A bibliometric perspective on the academic contributions of Loet Leydesdorff

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Abstract

The purpose of this paper is to commemorate the late scholar Loet Leydesdorff for his great academic contribution on the basis of data from *Web of Science*. In the span of more than 40 years, he had 526 publications, with the years 2004-2021 being the most productive (394 publications). His international collaborations spread widely across 36 countries, with Germany, the USA, the UK, China, Russia, and South Korea being the most significant. His most frequent collaboration partners included Lutz Bornmann (Germany), Staša Milojević (USA), Caroline Wagner (USA), Henry Etzkowitz (USA), Jonathan Adams (UK), Ronald Rousseau (Belgium), and Ping Zhou (China). With a broad and deep knowledge background, Leydesdorff's research extended across multiple disciplines and fields, but he was most active in library and information science and computer science. He made profound contributions to the study of bibliometrics, innovation systems (the Triple Helix model), and communications. Leydesdorff had a remarkable and extensive citation impact, with citations in 221 *WoS* subject categories from 120 countries. His publications in 1996, 1998, 2000, 2005, 2006, and 2012 are highly cited, and those on university-industry-government relations (the Triple Helix model) are the most cited.

Keywords

Loet Leydesdorff; Bibliometrics; Informetrics; Scientometric portrait; Academic contributions; Researchers; Library and information science; Computer science.

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1. Introduction

Loet Leydesdorff was professor emeritus at the *Amsterdam School of Communications Research* (*ASCoR*) at the *University of Amsterdam*, with degrees in different disciplines (Ph.D. in sociology, M.A. in philosophy, and M.Sc. in biochemistry). He published extensively in systems theory, social network analysis, scientometrics, and the sociology of innovation. With Henry Etzkowitz, he initiated a series of workshops, conferences, and special issues about the Triple Helix of university-industry-government relations. He received the *Derek de Solla Price Award for Scientometrics and Informetrics* in 2003 and held "The City of Lausanne" Honor Chair at the *School of Economics*, *Université de Lausanne* in 2005. In 2007, he was Vice President of the *8th International Conference on Computing Anticipatory Systems* (*CASYS'07*, Liège). He has been listed as a highly cited author since 2014 (*https://clarivate.com/hcr/*), and was ranked as the 27th (world) and 1st (the Netherlands) top scientist in the social sciences and humanities on the basis of citations data collected on 21-12-2022 by *Research.com* (*https://research.com/scientists-rankings/social-sciences-and-humanities*).

> In 44 years (1980-2023), Leydesdorff had more than 500 *WoS*-indexed publications, with the years 2004-2021 being the most productive.

With profound knowledge across a wide range of disciplines, such as philosophy of science, social network analysis, communication science, informatics, and sociology, Leydesdorff was able to make innovative contributions to a variety of subjects. Academic research was his lifelong passion. Even though he suffered from illness, he managed to publish his last book, *The Evolutionary Dynamics of Discursive Knowledge: Communication-Theoretical Perspectives on an Empirical Philosophy of Science*, which integrates his major contributions to three core issues: (1) the dynamics of science, technology, and innovation; (2) the measurements of the core concepts of scientometrics; and (3) the Triple Helix of university-industry-government relations (**Leydesdorff**, 2021). If he had not been unable to read and write owing to his illness and the surgeries he underwent, he would have continued his research until the last moment of his life.

In the informetric community, numerous "scientometric portraits" of eminent scholars have been published, such as those of Judit Bar-Ilan (**Halevi**, 2020; **Orduña-Malea**, 2020), Bimal Kanti Sen (**Dutta**, 2019), Eugene Garfield (**Glänzel**; **Abdulhayoğlu**, 2018), Jan Hendrik Oort (**Koley**; **Sen**, 2018), Mike Thelwall (**Vellaichamy**; **Amsan**, 2016), Santiago Grisolía (**González-Alcaide**, 2014), Nayana Nanda Borthakur (**Hazarika**; **Sarma**; **Sen**, 2010), Sivaraj Ramaseshan (**Sangam**; **Savanur**; **Manjunath**, 2007), Dorothy Crowfoot Hodgkin (**Kademani**; **Kalyane**; **Jange**, 1999) and Ronald Rousseau (**Sun**; **Jiang**, 2012). This paper aims at drawing a scientometric portrait for Loet Leydesdorff to express our remembrance of him by tracing his academic contributions from perspectives of historical trend of publications, international collaboration, interdisciplinarity, and academic impact.

