the making of the Hawkins-Simon conditions

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Abstract: The Hawkins-Simon conditions, which are necessary and sufficient for the viability of input-output systems, are described in many encyclopedias, textbooks and papers, but always without historical details about the philosopher David Hawkins. The rich literature on the history of input-output economics has neglected Hawkins, probably because he spent only a few years among the economists. My paper fills this gap. By using the relevant archival material on Hawkins, Simon, and Leontief, I correct and expand some scarce remarks on Hawkins by Simon and Samuelson. I discuss Hawkins's three remarkable contributions to economics. First, Hawkins's dynamic input-output model in *Econometrica* in 1948 scooped Leontief. Second, I show how the correspondence between Hawkins and Simon created their famous joint note in *Econometrica* in 1949. Third, an overlooked chapter in Hawkins's 1964 book *The Language of Nature* discussed the commodity values of commodities, thereby putting into perspective Marx's labour values and the Technocrats's energy values.

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1. Introduction

It is remarkable how many Nobel laureates in economics published on linear models of the input-output type or Leontief-Sraffa systems. Besides Leontief himself, the list also includes Frisch, Simon, Koopmans, Arrow, Samuelson, Solow, Klein, Debreu, Hurwicz, Markowitz, Hicks, Mundell, Mirrlees, Stone, Stiglitz, Sen, and others.[1] When Herbert Simon received his Nobel Prize in 1978, William Baumol (1979) wrote the traditional laudatory article in the *Scandinavian Journal of Economics*. Baumol (1979, p. 74) described 'Simon's two most crucial contributions to economics': first, his work on organization theory, and second, a short, but often cited paper in *Econometrica,* written by Herbert Simon and a young philosopher, namely David Hawkins. This paper by Hawkins and Simon (1949) provides necessary and sufficient conditions for the viability of an input-output system.[2] Today these Hawkins-Simon conditions appear in many textbooks and encyclopedias, but without historical background. For example, the fourth edition of Chiang's best-selling textbook introduced new sections on the analytics of the Hawkins-Simon conditions, but nothing on its history (Chiang & Wainwright, 2005, pp. 116-119). This history is also not mentioned in the 750 pages of the well-known textbook on input-output by Miller and Blair (2009). The 2008 *New Palgrave* encyclopedia of economics contained entries on the analytics of the Hawkins-Simon conditions, and on Herbert Simon, but it offered no information on his co-author David Hawkins.[3]

In his long career David Hawkins (1913-2002) published mainly on philosophy and childhood science education, but he also wrote interesting texts on the history of the first atomic bomb, physics, mathematics, probability, game theory, and the political and the social sciences. During his short stay in economics, he made some remarkable contributions: his pioneering dynamic input-output model in *Econometrica* in 1948; the famous Hawkins-Simon paper in *Econometrica* in 1949; and a few overlooked ideas on the commodity values of commodities in *The Language of Nature,* his 1964 book on the philosophy of science.

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[1] For a more extended list and bibliographical details, see Parys (2013, note 1).

[2] For reprints of the Hawkins-Simon paper, see, for example, the compilations edited by Newman (1968); Cass and McKenzie (1974); Sohn (1986); Kurz, Dietzenbacher and Lager (1998); and Dimand (2002). Newman (1968) presented a collection of 'some of the best mathematical economics of the last generation' (p. viii). Cass and McKenzie (1974) compiled 'the best of *Econometrica'*. Sohn (1986, p. 4) tried 'to strike a balance between some of the now "classic" literature in input-output analysis and the more recent developments'. Kurz, Dietzenbacher and Lager (1998) included the Hawkins-Simon paper as one of the six articles in their section on the foundations of input-output analysis. The paper also appears in the compilation by Dimand (2002) on the origins of macroeconomics, and perhaps in various other books of readings.

[3] The *New Palgrave* entry on the Hawkins-Simon conditions was written by Nikaido for the 1987 edition and reappeared in the second edition in 2008. The entry on Simon was written by Augier (2008).

In its first decades, *Econometrica* published a large part of the innovating results on mathematical economics, and the list of members of the *Econometric Society* contained the names of numerous important economists, statisticians and mathematicians. The 1950 list (*Econometrica,* 1950, pp. 395-446) also included one professor of philosophy. This remarkable 'outsider' in the long alphabetical list was *Hawkins, Dr. David, Professor of Philosophy, University of Colorado, Boulder.*

Hawkins stayed on the *Econometric Society* membership lists only a few years, because he concentrated on other disciplines. The autobiography by Herbert Simon (1996, p. 129) offers only a few biographical lines about his collaboration with Hawkins. Three years after Simon's death, Paul Samuelson (2004) contributed a short chapter on Hawkins-Simon, in a book of essays in memory of Simon, edited by Augier and March (2004). Both Simon and Samuelson rely on some personal memories, not on archival material related to Hawkins. It is evident that Hawkins received less attention from historians of economic thought than other pioneers of input-output analysis, most probably because he spent only a short time 'among the Econ'.[4] My paper tries to remedy this situation.

First, I define some terminology (Section 2) and provide a few biographical details on Hawkins (Section 3), and then the main purpose of my paper is to investigate the following topics:

- How did a solo effort by a philosopher of science like Hawkins lead to a seminal *Econometrica* publication in 1948 on dynamic input-output systems, thereby anticipating Leontief's work on the same topic? (Section 4)

- How did Hawkins and Simon ultimately produce their famous *Econometrica* note in 1949? (Section 5)

- What contributions to economics did Hawkins make after his two *Econometrica* papers? (Sections 6, 7 and 8)

- Are most authors using the correct eponyms when referring to Hawkins's contributions to economics? (Section 9)

[4] On other pioneers of input-output economics, see Kurz and Salvadori (2000), and the special issue of *Economic Systems Research,* on the history of input-output analysis, introduced by Bjerkholt and Kurz (2006).

By means of archival material in the David Hawkins Papers in Boulder, the Herbert Simon Collection in Pittsburgh, and the Wassily Leontief Papers at Harvard, it is possible to clarify, correct and expand on the narratives in Simon (1996) and Samuelson (2004).

2. Terminology

Perhaps it may be useful to spend a short section here on terminology. Consider a simple Leontief system with input matrix **A**, gross output vector **x** and net output vector **c**, with the well-known relation $\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{c}$ (Nikaido, 2008, p. 848). A fundamental problem is the viability of the economic system, in the following strong sense: is the system able to produce a positive net output vector **c** corresponding to an economically meaningful (i.e., positive) vector **x** ? [5]

In the trivial case of a 1 x 1 input matrix **A,** such viability exists if and only if the only input coefficient a_{11} is less than 1 (in more sophisticated terminology: the one and only eigenvalue of the matrix **A** is less than 1). An equivalent necessary and sufficient condition is the positivity of $1 - a_{11}$ (positivity of the one and only principal minor of the matrix $\mathbf{I} - \mathbf{A}$).

