Reference publication year spectroscopy (RPYS) of papers published by Loet Leydesdorff: A giant in the field of scientometrics passed away

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Abstract

Loet Leydesdorff (mentioned as Loet in the following) passed away in March 2023. Our paper is dedicated to the important contributions of this exceptional researcher (in scientometrics). We investigated which studies, theories, methods, and ideas have influenced Loet's scientific work. The method reference publication year spectroscopy (RPYS) can be used to answer this and related questions. Many RPYS studies have been published regarding the historical roots of research fields, journals, and scientists. The program *CRExplorer* was specifically developed for RPYS. In this study, we used *CRExplorer* to investigate the historical roots and influential publications of Loet's oeuvre. The results demonstrate the wide range of topics in Loet's research and their fundamental meaning for the scientometric field.

Keywords

Reference publication year spectroscopy; RPYS; Citation analysis; Scientometrics; Bibliometrics; Researchers; Loet Leydesdorff.

1. Introduction

Loet Leydesdorff (mentioned as Loet in the following) passed away in March 2023. Loet was a giant in the field of scientometrics. We are not aware of any other researcher in the field of scientometrics with a similarly important contributing impact. Loet published more than 400 papers (the number that we found in *Clarivate*'s *Web of Science*, *WoS*, database). These papers focus not only on one or a few scientometric topics but have an enormous width (**Wouters**; **Wagner**, 2023). Loet dealt in his research with the history, philosophy, sociology, and economy of science –among many other disciplines, topics and themes. He was a specialist in science networks (e.g., **Leydesdorff** & **Persson**, 2010) and bibliometric indicators (e.g., **Leydesdorff** & **Bornmann**, 2012). For example, **Opthof** and **Leydesdorff** (2010) started an important discussion on the field-normalized citation score based on average citation rates –the standard indicator in bibliometrics at that time. At the end, the discussion led to a far-reaching revision of the standard indicator.

One of the authors of this paper (LB) published his first paper together with Loet in 2007. LB's first co-authored study with Loet dealt with the citation network of the chemical journal *Chimia* (**Bornmann**; **Leydesdorff**; **Marx**, 2007). This paper was followed by around 70 papers in collaboration between Loet and LB (according to the *WoS*). Many of the co-authored papers focused on the development of alternative indicators to the field-normalized citation score based on average citation rates: Loet and LB favored citation percentiles (**Leydesdorff**; **Bornmann**, 2011; **Leydesdorff**; **Bornmann**; **Mutz**; **Opthof**, 2011). This alternative was introduced already in the 1980s by Francis Narin –another giant in the scientometric field (**McAllister**; **Narin**; **Corrigan**, 1983). Another topic of Loet and LB was the development of science maps

(**Bornmann**; **Leydesdorff**, 2011; 2012). For example, they published software that could be used to generate institutional maps of science showing regional areas of high and low research performance (**Bornmann**; **Leydesdorff**; **Walch-Solimena**; **Ettl**, 2011).

The other author of this paper (RH) and Loet published their first paper together in 2015. The paper dealt with network analyses of country and reader status using data from *Mendeley* (**Haunschild**; **Bornmann**; **Leydesdorff**, 2015). The results of this collaboration were presented at the *2:AM* conference in Amsterdam (**Dinsmore**, 2015). RH had the pleasure of meeting Loet in person during the conference and enjoying Loet's hospitality. Several papers followed in collaboration between Loet and RH about network analyses and cited reference analyses. The last paper co-authored by Loet and RH reported the most influential publications in the *Web of Science* subject categories on the basis of a cited reference analysis (**Thor**; **Bornmann**; **Haunschild**; **Leydesdorff**, 2021).