2. Data and methods

Publication data were obtained from two sources: *Web of Science* (*WoS*) from *Clarivate* and *Google Scholar*. We collected 406 publications with metadata records from *WoS*. We supplemented this with 120 records from *WoS*, *Google Scholar*, and his personal homepage, resulting in a collection of 526 scientific publications, including articles, reviews, and conference papers (search date: May 30, 2023). Software packages such as *Microsoft Excel*, *R*, and *VOSviewer* were used for descriptive statistics analysis, citation analysis, and co-occurrence analysis. The jcitnetw.exe and mode2div.exe programs, developed by Leydesdorff (**Leydesdorff**; **Wagner**; **Bornmann**, 2019), were used to analyze the interdisciplinarity of his academic contributions, which generate the indicators of Variety, Disparity, Gini coefficient, and Rao-Stirling diversity (**Leydesdorff**, 2018; **Stirling**, 2007). Variety reflects the number of distinctive categories, "1 - Gini coefficient" depicts the balance in the distribution of categories, and Disparity indicates the degree to which the categories are different (**Purvis**; **Hector**, 2000; **Ràfols**; **Meyer**, 2010). The Rao-Stirling indicator explicitly or implicitly measures the properties of integrated diversity, namely the combination of variety, balance, and disparity (**Stirling**, 1998; 2007). The interdisciplinarity of each document is calculated on the basis of the subject category distribution of its references (calculation formulas for the interdisciplinarity indicators are presented in Table 1).

Table 1. Interdisciplinarity indicators.

Indicator	Formula	Description
Variety	$Variety_c = \frac{n_c}{N}$	*N* is the number of available categories.
Balance	$Balance = 1 - Gini_c = 1 - \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\lvert x_i - x_j\rvert}{2n^2\bar{x}}$	*x* is an observed value; *n* is the number of disciplines involved in the observed value; x_i is the number of observations belonging to the i^{th} discipline.
Disparity	$Disparity_{\substack{i=n_c,j=n_c \\ i,j=1;i\neq j}} = \sum \frac{d_{ij}}{n_c(n_c-1)}$	d_{ij} is the distance between subjects *i* and *j*, normalized by $n_c(n_c\text{-}1)$.
Rao-Stirling diversity	$RS = \sum_{i\neq j}(d_{ij})^{\alpha}(p_i p_j)^{\beta}$	$p_i = x_i/\sum x_i$, and x_i denotes the number of elements belonging to subject *I*; α and β are two parameters for adjusting the relative weights of distance d_{ij} and balance or variety $p_i p_j$.

3. Results and analysis

3.1. Publication history

Figure 1 illustrates Leydesdorff's publication history. In 44 years (1980-2023), Leydesdorff published more than 500 papers. His publishing activity can be divided into three periods according to the number of yearly publications:

1. 8 years of relatively low productivity (i.e., fewer than 4 papers per year) in 1980-1988. As an academic newcomer in this period, his main task might have been to publish by applying learned knowledge to solve academic problems. Although being a newcomer, his broad scope of knowledge in different fields, such as mathematics, statistics, informatics,

and social systems theory, was well demonstrated in his publications;

2. 15 years of growing productivity in 1989-2004 with annual number of publications ranging between 4 and 11. The significant contribution he made regarding the Triple Helix (TH) model, together with Henry Etzkowitz, came out of this period; and

3. 19 years of high productivity since 2004 (i.e., more than 10 papers per year). With the first period of knowledge accumulation and the second period of knowledge creation, Leydesdorff had laid a solid foundation for this third period of high productivity. With 28, 33, 33, and 24 publications in the years 2006, 2011, 2012, and 2020, respectively, these years were most prominent. His high yield in 2020 is the most impressive, taking into account that, by that point in time, he was already suffering from the illness that eventually ended his life. His focuses in this period include new indicators, theoretical issues, and evaluation methods.