In the general case of an *n* x *n* input matrix **A**, the present-day literature offers many alternative conditions for the viability of the system. In my paper the following three equivalent conditions are the most relevant:[6]

- *all* principal minors of $\mathbf{I} - \mathbf{A}$ are positive (*original* Hawkins-Simon conditions)
- the *leading* principal minors of $\mathbf{I} - \mathbf{A}$ are positive (*economical* Hawkins-Simon conditions)
- all eigenvalues of **A** are less than 1 in absolute value

All three conditions are *necessary and sufficient.* The original Hawkins-Simon conditions are of course explicit in their 1949 paper. The economical version is implicit in their argument on the arbitrary numbering of the equations and the commodities (Hawkins & Simon, 1949, p. 248, line 6-8). The existence of an economical version is emphasised by Georgescu-Roegen (1951b,

[5] Some texts replace 'viability' by other terminology, like productivity, feasability, workability, solvability, etc. Some authors call the above system strictly viable, and also consider the case where it is just viable, i.e., when the system is just able to reproduce itself, without a surplus. See Kurz and Salvadori (1995), and Bidard (2004). For my historical narrative on Hawkins-Simon, I consider the simple case of viability in the strict sense.

[6] Consider a matrix with *n* rows and *n* columns. Delete *k* arbitrarily chosen rows and the corresponding *k* columns ($k = 0, 1, 2, \ldots, n - 1$) and obtain a submatrix of order $n - k$. The determinant of this submatrix is called a principal minor of order $n - k$. If we delete the *last k* rows and the *last k* columns, the determinant is called the *leading* principal minor of order $n - k$.

1966). Samuelson (2004, p. 158) uses the example of a 10 x 10 matrix to illustrate the computational advantage of the economical version. In Samuelson's example the original Hawkins-Simon conditions require the computation of the 1023 principal minors, whereas the economical version needs only the 10 *leading* principal minors (which is also a much faster procedure than the cumbersome calculation of the eigenvalues of A).

3. A few biographical details

David Hawkins was born on February 28, 1913 in El Paso, Texas, and was raised in New Mexico.[7] A few decades later, Hawkins's special knowledge of the terrain of New Mexico contributed to the selection of a site in the southern New Mexico desert, for one of the most dramatic tests in human history: the explosion of the first atomic bomb on 16 July 1945. This was the climax of the Manhattan Project, involving years of secret research in the Los Alamos Laboratories, New Mexico, including many top scientists, under the direction of Robert Oppenheimer. The project also employed thousands of ordinary civilian and military personnel; many of them were unaware of the final purpose of their work. Oppenheimer had learned to know Hawkins at Berkeley in the 1930s, and choose him as his administrative assistant in 1943, to act as a liaison between the military and the civilian personnel.

Hawkins (1946) wrote the history of the project, a 'secret' text that became declassified in 1961. In the meantime Hawkins had lost access to his own files, because of his prior membership of the Communist Party from 1938 to the early 1940s (United States Senate, 1953, pp. 929-938).[8] At the end of the 1930s many intellectuals at Berkeley, like David Hawkins, Leslie Fishman, and Kenneth May had joined the Party.[9] In a 1982 interview, Hawkins mentioned that he and his Berkeley friends were not thinking about barricades and revolution, but about dealing with the social problems caused by the Great Depression in the 1930s:

> we were self-consciously a left-wing component of the New Deal … we were all very much interested in historical materialism and the theory of history (Sherwin's interview with Hawkins in 1982, quoted by Bird and Sherwin, 2005, p. 173).

[7] For biographical details, see also Hawkins (1981), Palevsky (2000), Lehmann-Haupt (2002), and Woo (2002).
[8] According to his daughter Julie (mail of 14 August 2019) David Hawkins was shocked about the uncritical attitude of many Communists when German troops invaded Belgium and Holland in May 1940 (at that moment, the Treaty of Nonaggression between Germany and the USSR was still in use, and many Communists followed Moscow's orders with respect to Germany).
[9] At the end of the 1930s, the Party's membership in the U.S. increased to approximately 66,000 (Gregory, 2020).

In the academic year 1950-51 Hawkins was summoned to testify before the *House Committee on Un-American Activities*. Despite attacks in the local press in Colorado, Hawkins was able to keep his professorship at the University of Colorado in Boulder.[10]

When Hawkins died on 24 February 2002, the obituaries in most newspapers concentrated on stories about the atomic bomb or on Hawkins's problems in the Communist-hunting 1950s. But in the academic world, the name David Hawkins is associated with innovating contributions in widely different disciplines.

His formal academic education was in philosophy, leading to a Bachelor's degree in 1934 and a Master's degree in 1936, both at Stanford. He then continued as a graduate student (1936-40) and as a teaching assistant (1938-40) at the University of California, Berkeley. In 1940 he earned his Ph.D. in philosophy at Berkeley, with a dissertation *A Causal Interpretation of Probability*. The dissertation includes some references to Keynes's and Cournot's ideas on probability, to Wittgenstein, etc. But it did not contain any argument directly relevant to Hawkins's later contributions to economics. In a sense Hawkins shared Keynes's ability to understand many different disciplines, with special attention to their foundations. The famous Polish mathematician Stanislaw Ulam, a close friend of John von Neumann, learned to know Hawkins at Los Alamos, and singled out Hawkins as unusually gifted:

> Hawkins is a man of wide interests, with great breadth of knowledge, very good education, and a very logical mind. He regards scientific problems not as a narrow specialist, but from a general epistemological and philosophical point of view. To top it off, he is the most talented amateur mathematician I know. He told me that at Stanford he took some courses from Ouspenski, the Russian émigré specialist in probability and number theory, but he has not had any extensive training in mathematics. He has a very great natural feeling for it and a talent for manipulation. He is the most impressive of the non-professional mathematicians or physicists I have met anywhere in the world (Ulam, 1976, p. 159).

Hawkins even did some teaching on physical sciences, but his main specialty was philosophy. He lectured at many universities but spent most of his career as a professor of philosophy at the University of Colorado in Boulder. There David Hawkins and his wife Frances Pockman, a specialist in early childhood education, founded the *Mountain View Center for Environmental*

[10] Many years earlier, Kenneth May had lost his teaching assistantship at Berkeley because of his widely known membership of the Communist Party (Moore, 2007, p. 123). Later May published on Marxian and classical economics, social choice theory, the history of mathematics, and many other topics. David Hawkins is mentioned in the acknowledgements of May's papers on the structure of classical value theories (May, 1949) and on aggregation of preferences (May, 1954).