In this paper, we present the results of a Reference Publication Year Spectroscopy (RPYS) with the goal of uncovering the roots of Loet's research (**Marx**; **Bornmann**; **Barth**, 2013). Previously, RPYS has been applied to other researchers, for example to Eugene Garfield by **Bornmann**, **Haunschild**, and **Leydesdorff** (2018). For applying RPYS, it is necessary to retrieve the complete set of Loet's papers. RPYS counts and visualizes the occurrences of single cited references in this set. High numbers of occurrences point to historical roots of Loet's research –especially those cited publications from early years. Although RPYS has been initially introduced by Werner Marx (WM), the method has been further developed in collaboration between Loet, WM, RH, LB, Rüdiger Mutz (RM), and especially Andreas Thor (AT). The researchers developed and published the *CRExplorer* (**Haunschild**; **Marx**; **Thor**; **Bornmann**, 2020; **Thor**; **Bornmann**; **Marx**; **Mutz**, 2018; **Thor**; **Marx**; **Leydesdorff**; **Bornmann**, 2016a, 2016b) –a software that can be used free of charge for RPYS: *https://www.crexplorer.net*

2. Dataset

We downloaded the metadata (including cited references) of the papers published by Loet from the *WoS* using the search query:

AU = (leydesdorff l OR leydesclorff l OR leydesdorfl l)

We also checked his *ORCID* and *WoS Researcher Profile* records to collect the complete set of papers. However, no additional correct papers could be found here. The extracted files from the *WoS* were imported into the *CRExplorer* for further processing. The *WoS* export contains metadata of 413 papers including 17,385 cited references. We applied the clustering and merging functionalities of the *CRExplorer* to clean up the cited references dataset with respect to reference variants of the same cited publication. *CRExplorer* determines the pair-wise similarity of variants of CRs based on the Levenshtein similarity (**Thor**; **Bornmann**; **Haunschild**, 2018). To support the disambiguation process, volume and page numbers of the referenced papers have been used. After the disambiguation process, we removed all cited references that were cited less than five times to focus on publications with a substantial impact on Loet's research. The final dataset which we used for the RPYS contains metadata of 413 citing papers (from 1981 to 2023) including 742 cited references (from 1902 to 2019).

3. Methods

It is the premise of the RPYS that important publications for a certain researcher are often cited in his (or her) papers (**Bornmann**; **Marx**, 2014). The basic result of the cited references analyses using Loet's papers is a spectrogram showing the number of cited references per reference publication year. Peaks in the spectrogram are hints to possible important publications in certain reference publication years.

We analyzed the spectrogram to find relevant peaks by using the five-year median deviation. The five-year median deviation compares the number of cited references in reference publication year *t* (i.e., the peak in year *t*) with the number of cited references in bordering years: *t*-2, *t*-1, *t*+1, and *t*+2. If the peak of the median deviation is very high for year *t*, many cited references fall on year *t* –compared to the bordering years. Tukey's fences (**Tukey**, 1977) were used to support the identification of the most important peaks in the spectrogram: Important peaks were flagged based on the interquartile range of the median deviations (**Thor**; **Bornmann**; **Haunschild**, 2018).

Thor, Bornmann, Marx *et al.* (2018) developed methods that can be used to analyze cited references data further on. In this study, we used the N_TOP10 indicator for identifying landmark papers over a longer period. The indicator shows the number of cited years in which a publication belonged to the 10% most frequently referenced publications by Loet.

In this study, the spectrogram was plotted using R (*R Core Team*, 2021) with the R package 'BibPlots' (**Haunschild**, 2021). In addition to the static spectrogram presented in this paper, we produced an interactive version using the R package 'dygraphs' (**Vanderkam** *et al.*, 2018).

4. Results

4.1. Reference publication year spectroscopy

Figure 1 shows the number of cited references (grey columns) and the deviation of the number of cited references in one reference publication year from the number of cited references in bordering years (blue line). The RPYS is based on the

principle that high peaks (deviations) are hints to important publications of the analyzed researcher (publications in Loet's oeuvre). Peaks in early cited reference years point to the historical roots of the researcher (rather old papers frequently cited by Loet). Peaks with significant deviations from peaks in bordering reference publication years (identified by Tukey's fences) are labeled with an asterisk and the corresponding publication year in Figure 1.

Table 1 shows the publications that are mainly responsible for the highest peaks in Figure 1: 1948, 1972/1973, 1979, 1994, 1997, and 2006. Besides the titles, the table presents the cited references counts (in other words, how often the individual publications have been cited in Loet's papers).