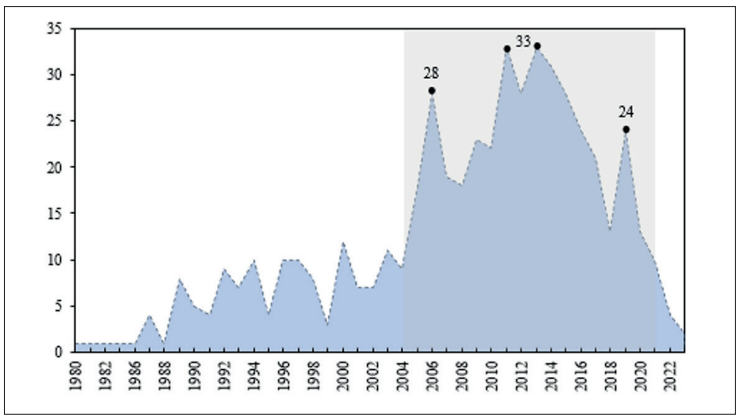

Figure 1. Annual publications of Loet Leydesdorff.

Leydesdorff published in more than 100 journals, most of which were leading informetrics journals such as *Scientometrics* (20.1%), *Journal of the Association for Information Science and Technology* (*Jasist*, 18.3%), and *Journal of informetrics* (9.0%). In other words, most of Leydesdorff's output was in informetrics or bibliometrics. The two most important journals in bibliometrics, *Scientometrics* and *Jasist*, have published 38.4% of Leydesdordff's papers throughout his publishing history. His publishing career accompanied the growth and development of the *Journal of informetrics* since its first issue in 2008. In addition to bibliometric studies, science policy was one of Leydesdorff's research interests, which is why 3.82% of his papers were published in the leading policy-related journal *Research Policy* over the years 1984-2016 (Figure 2).

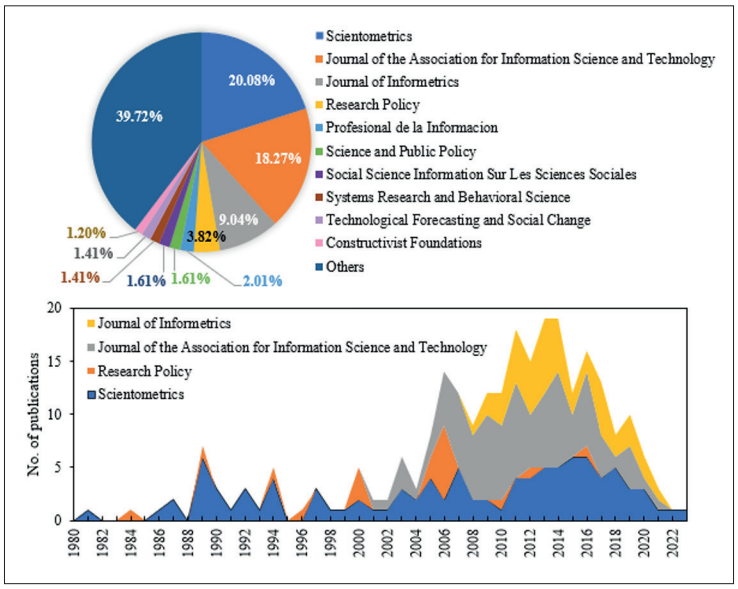

Figure 2. Publication distribution among journals.

3.2. International collaboration

International collaboration plays a significant role in the development of science, and related topics have been explored extensively (e.g., **Luukkonen**; **Persson**; **Sivertsen**, 1992; **Katz**; **Martin**, 1997; **Freeman**, 2010; **Dusdal**; **Powell**, 2021; **Gui**; **Liu**; **Du**, 2019; **Zhou**; **Tijssen**; **Leydesdorff**, 2016; **Zhou**; **Glänzel**, 2010; **Leydesdorff**; **Wagner**, 2008; **Leydesdorff** *et al.*, 2013). International collaboration has been regarded as an important indicator when measuring the research performance of individuals and the internationalization of an organization or country. Leydesdorff's international collaborations spread across 36 countries. More than half of his publications came out of international collaborations, with most (45.5%) being with one foreign country and 14.38% with two foreign countries. Leydesdorff's international collaborations developed in step with his publication productivity, with the year 2004 serving as a divide (Figure 3). Since 2005, the number of publications stemming from international collaborations as well as the number of foreign countries collaborated with grew significantly. On average, half of his publications during 2005-2010 came out of international collaborations. Since 2011, however, most of his publications stemmed from them, with the years 2019, 2022, and 2023 being extreme cases where all of his publications resulted from internationally collaborations. A simple deduction can be made from this: growing publication productivity brought growing academic impact and thus promoted international collaboration with Leydesdorff.