Education, supporting curiosity-based education for young children, rather than inflexible prepared curricula. For more details, see www.hawkinscenters.org (the website of the *Hawkins Centers of Learning*).

4. A young philosopher scoops Leontief

Users of the *EconLit* database will notice that the name David Hawkins corresponds to only two articles on economics, both in *Econometrica*, in 1948 and 1949. Later Hawkins switched to various other fields. Perhaps because of Hawkins's broad knowledge of many disciplines, in the 1990s Leontief sent him a proposal to use input-output methods for studying the nature of interdisciplinary citations. Hawkins and Leontief then exchanged a series of letters, on various scientific and social problems. Hawkins also used the occasion to look back at the late 1940s, and wrote to Leontief in 1995:

> Being in touch with you again has reminded me of past flirtations with economic theory. The realization first occurred to me that my friends on the left (this is Berkeley, late 30's) had an overly simple idea of Marx. So I 'invented' (with some help from Capital, v. 3!) the dynamic input-output matrix as a closed system. When Econometrica accepted it I got a very good letter from you, saying I had scooped you! What flattery to the young philosopher! Especially when you told me that the germ of your idea also came from v. 3 of Papa Marx! I reminisce, I hope you will be amused […] I have been off in other fields ever since then (DH/Box18/Fd8).[11]

The exact date of this 1995 letter from Hawkins to Leontief is unknown. The 'very good old letter' it referred to, was written nearly half a century earlier, on 17 December 1948. At that time Leontief was ignorant of the young philosopher Hawkins and his address. Therefore, Leontief sent his 1948 letter through Dickson H. Leavens (managing editor of *Econometrica*) and mentioned that he was working on similar dynamic systems for some time.[12] In his reply

[11] My notation DH/Box18/Fd 8 means that the item is conserved in the David Hawkins Papers, Box 18, Folder 8, in the University of Colorado at Boulder Libraries, Archives Department. It is bizarre that in this letter (and some others), and even in his 1948 article (p. 320) and in his 1964 book (p. 337), Hawkins refers to volume 3 of Marx's *Capital*, although volume 2 is the relevant one for Marx's reproduction schemes.

[12] In February 1949, Leontief presented his dynamic model before the staff of the Harvard Economic Research Project (Georgescu-Roegen, 1951a, p. 117). In September 1949 he presented his results in a symposium on large-scale digital calculating machinery at Harvard. His short contribution was finally published in the proceedings two years later (Leontief, 1951). A much longer study of the same system appeared in Leontief (1953), where his page 55 explicitly mentioned that Hawkins (1948) had already discussed 'the same dynamic system based on stock-flow relationships'.

of 29 December 1948, Hawkins explained that as a philosopher he paid a lot of attention to scientific methodology in various disciplines, including economics:

> In reading economics it seemed to me that the tendency in contemporary economics is mainly to discuss questions which should enter only in as second or *n*th approximations, and that the study of the tableau économique was really the first approximation, yet much neglected…[13]

The rest of this 1948 letter makes it clear that Hawkins wanted to put more emphasis on the objectively visible conditions of production and less on 'complex teleological assumptions' (like utility maximization). His letter drew attention to problems of major instability as between producer goods and consumer goods sectors 'as I believe Marx and others who emphasize disproportion have assumed'.

In the text of Hawkins's (1948) *Econometrica* article, the only explicit references to Marx were collected in his very long footnote 6 (Hawkins, 1948, pp. 320-321). In the core of his article Hawkins presented what today is called a dynamic input-output system, and he investigated its stability properties. Starting in complete independence of each other, both Hawkins (1948) and Leontief (1951, 1953) introduced a capital coefficient matrix, dealt with continuous time, and used the mathematical theory of linear differential equations to investigate the stability properties of their system.[14] Today, the basic balance equation of their system is often written in the well-known matrix form $\mathbf{x} = \mathbf{A}\,\mathbf{x} + \mathbf{B}\,\dot{\mathbf{x}} + \mathbf{f}$, with gross output vector $\mathbf{x}$, its time derivative $\dot{\mathbf{x}}$, final demand vector $\mathbf{f}$, matrix $\mathbf{A}$ of current input coefficients, and matrix $\mathbf{B}$ of capital coefficients.[15]

The long footnote 6 of Hawkins (1948) referred to 'Marx's models of "extended reproduction" in *Capital*, Vol. III'. Hawkins applied his general stability results to the special case of Marx's simple two-industry model:

> The condition of stability can be read as requiring that the organic composition of consumer-industry capital be greater than the organic composition of producer-industry capital (Hawkins, 1948, p. 321).

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[13] Observe that Hawkins in his handwritten letter underscored the expression 'tableau économique'. The 1948 correspondence between Leontief and Hawkins is conserved in the Wassily Leontief Papers, Harvard University Archives, HUG 4517.5, Box 5, C-G, 1948-50, Folder Econometric Society.

[14] Many later studies, including some papers by Leontief himself, preferred to deal with discrete time periods, which implies the use of difference equations instead of differential equations. See the comprehensive treatment of dynamic input-output systems with discrete time by Takayama (1985, pp. 503-558).

[15] Hawkins (1948) concentrated on a closed system (where $\mathbf{f} = \mathbf{0}$).

This condition is an example of what Hawkins calls *close coupling*. Intuitively speaking, this is a situation of strong interdependence between the two industries; one (the 'producer-industry') produces the capital good, the other (the 'consumer-industry') has the highest organic composition of capital. On the stability of the system with two sectors, Hawkins (1948, p. 317) also writes:

> Stated qualitatively, stability depends upon the extent to which the two compartments are *coupled* together by the constitution of each other's capitals. If the compartments were *completely uncoupled*, we would have two independent systems. If they are *loosely coupled*, the system is unstable. If they are *closely coupled* the system is stable.[16]

Although Hawkins was a philosopher without any formal degree in mathematics, he handled the general case with *n* sectors, and he employed more sophisticated mathematics than the average 1948 paper in *Econometrica*. Hawkins's first version was submitted in October 1947.[17] Kenneth Arrow refereed it, and thought the revised version was suitable for publication. Leavens informed Ragnar Frisch (19 April 1948), who then asked Trygve Haavelmo to check the mathematics. Haavelmo just returned an OK to Frisch, but Frisch also read the paper with care, and then informed Leavens it was excellent. In his editorial letter of acceptance to Hawkins (1 September 1948), Frisch praised not only the pioneering content of Hawkins's paper, but also the style: 'May I also add that personally I like very much your compact and precise style, but I am aware of the fact that not everybody may do so.'[18]

Frisch even invited Hawkins to submit further work to *Econometrica*. He surely must have been impressed by the wide background of Hawkins, who cleverly combined his knowledge of economics and mathematics, and referred to other sources of inspiration:

> The model thus developed is expressed by means of ordinary differential equations, throwing the problem of stability into a form already thoroughly familiar in connection with investigations of electrical and mechanical systems. (Hawkins, 1948, p. 310).