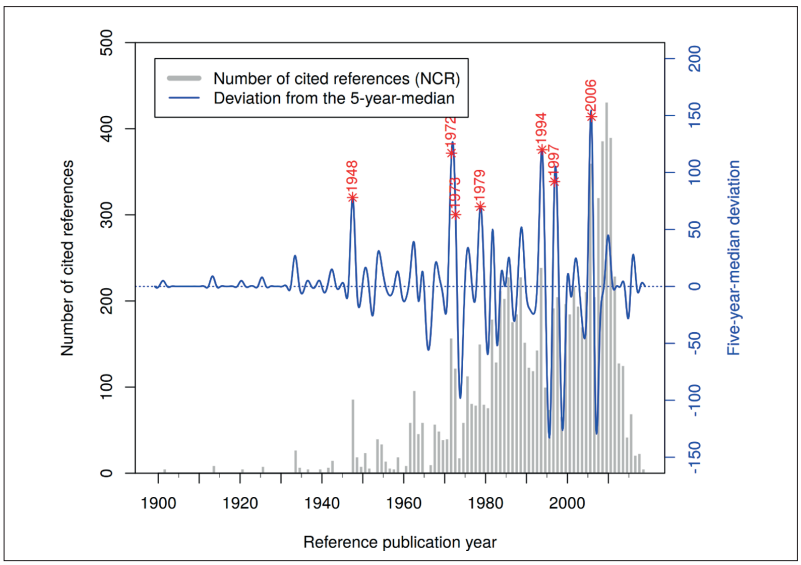

Figure 1. Number of cited references (grey columns) and median deviations of cited references (blue line). The peaks (with positive values) in the blue line show reference publication years with a significantly greater number of cited references than bordering years. An interactive version can be viewed at: *https://s.gwdg.de/uGPMP2*

Table 1. Cited references with the largest number of cited reference counts in cited reference years with the highest peaks in Figure 1

Nº	Title of the cited reference	Author, Publication year	Cited references counts
	1948		
1*	A mathematical theory of communication	(**Shannon**, 1948b)	65
2	A mathematical theory of communication	(**Shannon**, 1948a)	21
	1972		
3	Statistical decomposition analysis: With applications in the social and administrative sciences	(**Theil**, 1972)	63
4	Citation analysis as a tool in journal evaluation: Journals can be ranked by frequency and impact of citations for science policy studies	(**Garfield**, 1972)	48
	1973		
5	The organization of complex systems	(**Simon**, 1973)	37
	1979		
6	Is citation analysis a legitimate evaluation tool	(**Garfield**, 1979b)	26
7	Citation indexing: Its theory and application in science, technology, and humanities	(**Garfield**, 1979a)	26
8	Centrality in social networks conceptual clarification	(**Freeman**, 1978/1979)	21
	1994		
9	The new production of knowledge: The dynamics of science and research in contemporary societies	(**Gibbons** *et al.*, 1994)	33
10	Tracking areas of strategic importance using scientometric journal mappings	(**Leydesdorff**; **Cozzens**; **Van-den-Besselaar**, 1994)	27
	1997		
11	Scientometrics and communication theory: Towards theoretically informed indicators	(**Leydesdorff**; **Van-den-Besselaar**, 1997)	21
12	Why words and co-words cannot map the development of the sciences	(**Leydesdorff**, 1997)	20
13	The regional world: Territorial development in a global economy	(**Storper**, 1997)	20
14	Why the impact factor of journals should not be used for evaluating research	(**Seglen**, 1997)	18
	2006		
15	Can scientific journals be classified in terms of aggregated journal-journal citation relations using the *Journal Citation Reports*	(**Leydesdorff**, 2006)	43

Note. * Two variants of the same cited reference were merged manually.