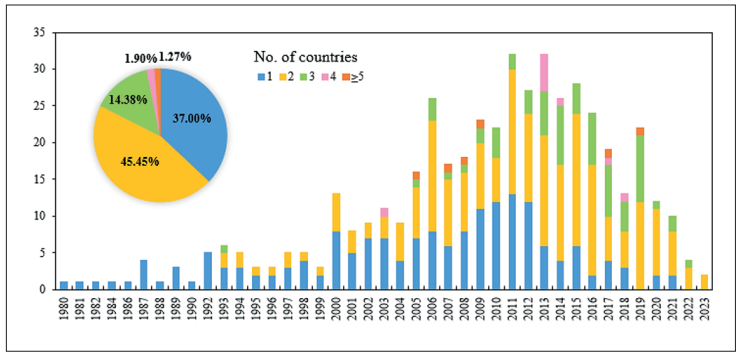

Figure 3. Annual distribution of publications with collaboration.

With regard to the country of origin of the scholars who collaborated with Leydesdorff, Western countries including Germany, the USA, the UK, and Belgium were at the top of the list (Table 2), with Germany taking the absolute lead. Scholars from Germany included Lutz Bornmann, Robin Haunschild, and Michael Fritsch and generated 120 publications, while collaboration with scholars from the USA included Caroline Wagner, Staša Milojević, Henry Etzkowitz, Jordan Comins, and Alan Porter and produced 91 publications. Collaboration with scholars from Asia, especially China, South Korea, and Russia, and including Ping Zhou, Han Woo Park, and Inga Ivanova, was also frequent.

Table 2. Top countries and scholars collaborating with Loet Leydesdorff.

Countries (Top10)	*N*	Co-authors
Germany	120	Lutz Bornmann; Robin Haunschild; Michael Fritsch; Werner Marx; Tobias Hecking; Alexander Tekles
USA	91	Caroline Wagner; Staša Milojević; Henry Etzkowitz; Jordan Comins; Alan Porter; Alexander Petersen; Stephen Carley; Mark William Johnson; Andy Stirling
UK	72	Martin Meyer; Jonathan Adams; Daniele Rotolo; Helen Lawton Smith
China	32	Ping Zhou; Lin Zhang; Xiaojun Hu; Fred Y Ye.
Belgium	22	Ronald Rousseau; Leo Egghe; Raf Guns; Tim Engels
Spain	21	Igone Porto-Gómez; Félix De-Moya-Anegón
Russia	20	Inga Ivanova; Nataliya Smorodinskaya
South Korea	20	Han Woo Park; Jungwon Yoon; Ki-Seok Kwon
Switzerland	12	Ruediger Mutz; Hans-Dieter Daniel; Carole Probst
Italy	11	Cinzia Daraio; Simone Di-Leo; Michelina Venditti

The historical evolution of Leydesdorff's international collaborations (Figure 4) shows that his early collaborations were with USA researcher Henry Etzkowitz, with whom he created some of his most influential output –the TH model (**Etzkowitz**; **Leydesdorff**, 1995, 2000; **Leydesdorff**; **Etzkowitz**, 1996)- and with whom he explored the knowledge infrastructure of the global system or a knowledge economy. They argued that three distinguished dynamics exist in the global system or in a specific economy: the economic dynamics of the market (industries), the internal dynamics of knowledge production (universities), and the governance of their interface at different levels (government). These three sectors –university, industry, and government (UIG)– interact with each other in promoting the development of the knowledge economy. The TH model was widely accepted, and 11 TH conferences have been held globally (*https://www.leydesdorff.net/th2*).

By applying the Shannon-type information generated in the interactions among the three actors, Leydesdoff made it possible to quantify the UIG relationship (**Leydesdorff**, 2011), and thus brought about a boom of quantitative studies related to UIG relationships (e.g., **Khan**; **Park**, 2011; **Park**, 2014; **Zhang**; **Chen**; **Fu**, 2019).

The second country involved in Leydesdorff's early period of international collaborations was the UK. In 2003, Leydesdorff collaborated with Martin Meyer to explore three different sub-dynamics –economic exchanges on the market, geographical variations, and the organization of knowledge– by applying the TH model (**Leydesdorff**; **Meyer**, 2003). Since 2005, Leydesdorff's international collaboration expanded to more countries, including Germany and China. With German scholar Lutz Bornmann, Leydesdorff collaborated most frequently on a wide range of topics including citation analysis, knowledge mapping, research evaluation, and bibliometric indicators (e.g., **Leydesdorff** *et al.*, 2011; **Bornmann**;