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[16] Hawkins (1948, p. 317) referred to Goodwin (1947), who also had used the term 'coupling' when describing degrees of interdependence, but in a different context, i.e. in his dynamic study of markets having production lags (the cobweb theorem and related topics).

[17] For information on the reviewing process of Hawkins (1948) and Hawkins & Simon (1949) by *Econometrica*, I am much indebted to Olav Bjerkholt for sharing his detailed knowledge of Frisch's editorial files.

[18] For the letter of acceptance, see DH/Box17/Fd13. Remember that in its first decades *Econometrica* was often much less mathematical than today. For example, the *Econometrica* article by Joan Robinson (1951) contained twenty pages and never used a mathematical symbol or argument. Some other *Econometrica* articles required only a decent knowledge of today's undergraduate mathematical economics, but Hawkins's 1948 paper was heavier.

During the war, Hawkins had met John von Neumann at the Los Alamos Laboratories. Hawkins (1945) also reviewed the classic on game theory by von Neumann and Morgenstern (1944).[19] But it is doubtful whether Hawkins knew the linear growth model of von Neumann (1937). Most probably Hawkins produced his 1948 paper by combining his knowledge of philosophy, the mathematics of linear differential equations, electrical and mechanical systems, Quesnay and Marx. It was definitely a solo effort. Only one acknowledgement is included, to a Boulder colleague, the mathematician Aubrey J. Kempner, who suggested a proof for the 'treacherous' lemma on page 312, which presented a defective sufficient condition for a system of linear equations to have solutions with all variables positive.

In the rest of my paper I refer to this proposition as *Hawkins's Lemma.* I called it 'treacherous' for good reasons. Kempner was a competent mathematician, but he did not see that the proof was flawed and that the lemma was false. When the 1948 paper was published, neither Kempner nor Hawkins realised this. We can hardly put special blame on these two Boulder scholars, because four future Nobel laureates missed the error too, either in the refereeing process (Arrow, Haavelmo, Frisch) or in a letter (Leontief's letter of 17 December 1948 mentioned above). Ultimately, the defect was discovered by another future Nobelist: here Herbert Simon makes his appearance.[20] Another irony is that the 1949 correction became a self-contained paper on statics that now is more famous than the pioneering 1948 paper on dynamics.

5. The chronology of the Hawkins-Simon collaboration

The autobiography by Herbert Simon (1996, p. 129) mentions that at the end of 1948 he had doubts about 'Hawkins's Lemma':

> Examining it closely, I soon found a counterexample which I sent to Hawkins. As we began to correspond about it, I also found the (weaker) correct theorem, and we agreed to write a joint paper making the correction and discussing the new theorem, which had interest in its own right. Our paper appeared in *Econometrica* in 1949. Some years later Hawkins appeared in Washington

[19] Later, Hawkins (1956) reviewed a book on game theory by Braithwaite (1955). Hawkins's (1977) book *The Science and Ethics of Equality* emphasised the role of educational equality and related topics, but it also contained a few remarks on von Neumann and game theory: 'John von Neumann once explained, in private conversation, that he hoped to show, by formal analogy, how under altered standards of behavior the game of capitalism could be brought to compete with that of socialism in providing distribution standards at least as fair and equitable as those which socialism promised' (Hawkins, 1977, p. 22).

[20] Another future Nobelist, Robert Solow (1959, p. 30), corrected a flaw in the price equation (11) on page 315 of Hawkins (1948).

> to testify (with dignity) before a congressional committee as an ex-Communist. I had co-authored a paper with a Communist whom I had never met – an excellent example of the potential for guilt by association![21]

Samuelson (2004) studied Simon's autobiography, he repeated a similar short story, and concluded:

> The story of events told here, which I have gleaned from Simon's writing, is one that sheds credit on two noble characters. In present-day publish-or-perish academic times, customarily when A spots an error in B's publication, A rushes into print with a rebuttal and a correction. There have been exceptions in history, but not too many. (Samuelson, 2004, p. 159)

Samuelson (2004, p. 158) also repeated: 'Herbert Simon never met David Hawkins'. This might be misleading, because Simon and Hawkins both contributed papers to the elite conference in Chicago at the Cowles Commission on June 20-24 in 1949. Many papers were included in the classic book *Activity Analysis of Production and Allocation*, edited by Tjalling Koopmans (1951). From the letters exchanged between Hawkins and Simon, it is obvious that they met at the Chicago conference in June 1949, a few weeks after the final version of their *Econometrica* text had gone to the printer. To refine the informal stories by Simon (1996) and Samuelson (2004), it is necessary to combine the archival material in Boulder and Pittsburgh, and to look at it in chronological order.[22]

24 December 1948: Simon to Simpson for Econometrica. Simon was working on linear equations and inequalities and knew the work of the mathematician Lloyd L. Dines on the existence of positive solutions to linear systems. Just at that time he noticed Hawkins's *Econometrica* paper of October 1948, and wrote a short comment, containing a counterexample to Hawkins's Lemma, using four equations, and references to articles by Dines (1925) and Stokes (1931). Partly inspired by Dines's results, Simon then proposed a *necessary* condition in terms of the *principal minors of order two*. He immediately sent the comment to William B.

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[21] The FBI had noticed Simon's membership of the NAACP (National Association for the Advancement of Colored People), and Simon had to answer some questions about it in his security interviews. However, the scholarly connection between Simon and Hawkins never caught security attention during McCarthyism. Apparently nobody at the FBI read *Econometrica*.

[22] When it is obvious that the sender of a letter used the wrong date (wrong year), I correct it without further comment. For example, Simon's letter dated '6 January 1948' was obviously written on '6 January 1949', because it replies to a December 1948 letter and discusses the October 1948 paper. Both Hawkins and Simon made this well-known mistake quite often when dating their letters, even in February. During the construction of the Hawkins-Simon note (December 1948 - May 1949), Hawkins was in Boulder, and Simon was writing from the Illinois Institute of Technology in Chicago. He joined the Carnegie Institute of Technology in Pittsburgh in September 1949.