As the underlying references of the 1948 peak show (see Table 1), Loet has cited two early papers very frequently which were published by **Shannon** (1948a; 1948b). Both papers appeared with the same title and author, but in different issues of the *Bell System Technical Journal*. In his research, Loet preferred a communications view on the sciences (see here

Luhmann, 2012a; 2012b) whereby knowledge claims are usually organized into scientific papers building the archive of science (that can be bibliometrically analyzed). This view differed, e.g., from a sociological view which is focused on individuals (e.g., authors) or communities (e.g., research groups or institutions) (**Leydesdorff**, 2021). **Shannon** (1948a; 1948b) lays the basis for Loet's view by providing the corresponding mathematical foundation.

The next peak in Table 1 is visible for the years 1972 and 1973. This peak is mainly due to three publications from 1972 and one from 1973. The publication most cited by Loet below this peak is **Theil** (1972), which is a statistics book for decomposition analysis in the social sciences. Loet cited (used) (statistics from) this book very broadly such as in a paper on the European monetary system (**Leydesdorff**; **Oomes**, 1999), in a paper on networks of journal-journal citations (**Leydesdorff**, 2003), and in a paper on animations of journal maps (**Leydesdorff**; **Schank**, 2008). The other publication from 1972 (see Table 1) which Loet referenced frequently is **Garfield** (1972). Eugen Garfield is the founder of citation indexing in (large) databases (**Garfield**, 1955; 1970) for studying science. With the paper from 1972, **Garfield** (1972) proposed to evaluate scientific journals based on citation impact. In this paper, **Garfield** (1972) introduced the impact factor –one of the most popular metrics in citizen bibliometrics. The most important referenced publication from 1973 is **Simon** (1973). It is a chapter in the book "Models of discovery" and deals with several statistical topics such as the empirical Bayes approach or the aggregation of variables.

The next peak occurs in 1979. The peak in 1979 is fed by two classic publications from Eugen Garfield (see above). **Garfield** (1979b) deals with the question whether citation data can be used for research evaluation purposes. The paper picks up several critical points of citation analysis that are frequently discussed (e.g., the problem of self-citations and negative citations). It concludes that

> "when properly used, citation analysis can introduce a useful measure of objectivity into the evaluation process at relatively low financial cost" (**Garfield**, 1979b, p. 359).

Garfield (1979b) is a modification of a chapter in **Garfield** (1979a) –the next publication in Table 1.

Garfield (1979a) is a classical textbook of citation analysis entitled "Citation indexing: Its theory and application in science, technology, and humanities". It is a must-read for all scientists entering the field of bibliometrics (until today). Various important topics in the context of citation analysis are treated such as the use of citations as a search tool for literature, the use of citations in science management, the application of citations in the historical analysis of science, and the use of citations for science mapping purposes. Science mapping is also the topic of **Freeman** (1978/1979) –the following publication in Table 1. This publication deals with measures of structural centrality in social networks. The conceptualization of networks based on bibliometric data is a popular topic in bibliometrics, and a favourite with Loet (e.g., **Leydesdorff**, 2003; **Wagner**; **Leydesdorff**, 2005). **Freeman** (1978/1979) is a classic in this context.

The results in Figure 1 and Table 1 indicate that 1994 is the next peak year after 1979. As Loet's most important referenced publications in this year, we have **Gibbons** *et al.* (1994), on the one hand. The book deals with the major changes in the way research results are generated in the modern science system of today –compared to the academic science system decades ago (**Ziman**, 1996). The authors argue that the modern science system is characterized by globalization, collaboration, and competitiveness, which have led to new modes of knowledge production. Various terms have been proposed to name these new modes: post-academic science, Mode-2 (compared to Mode 1 –the academic science) or post-normal science. On the other hand, we find **Leydesdorff** *et al.* (1994) under the 1994 peak. This paper deals with the topic of identifying areas of growth or fast-changing areas in research fields. Science policy is especially interested in knowing and funding these areas, since these areas may define the research fronts in science. **Leydesdorff** *et al.* (1994) proposed a method for identifying such areas based on journal maps and applied the method to research on AIDS, superconductivity, and oncogenes.