Simpson, the new Managing Editor of *Econometrica*, 'for possible publication in the next issue'. If Samuelson (2004) had seen this letter, he would have omitted his remark about Simon not rushing into print. Simon also informed Simpson that Hawkins would get a copy of the comment (HS/Box101/Fd9104).[23]

24 December 1948: Simon to Hawkins. The same day Simon reported to Hawkins about the comment he sent to *Econometrica*, and about his plans to prepare 'a more complete analysis of necessary and sufficient conditions'. He promised to send it to Hawkins when it was in more finished form (DH/Box17/Fd13 and HS/Box101/Fd9104).

28 December 1948: Hawkins to Simon. Hawkins agreed that Simon's counterexample was entirely correct. After receiving Simon's letter, Hawkins worked over some early statements in his old drafts which he 'mistakenly thought were superseded by the "Lemma" of bad repute'. These statements were based upon the *sufficiency* of the condition that *all principal minors of all orders* should be positive. Hawkins believed without proof that these conditions were also *necessary*. Moreover, he claimed that the conditions had a simple economic meaning: 'any group of compartments formed by aggregation must be able to satisfy at least their own internal demands upon each other' (HS/Box101/Fd9104).

4 January 1949: Simon to Hawkins. Simon presented a *proof* of the necessity and the sufficiency of the condition that the principal minors are positive. He enclosed the proof in his attachment. In his letter Simon also noted that a system that is able to produce *some* fixed vector of consumption goods, can produce consumption goods in *any* desired proportion. Then Simon made the famous proposal to Hawkins:

> It has occurred to me that, instead of asking Econometrica to publish the counter-example disproving your lemma, it might be more constructive if we jointly wrote a brief note giving the counter-example, setting forth and proving the new theorem, and perhaps commenting on the economic significance of it. What do you think?

A copy of this important letter can be found in both the Boulder (DH/Box17/Fd13) and Pittsburgh (HS/Box101/Fd9104) archives. Unfortunately, in both archives the attachment with the proof is missing. The original typewritten letter in Boulder contains a handwritten message below Simon's signature: 'Kenneth May, whom I have seen in the last few days, sends his

[23] My notation HS/Box101/Fd9104 means that the item is conserved in the Herbert Simon Collection, Box 101, Folder 9104 (Carnegie Mellon University Archives, Pittsburgh, PA).

regards'. Before the start of their correspondence, Simon and Hawkins did not know each other, but both had spent some time at Berkeley and had learned to know May there (later Simon met May again at the Cowles Commission).

6 January 1949: Simon to Hawkins. Simon promised not to bombard Hawkins with daily letters. He presented a method that might be less labour intensive than finding the signs of the requisite principal minors, but it had no direct economic interpretation. An example with a 5 x 5 matrix was included in attachment. (DH/Box17/Fd13).

18 January 1949: Hawkins to Simon. This letter is not extant.

27 January 1949: Simon to Hawkins. Simon thanked Hawkins for his letter of 18 January. He had talked to Simpson, the Managing Editor of *Econometrica*, about a joint note. Simpson was quite receptive, but the note should stand on its own feet, to be of interest even to persons who had not read the original 1948 paper (DH/Box17/Fd13).

2 February 1949: Simon to Hawkins. Simon thanked Hawkins for a draft of the note and enclosed a revision with a few changes to make the paper shorter and more readable for economists. The references to Dines (1925) and Stokes (1931) had disappeared, but now there was a reference to Birkhoff and MacLane (1941), a well-known textbook of algebra. Later this was dropped too (HS/Box101/Fd9104).

11 February 1949: Hawkins to Simon. Hawkins suggested a few minor changes of exposition, and asked the question: 'Is order of names in *Econometrica* alphabetical or honorific? If the latter, suggest Simon and Hawkins' (DH/Box17/Fd13 and HS/Box101/Fd9104).[24]

16 February 1949: *Simon to Hawkins.* Simon had sent the manuscript to Simpson (DH/Box17/Fd13 and HS/Box101/Fd9104).

21 April 1949: Simpson to Simon. The joint note had been examined by several referees, and Simpson included a report that collected the comments from the anonymous referees. Simpson now asked Simon to revise the note in collaboration with Hawkins, and to resubmit it. Then it would be sent to Frisch for his final decision. Copies for the combined July-October 1949 issue of *Econometrica* had to go to the printer in May, and thus Simpson asked Simon to act quickly.

[24] In the end, it became 'Hawkins & Simon'. Ironically, the otherwise sophisticated bibliography by Woodbury (1954, p. 362) places the paper under S, as 'Simon & Hawkins', and the same error appears in Leontief's reading lists of his courses on input-output analysis at New York University (Wassily Leontief Papers, Accs. 13712, Box 9, reading lists Fall 1979, Fall 1988).

The report of the referees. Because of the time constraints, Frisch quickly approved the publication. The report of the referees suggested a reference to Leontief, because the equations of Hawkins and Simon were similar to those of a static Leontief system. The referees also pointed out that Leontief often expressed everything in dollar terms, and that for this special case 'Jerry Cornfield, Jack Grauman, Murray Geisler and W.W. Leontief' had already obtained interesting results. The referees then mentioned that the Hawkins-Simon conditions become more important if commodities are not measured in dollar terms, but in arbitrary units (tons of steel, number of motor cars, etc.). The referees pointed out that Cornfield and Grauman had shown that in this general case an alternative necessary and sufficient condition for viability was that all the eigenvalues of the input matrix are less than unity (DH/Box17/Fd13).

In their published version, Hawkins and Simon ultimately included only two bibliographical references: Leontief's (1941) book and of course Hawkins's (1948) paper. No reference to Jerome ('Jerry') Cornfield and Jacob ('Jack') Grauman was given.

Later correspondence between Hawkins and Simon. The archives in Pittsburgh contain some additional correspondence between Hawkins and Simon, from 1949 till 1991, all located in HS/Box101/Fd9104. On 1 December 1949, Simon informed Hawkins that he received twenty-five reprints of their note in *Econometrica*, and that at his new job in Pittsburgh he had not spent too much time on linear programming. This remark surely was related to the 'linear programming conference' at Cowles (Chicago) in June 1949, where Simon and Hawkins must have met for the first time, a few weeks after their joint paper had gone to the *Econometrica* printer in May 1949. After the conference, all later letters finally replaced the formal 'Dear Mr. Hawkins' or 'Dear Mr. Simon' or 'Dear Professor Simon' by 'Dear Dave' and 'Dear Herb'. Hawkins (13 December 1949) received reprints too, 'prayed' for a little more mathematical formality in an unspecified recent text by Samuelson on stability, and planned to extend some work by Hurwitz and others on stability.[25] In point of fact, a bit later Hawkins left economics, but he kept in correspondence with Simon, not only about giving permission for the many reprints of their paper, but also about statistical patterns, causality, organization, scientific methodology, evolutionary biology, etc. Hawkins and Simon also must have met a few times; their letters mention 'when you were out here' (Hawkins, 10 November 1959), 'the topic that we talked about' (Hawkins, 5 February 1960), or 'I always enjoy seeing you, but it happens too

[25] He means Adolf Hurwitz, the German mathematician known from the Routh-Hurwitz condition. Hawkins's critical remark on Samuelson probably is directed at his informal treatment of dynamics in Part 3 of his Rand Corporation paper (Samuelson, 1949).

infrequently' (Hawkins, 9 November 1971). Simon's autobiographical statement, quoted by Samuelson, about 'Simon never met Hawkins', is true only if we end their biography in May 1949.