Table 1 includes four publications for the year 1997, two of which were published by Loet himself. The four publications focus on different topics. **Leydesdorff** and **Van-den-Besselaar** (1997) deal with citation theories. Since bibliometrics is used in various contexts on a larger scale, researchers proposed concepts or theories for explaining citing decisions such as the normative and the social-constructivist theories (see **Tahamtan** & **Bornmann**, 2018, for an overview). The last proposal in this series was introduced by **Tahamtan** and **Bornmann** (2022): the Social Systems Citation Theory (SSCT). **Tahamtan** and **Bornmann** (2022) picked up from **Leydesdorff** and **Van-den-Besselaar** (1997) that a citation theory should rather focus on communications and not on cited or citing agents. In sociology, Loet's focus is rooted in Niklas Luhmann's *social systems theory* (**Luhmann**, 2012a; 2012b).

Leydesdorff (1997) –the second paper in Table 1 for 1997– also deals with communications in the network of science. Based on a set of articles from biochemistry, the study reveals that the network level –the level of the publication set– may be different from the individual paper-level perspective:

> "Words change both in terms of frequencies of relations with other words, and in terms of positional meaning from one text to another" (**Leydesdorff**, 1997, p. 418).

The differentiation between a social level that is linked but cannot be directly traced back to single individuals is a genuinely sociological perspective (**Coleman**, 1990). The next publication under the peak of 1997 is **Storper** (1997). The book can be denoted as a contribution from political science which proposes a theory of how regions worldwide have

maintained their economic viability. We assume that the interesting point for Loet was the system-theoretical root of the book: The world is seen as a social system with inter-connected regional economies.

The fourth publication in Table 1 for 1997 is **Seglen** (1997). The author argues conceptually and reveals empirically that the Journal Impact Factor (JIF) should not be used as a proxy for the citation impact of single papers. The JIF is defined as the mean number of citations in one year gathered by publications appearing in the two years before. The paper was directed against the usual practice in research evaluation (at that time) of using the JIF instead of the times cited information (e.g., from the WoS) to measure citation impact. Today, many initiatives and manifestos exist against this use of the JIF such as the *Leiden manifesto* (**Hicks** *et al.*, 2015).

For the peak in 2006, we identified **Leydesdorff** (2006) as an influential paper for Loet himself (see Table 1). This paper is part of one of the most important research programs by Loet: the classification of (all) scientific journals by using data on the citation patterns of the journals from the *Journal Citation Reports* in the *Essential Science Indicators* (*Clarivate*). Loet used factor analytic methods to discover latent structures in the matrix of citation relations between the journals. One of the authors of this study (LB) was involved in follow-up studies that continued Loet's research program (e.g., **Leydesdorff**; **Bornmann**; **Wagner**, 2017; **Leydesdorff**; **Bornmann**; **Zhou**, 2016).

4.2. Publications that Loet cited very frequently over many years

Whereas Table 1 lists the publications that have been referenced by Loet very frequently, we additionally used the N_TOP10 indicator for identifying the important (most influential) publications for Loet over many citing years. Table 2 lists the cited references in our dataset that were referenced significantly more frequently than other publications in at least 10 citing years. There is only a single cited reference in Table 2 that also occurs in Table 1: **Simon** (1973).

Table 2. Cited references that belong to the 10% most frequently referenced in more citing years than other cited references. The table shows the cited references that are highly referenced in at least 10 citing years. The publication numbers (Nº) from Table 1 are continued.

Nº	Title of the cited reference	Author, Publication year	Cited references counts	N_TOP10
16	The intellectual and social organization of the sciences	(**Whitley**, 1984)	54	15
17	An algorithm for drawing general undirected graphs	(**Kamada**; **Kawai**, 1989)	68	14
18	Evaluative bibliometrics: The use of publication and citation analysis in the evaluation of scientific activity	(**Narin**, 1976)	40	13
19	Requirements for a cocitation similarity measure, with special reference to Pearson's correlation coefficient	(**Ahlgren**; **Jarneving**; **Rousseau**, 2003)	67	13
5	The organization of complex systems	(**Simon**, 1973)	37	10
20	Toward a structural theory of action: Network models of social structure, perception, and action	(**Burt**, 1982)	43	10
21	The static and dynamic analysis of network data using information-theory	(**Leydesdorff**, 1991)	32	10
22	The dynamics of innovation: From national systems and "Mode 2" to a Triple Helix of university-industry-government relations	(**Etzkowitz**; **Leydesdorff**, 2000)	50	10
23	The challenge of scientometrics: The development, measurement, and self-organization of scientific communications	(**Leydesdorff**, 2001)	58	10