6. The commodity values of commodities

Today we know that, from a logical point of view, it is possible to choose an arbitrary commodity *k* that enters directly or indirectly into all production processes, and to compute the *commodity k-value* of any commodity *j*, i.e., the direct and indirect quantity of *k* necessary to produce one unit of *j*. If *k* corresponds to labour, then we obtain the *labour value* of *j*.

When reading the stories by Merrett (1977) on labour values vs. wheat values, by Roemer (1982) on labour values vs. steel values, and by several other authors in the same period, it is obvious that the notion of the commodity value of a commodity became a well-known concept in the specialist economic literature somewhere in the late 1970s and early 1980s. Some non-economists propagated the use of energy values. For example, Robert Costanza (1980) in the prestigious journal *Science* defended the one sided energy theory of value with arguments that were remarkably similar to those used by some orthodox supporters of the labour theory of value; see Berndt (1985), Mirowski (1988) and Parys (2018) for more historical details on such adherents of the energy theory of value.

It is hard to establish credit for the first formal treatment of such commodity values. In the 1920s, Sraffa and Leontief, independently of each other, questioned the special role of labour values, and suggested that it was possible to compute other commodity values as well; for example, Sraffa pointed to the existence of wheat values, coal values, etc. (Kurz & Salvadori, 2010; Kurz, 2011; Parys, 2018). For many decades, these insights remained hidden in Sraffa's unpublished papers and in Leontief's (1928) German dissertation, which was partially translated into English only in 1991. However, it is remarkable and not widely realised that a similar idea was published in English in 1964, in *The Language of Nature*, the wide-ranging book on the philosophy of science by David Hawkins.[26] The book received interesting reviews in philosophy and physics journals, but hardly any attention from economists.

[26] As far as I know, the Leontief-Hawkins correspondence never discusses commodity values. Neither do commodity values appear in the limited interaction between Leontief and Sraffa (Parys, 2016a). It seems that Hawkins had no contacts with Sraffa (see also my section 8 below, on the economics of Cambridge).

Hawkins's book paid special attention to the relation between the sciences and philosophy, and included chapters on the foundations of number theory, geometry, motion and analysis, measurement, probability, physics, psychology, ethics and (in the final chapter 13) economic theory and social choice. The economic chapter concentrated on the fundamental concept of 'value', in three different meanings: value as substance (from Quesnay to Marx), value as individual preference (utility theory), and value as social choice. The latter topic had become fashionable after Arrow (1951), but it probably had caught Hawkins's special attention when his former Berkeley colleague Kenneth May published on related topics. The paragraphs on value as individual preference and value as social choice are well-written, but the most interesting thoughts are found in Hawkins's treatment of value as a substance. He does not use explicit equations, but his footnote references (p. 337) to Hawkins (1948) and to Hawkins & Simon (1949) make it obvious that he thinks in the context of a Leontief system.

In such a system, production is something that goes on in certain 'black boxes'. The corresponding equations of production describe how in these boxes some commodities are transformed into other commodities, and from this fact we can introduce an arbitrary universal unit of measurement. For example, Hawkins calls it commodity *A*:

> Pick the output of one box, *A*. The unit in which this output is measured will become the universal unit. When an amount of some other commodity is measured in the *A* units, this measure is called the value of that amount. The procedure is as follows: the *value* of the output of box *B* is defined as the physical measure of the input from *A* to *B*, plus the *values* of all other inputs so used, from *C*, from *D*, etc. This sounds circular but is not; for, if these value-defining equations are written for all boxes and solved simultaneously, everything comes out in units of *A*. In effect, the value of an output from *B* is measured by the total amount of *A*, over past time, accounted for in the output thus evaluated. (Hawkins, 1964, pp. 336-337)

To make Hawkins's argument less abstract, I assume for a moment that the special commodity *A* is coal.[27] Then the coal value of *B* corresponds to the direct input of coal into the production process of *B* plus the coal values of all other inputs used up in the production process of *B*. By solving simultaneous equations, we can find the coal values of all commodities. Hawkins (1964, p. 338) does not use an example with coal values, but he mentions the labour values of Ricardo-Marx and the energy values of the Technocrats in the 1930s.[28]

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[27] I also assume that coal is a basic commodity, i.e., that it enters directly or indirectly into the production of all commodities.

[28] On the Technocratic movement and the connection with energy values, see Berndt (1985) and Mirowski (1988).

It is not surprising that the co-founder of the Hawkins-Simon conditions makes some remarks on the viability of the system. In his 1964 book, Hawkins does not use principal minors, but presents an alternative approach, by looking at the commodity *A*-value of commodity *A* itself:

> In the unique case of box *A* we have two measures of output that are both in the same units. One is the direct physical measure of that output; the other is its value defined as for every box. If the value of *A*'s output exceeds its physical measure, the system is declining and, in the steady state, unable to reproduce itself (Hawkins, 1964, p. 337).

When I choose coal as the standard, then the system is declining if the coal value of one unit of coal is more than one. If the coal value of coal is less than one, the system is viable: it is able to generate a surplus that can be used for expansion or for unproductive consumption.