The book "*The intellectual and social organization of the sciences*" by **Whitley** (1984) belongs to the 10% most frequently cited in 15 years of Loet's scientific career. **Whitley** (1984) conceptualizes science as a sector of society including specifically organized social systems with the goal of producing and validating knowledge. The different systems exist in particular contexts and generate knowledge in a particular way. Besides the book by **Whitley** (1984), there is another theoretically oriented publication in Table 2: "*Toward a structural theory of action: Network models of social structure, perception, and action*" published by **Burt** (1982). In this publication, **Burt** (1982) formulates basics of a structural action theory. The theory is not only based on concepts of sociological network theories, but also on classic texts from the sociology of science (published, e.g., by James S. Coleman, Robert K. Merton, and Talcott Parsons).

As Table 2 reveals, the paper by **Kamada** and **Kawai** (1989) is one of the most referenced publication by Loet over many years. The authors proposed an algorithm that can be used for an optimized layout of networks. Since Loet published many manuscripts including several types of networks based on bibliometric data, the layout of many networks was optimized based on the algorithm by **Kamada** and **Kawai** (1989). Some examples of Loet's papers using the algorithm by **Kamada** and **Kawai** (1989) are **Bornmann** and **Leydesdorff** (2015), **Bornmann**, **Wagner**, and **Leydesdorff** (2015), and **Haunschild**, **Leydesdorff**, and **Bornmann** (2020). In Table 2, we can find two other papers focusing on methods for (bibliometric) network analyses. (1) **Ahlgren** *et al.* (2003) has a specific focus on author co-citation analysis (ACA) and deals with the question whether Pearson's correlation coefficient can be used as a similarity measure in ACA. The authors conclude that this coefficient should not be used and "sets forth two natural requirements that a similarity measure applied in ACA should satisfy" (p. 550). (2) **Leydesdorff** (1991) proposes to use measures derived from information theory as a conceptual framework for multivariate analyses of bibliometric data. To empirically illustrate his approach, **Leydesdorff** (1991) used a matrix of aggregated citations among chemistry journals.

One of the most referenced publications over many years is the book "*Evaluative bibliometrics: The use of publication and citation analysis in the evaluation of scientific activity*" by **Narin** (1976). Francis Narin is another giant and pioneer in scientometrics similar to Loet. **Narin** (1976) can be denoted as one of the most influential publications by Francis Narin: The book introduced bibliometrics as an assessment tool for evaluating scientific activity. The book outlines how an evaluative study should be conducted and points to typical problems in bibliometric analyses such as multiple authorship, self-citations, homonyms, and field variations in citations. Since the publication of **Narin** (1976), many following papers in bibliometrics have dealt with these problems and proposed solutions such as the introduction of field-normalized indicators tackling field variations in citations (**Bornmann**, 2019).

With more than 3,000 citations in the *WoS* (times cited), **Etzkowitz** and **Leydesdorff** (2000) is the most cited publication by Loet with many more citations than his other publications. It is also one of the most referenced papers by Loet himself over many years, as the results in Table 2 point out. **Etzkowitz** and **Leydesdorff** (2000) deal with the transformation of the science system from academic to post-academic science (see above). Academic science is traditional science whereby researchers work at universities and other publicly funded research institutions. According to **Ziman** (1998),

> "academic science was intensely individualistic. People held personal appointments earned by published contributions to knowledge. Universities and research institutes had little direct influence on their research".

Academic science can be differentiated from industrial science in the history of scientific activities: Industrial science is characterized by scientists (employed by companies) who do not undertake "their own" projects and are not free to publish their research results:

> "industrial science –from agriculture through mental medicine, and missile manufacture to zookeeping– is intimately involved in the business of daily life. The personal values and needs of customers, patients, and other users have to be taken into account" (**Ziman**, 1998).