Nearly two decades later, Ki-Jun Jeong (1982) proposed explicit mathematical proofs for the connection between the 1949 Hawkins-Simon conditions (positivity of principal minors) and the properties of the own commodity value of commodities. I suppose Jeong did not know the discussion in Hawkins's 1964 book. This does not diminish the value of his interesting results, but it would have added a nice bibliographical reference to his paper. And probably Jeong was unaware that his 1982 paper, which he published in the *Journal of Macroeconomics*, was refereed and approved by Herbert Simon himself.[29]

Jeong's 1982 paper improved on the economic interpretation of the Hawkins-Simon conditions by Dorfman, Samuelson, and Solow (1958), and the next year Jeong's results were discussed and approved in an unpublished paper by Samuelson (1983), entitled *Hawkins-Simon Requirement That What a Good Requires of Itself, Directly and Indirectly, Be Less Than Unity.* Both Jeong (1982) and Samuelson (1983) mention an example where the Hawkins-Simon conditions mean that the direct and indirect requirements of coal to produce one unit of coal are less than one. Jeong, Samuelson and other protagonists of the Hawkins-Simon literature did not know that exactly the same theoretical insights and even the same coal example were already anticipated in a document of 22 September 1944, the file D3/12/39:41 in Sraffa's unpublished papers, where Sraffa wrote: 'If condition "one ton of coal requires dir. + indir. less than 1 ton of coal" is satisfied . . .' (for more details, see Parys, 2018, pp. 1065-1066). Note that the Sraffa Papers in Trinity College were opened to the public only in the 1990s.

[29] Letter of 4 November 1981, from Herbert Simon to the editor David J. Smyth (HS/Box78/Fd6316).

7. Economics in some unpublished papers by David Hawkins.

The David Hawkins Papers contain numerous unpublished texts on various topics. Some of these can be classified under economics, but they are much less important than his two *Econometrica* publications or his 1964 book.

Competition and Monopoly with Linear Models. Remarks on Questions of Methodology in Economic Theory (DH/Box2/Fd3). This undated text must be related to the paper that Hawkins read at the Cowles Conference in Chicago in 1949, because a similar title, *Linear Models in the Study of Competition and Monopoly,* is mentioned by Koopmans (1951, p. viii), in the list of conference papers that were not incorporated in the proceedings. Hawkins's reference to 'linear models' in the title may be misleading, because it is not an exercise in Leontief models, and there are no systems of equations in the text. It just offers a short discussion of a methodological nature. Its non-inclusion in the proceedings seems normal, because it is much less important than the many path breaking contributions selected for the proceedings.

Value Theory in Economic Science. Paper read at the Colorado-Wyoming Academy Meeting, 20 May 1952 (DH/Box9/Fd2; DH/Box10/Fd5). First, Hawkins considers the material production process of society, and the Ricardian conception of value as a substance. Then he studies the Marshallian approach which involves both production and subjective individual preferences. He emphasises that some macroeconomic variables are controlled not by single individuals, but by coalitions of individuals, and here game theory becomes useful. Finally, Kenneth Arrow, Kenneth May and related results on social choice theory enter the story. This approach seems a bit similar to the economic chapter of his 1964 book *The Language of Nature*, where Hawkins first treated value as substance, then value as individual preference, and finally value as social choice.

Sustainable Economics for a Sustainable Economy, 1994 (DH/Box22/Fd1). Hawkins's *Econometrica* paper of 1948 was inspired by 'red' authors, his papers and letters in the 1990s show more attention to 'green' issues. In this 1994 paper he makes speculations about a sustainable economic system of the stationary type. The paper contains an unexpected and unimportant reference to Sraffa (1960) at the very end, but it does not discuss linear systems or Cambridge economists. Hawkins stresses sustainability and seems to keep his distance from

models that concentrate on ever increasing production of commodities by means of commodities.[30]

8. Contacts with the economics of Cambridge (UK)

The vague reference to Sraffa in the above paper on sustainability raises the question about the relation between Hawkins and Cambridge UK. In the days of the New Deal, when Hawkins was a student at Stanford, he immediately bought a copy of the first printing of *The General Theory of Employment, Interest and Money* (Keynes, 1936), and he read it with care. Personal contacts with Cambridge economists, however, were rather scarce, but not zero. This is obvious from a letter of 13 July 1996, from Hawkins to Merle Turner and his wife Marjorie (she had written a book on Joan Robinson). Hawkins writes:

> I never met Kaldor, but I did meet Joan Robinson once, with Les Fishman, and had a wonderful sense of being included in a good circle (DH/Box16/Fd17).

Joan Robinson stayed in Boulder for a few days, in 1961 and in 1965 (Turner, 1989). The economist Leslie (Les) Fishman knew Hawkins from their left-wing Berkeley days. In 1961 Fishman was Hawkins's colleague in Boulder, in 1962 he obtained a fellowship to work with Kaldor in Cambridge. Later he moved to Britain permanently and became professor of economics at Keele University.[31] Hawkins (1964, p. 336) once referred to Fishman's (1958) work on Quesnay.[32] Note that Hawkins also presented a lecture on Quesnay at Harvard, but most of this material seems to be lost. The few surviving pages on Quesnay in the Boulder archives show no date, and no hints of high relevance (DH/Box3/Fd1).

9. Using correct eponyms

9.1. The Frobenius-Potron-Hawkins-Simon conditions

Today the Perron-Frobenius theorems on nonnegative matrices are standard material in textbooks on input-output systems and on many other topics (for example, the mathematics of

[30] In the 1990s both David Hawkins and his daughter Julie Fisher Melton were interested in problems of sustainability. A year before David's 1994 paper, his daughter Julie published a book on sustainable development and the nongovernmental movement in the Third World (Fisher, 1993).
[31] See his obituary, written by his daughter Nina Fishman (2008).
[32] Hawkins wrongly refers to 1959 instead of 1958.

Google's search engine). However, in the first decades after the original German articles by Perron (1907a, 1907b) and Frobenius (1908, 1909, 1912) appeared, most mathematicians and economists overlooked the Perron-Frobenius papers (for more details, see Parys, 2013, 2014). Hence, as emphasised by Samuelson (2004, p. 159), in 1949 Hawkins and Simon were not familiar with the results of these German mathematicians. Most mathematical economists learned about Perron-Frobenius only in the early 1950s, after reading two classic papers on nonnegative matrices in *Econometrica*: Solow (1952) and Debreu & Herstein (1953).

The situation was different in 1971 when Hawkins received a letter from Joseph Stiglitz, who acted as the general editor for a series of books that wanted to reprint the best *Econometrica* articles. The Hawkins-Simon paper was selected for 'the best of macroeconomics and capital theory', which would be edited by David Cass and Lionel McKenzie. Hawkins's reply of 9 November 1971 to Stiglitz gave a routine permission to reprint the paper, but also contained the following remark:

> I assume that Messrs. Cass and McKenzie know that the theorem was proved earlier by Frobenius, a fact unknown to the authors at the time. (HS/Box101/Fd9104)

Hawkins made a similar statement about Frobenius in a letter to Leontief in 1995 (exact date unknown; DH/Box18/Fd8). A year earlier, Richard Trahair (1994) had published a dictionary of eponyms with biographies in the social sciences, and he had consulted Hawkins for more information on 'Hawkins-Simon'. Here, too, Hawkins had mentioned the mathematics of Frobenius (letter to Trahair, 8 June 1993; DH/Box17/Fd14).[33]

In the same letter to Trahair, Hawkins suggested that more attention should be directed to the main argument of his 1948 paper on dynamic input-output. Its main results were not influenced by the error in his 1948 lemma. The 1949 Hawkins-Simon correction, which was presented in a *static* input-output system, probably led to insufficient attention to the central results of his *dynamic* 1948 model.