The modern post-academic science system became visible especially since the end of the Cold War (**Etzkowitz**; **Leydesdorff**, 2000). This system is characterized by groups of researchers (**Wu**; **Wang**; **Evans**, 2019) working in projects which are funded for specific outcomes: Funders expect that project results are not only useful for science itself, but also for the economy or other sectors of the society (**Bornmann**, 2013). Research in post-academic science "stems from problems 'arising in the context of application'" (**Ziman**, 1998). In post-academic science, universities and other research-focused institutions are seen as an important player in national economic development.

The significance of **Etzkowitz** and **Leydesdorff** (2000) lies in the fact that the authors proposed an alternative to the post-academic science concept: the Triple Helix of university-industry-government. The Triple Helix is a dynamic concept that denotes the relations between three actors: university, industry, and government. The dynamic concept can be used to describe the shape of national science systems or the development of science systems in the historical context. With

> "different possible resolutions of the relations among the institutional spheres of university, industry, and government" (**Etzkowitz**; **Leydesdorff**, 2000, p. 110)

it is possible

> "to generate alternative strategies for economic growth and social transformation" (**Etzkowitz**; **Leydesdorff**, 2000, p. 110).

The book "The challenge of scientometrics: The development, measurement, and self-organization of scientific communications" (**Leydesdorff**, 2001) is listed at the end of Table 2. The first edition of the book was published in 1995; the second edition from 2001 is nearly the same as the first edition. Loet explained in the book his own paradigm of undertaking science of science studies. The paradigm is characterized by an attempt to integrate qualitative and quantitative proposals to conduct science of science studies. Loet's royal road for the integrative perspective is the information theory: "By using this method [the information theory], central problems in science studies will be addressed, both on the qualitative side (e.g., the significance of a reconstruction) and on the quantitative side (e.g., the prediction of science indicators)" (**Leydesdorff**, 2001, p. 5).

5. Discussion

The death of Loet unfortunately joins in recent deaths of other giants in the field. Henk Moed –who published fundamental important publications in scientometrics such as **Moed** (2005)– passed away in 2021 and Tibor Braun, the founder of *Scientometrics*, in 2022 (**Glänzel**; **Heeffer**, 2023). These are great losses for the scientometrics field that can be scarcely compensated. Niklas Luhmann (the founder of the *social systems theory* that was fundamental for Loet's theorizing on science) summarized his research program about a decade before his death (**Luhmann**, 2012a; 2012b). In a similar way, Loet summarized his research program two years before his death: "*The evolutionary dynamics of discursive knowledge*" (**Leydesdorff**, 2021). **Wouters** and **Wagner** (2023) identified three formative themes in this program:

> "1) the dynamics of science, technology, and innovation; 2) the scientometric operationalization and measurement of these dynamics; and 3) the Triple Helix of university-industry-government relationships" (p. 3).

The empirical results of this study can confirm these themes in Loet's program. Based on the results of our study, we would like to add the theme "quantitative research evaluation". Loet was one of the most important actors in a far-reaching debate on optimizing field-normalized citation scores in scientometrics.

With Loet, we lose a prototype of a researcher. He was extremely interested in many research topics. This was expressed not only in many publications, but also in many verbal contributions. We cannot imagine a conference or meeting, in which Loet did not present own research or was very active in the discussions with many important contributions. Even until a few weeks before his death, Loet actively participated in the *CWTS* Friday afternoon seminar:
https://www.cwts.nl/seminars/information

In research collaborations, we experienced him as a researcher who was always interested in learning new methods, techniques or approaches. In collaborative research projects, he was not interested in handing off work (e.g., the statistical analysis of the data), but in learning how to do the work himself that others were doing in a project.

For us, it was a pleasure to work with Loet in many research projects, since he had excellent ideas and a fundamental background in scientometrics. We cannot imagine a common research project that would come to nothing: The way from the idea to the paper was always characterized by Loet's inspiring contributions. But Loet's contributions were not only restricted to research projects that led to publications; he also provided programs (with source code) on his webpage (see: *https://www.leydesdorff.net*) that he developed for research projects. Both, his publications and programs will surely continue to be extremely helpful to the scientometrics community.

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