Different scholars sometimes show different preferences for product differentiation, or different amounts of modesty. Compare Hawkins and Georgescu-Roegen. My Section 2 mentioned the equivalence of the '*original* Hawkins-Simon' (positivity of *all* principal minors) and the '*economical* Hawkins-Simon' (positivity of the *leading* principal minors). The proof of this

[33] The authoritative work on the mathematics of Frobenius has been written by Thomas Hawkins (2013). In spite of the same surname, there is no family relationship between David Hawkins and Thomas Hawkins.

equivalence will be judged rather trivial by most readers of the 1949 Hawkins-Simon paper, because on page 248, line 6-8, the authors suggest that their proof of the positivity of the *leading* principal minors remains the same in case of a simultaneous renumbering of the equations and the commodities, and thus *all* principal minors are positive. In spite of this, Georgescu-Roegen makes the rather excessive claim that he should receive the main credit for discovering the 'economical Hawkins-Simon' conditions. He complains about the wrong labelling in many publications:

> It is, no doubt, because of the frequency with which this statement is found in literature, that as careful a writer as Michio Morishima refers to my theorem as 'the Hawkins-Simon theorem' (Georgescu-Roegen, 1966, p. 336, footnote 7).

Moreover, to strengthen his claim to originality, Georgescu-Roegen also emphasises that it takes some clever mathematical steps to go from Frobenius to Hawkins-Simon.[34] Whereas Hawkins self-effacingly understates his own originality, Georgescu-Roegen could have shown more modesty in this context.

Ironically, only two decades ago it became clear that the French Jesuit mathematician Maurice Potron anticipated many results of the later Hawkins-Simon literature (see, for example, Potron 1913, 1937). Potron was an 'amateur' without a decent knowledge of the economic literature. He published on economics in the periods 1911-1914 and 1935-1942, but his results were not visible in the orthodox economic literature; they were mainly hidden in French journals for mathematicians or for Roman Catholic intellectuals.[35] Note that Potron explicitly started from Frobenius. Maybe some future textbooks would like to introduce the expression 'Frobenius-Potron-Hawkins-Simon conditions'?

9.2. The Hawkins-Leontief dynamic input-output system

Most 21st century authors could use a similar refinement when choosing eponyms for the origin of *dynamic* input-output (see my section 4 on Hawkins scooping Leontief). In his well-known study on dynamics, Leontief (1953, p. 55) explicitly singled out the paper by Hawkins (1948) as the first discussion of a dynamic input-output system. So does the old textbook by Chenery

[34] It is not the purpose of this paper to enter into the maze of mathematical details. Intuitively speaking, today most textbooks present Frobenius's results on eigenvalues and eigenvectors, but not his cumbersome old-fashioned proofs by means of determinants. Some of these determinants are principal minors, and therefore it is possible to make a connection between Frobenius and Hawkins-Simon.

[35] See my annotated Potron bibliography (Parys 2016b). Fifty-eight years after Potron's death, historians of economics finally became aware of his importance, thanks to Lendjel (2000). For more biographical details on Potron and for the English translation of his economic papers, I refer to Bidard & Erreygers (2010).

and Clark (1959, p. 71). Some old papers coined expressions like ‘a closed Hawkins-Leontief dynamic system’ (Chipman, 1953, p. 467; 1954, p. 2), or ‘the dynamic input-output system of Hawkins and Leontief’ (Jorgenson, 1961, p. 279), or ‘the Hawkins-Leontief dynamic input-output system’ (Brown & Jones, 1962, p. 88). More recent publications, however, often seem to be less familiar with the names of the pioneers in this context. For example, the dynamic input-output system receives a lot of attention in the standard works by Takayama (1985, pp. 503-558) and Miller & Blair (2009, pp. 639-654); both books contain many bibliographical and historical details on input-output, but they never mention the 1948 paper by Hawkins.

10. Conclusion

The history of input-output economics generated several unusual pioneers. David Hawkins, as a philosopher of science, surely is one of them. Without a degree in mathematics or economics, Hawkins scooped Leontief in 1948, by a pioneering *Econometrica* paper on dynamic input-output analysis. Solow (1959, p. 30) called it a ‘remarkable *tour de force’*.

Archival material reveals that Hawkins was influenced by Quesnay and Marx. Hawkins had studied their work because he was interested in the foundations of many disciplines, including economics. Unlike most other philosophers, Hawkins also tried to master mathematics, physics and many other sciences. His knowledge of the mathematics of electrical and mechanical systems, and of Quesnay and Marx, plus his attention to the social problems caused by the Great Depression, were leading him to an original mathematical system of the (in)stability of capitalism. It is doubtful whether his personal contacts with John von Neumann, Leslie Fishman or Kenneth May, played an important role here. Both the archives and the published text strongly suggest that Hawkins’s dynamic system was a brilliant solo performance, created completely independently of Leontief’s later work on dynamics.

The Hawkins-Simon 1949 note started from a correction of a lemma of Hawkins’s 1948 paper. The correction did not invalidate Hawkins’s main results on dynamics, but perhaps turned attention away from it. Archival evidence shows how the 1949 note was a real example of clever cooperation between Hawkins and Simon, completely done by correspondence. Simon (1996) and Samuelson (2004) create the impression that Hawkins and Simon never met. That is wrong. By coincidence, a few weeks after their joint *Econometrica* note had gone to the printer, they met for the first time at the 1949 Cowles Conference in Chicago, and they kept in contact.

After his two *Econometrica* papers, Hawkins published on many other fields. He returned to economics only once, in chapter 13 of his ambitious 1964 book on the philosophy of science, where he discussed the now familiar notion of the commodity value of a commodity, which has an obvious relation to the Hawkins-Simon conditions.

During his long academic career, Hawkins concentrated mainly on philosophy of science and childhood science education. Although he had no degree in mathematics or economics, and stayed in the economic networks only for a very short period, he was able to produce fundamental results in both dynamic and static input-output economics. After cooperating with Hawkins on the Los Alamos atomic bomb project, the mathematician Stanislaw Ulam (1976, p. 159) called him 'the most impressive of the non-professional mathematicians or physicists I have met anywhere in the world'. Most probably Hawkins was also one of the most impressive of the non-professional economists.

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