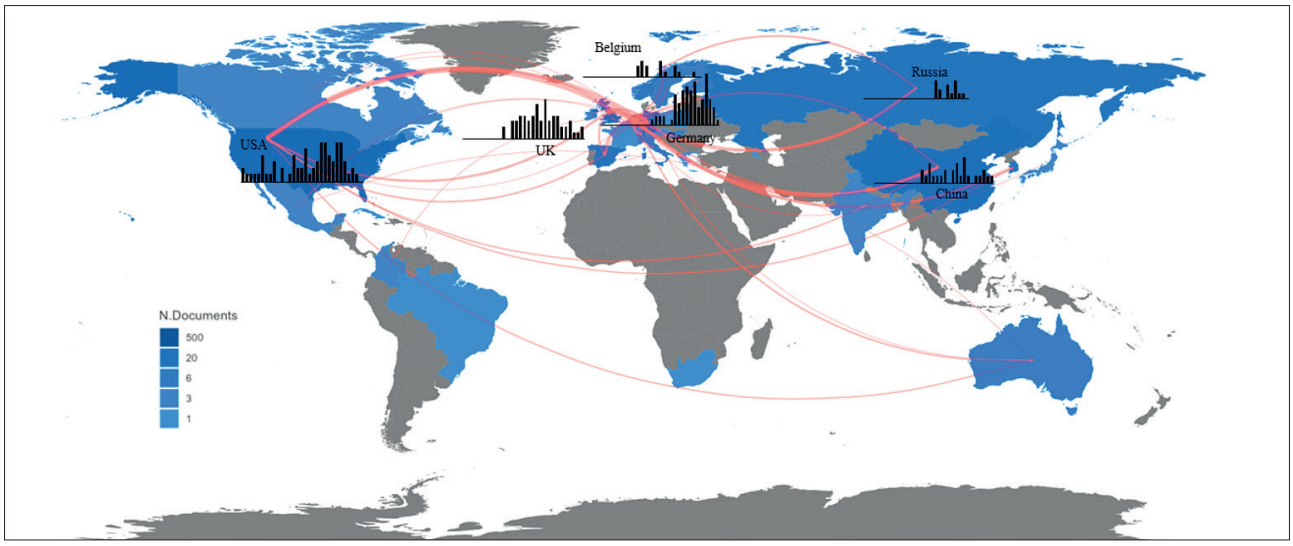

Figure 4. Geographical and historical distribution of Leydsdorff's international collaborations.
Note: The horizontal axes are for publication years (1993-2023), and vertical axes are for the number of publications (0-12).

Leydesdorff, 2012; **Bornmann**; **Tekles**; **Leydesdorff**, 2019; **Leydesdorff**; **Bornmann**; **Wagner**, 2021). Leydesdorff had a long period of collaboration with Chinese scholar Ping Zhou, his PhD student from 2005 to 2008 (e.g., **Leydesdorff**; **Zhou**, 2005; **Zhou**; **Leydesdorff**, 2006; **Zhou**; **Leydesdorff**, 2007; **Zhou**; **Su**; **Leydesdorff**, 2010; **Zhou**; **Tijssen**; **Leydesdorff**, 2016; **Zhou**; **Leydesdorff**, 2011). An important Russian collaborator of Leydesdorff was Inga Ivanova, although the collaboration started relatively late (from the year 2014). Their collaboration topics mainly involved the TH model, innovation systems, and synergetic effects (e.g., **Ivanova**; **Leydesdorff**, 2014; **Leydesdorff**; **Ivanova**, 2016; **Leydesdorff**; **Ivanova**; **Meyer**, 2019). In 2008-2020, Leydesdorff collaborated with the Belgian scholars Rousseau Ronald, Tim Engels, and Raf Guns.

> Leydesdorff published in more than 100 journals, most of which were leading journals in informetrics such as *Scientometrics*, *Journal of the Association for Information Science and Technology*, and the *Journal of Informetrics*.

3.3. Interdisciplinary studies

When it comes to interdisciplinary research, the first issue is discipline classification, a big challenge in bibliometrics. In this paper, we adopt two classification schemes: *WoS* subject categories and topic classification. The former defines disciplinary attribution based on the publishing journals, whereas the latter defines the disciplinary attribution of publications by their research content. It is clear that the former classification is not as precise as the latter; hence, we apply both classification schemes to provide a broader and finer view of Leydesdorff's involvement in different disciplines and fields.

We first apply the broader definition –*WoS* subject categories– to map Leydesdorff's involvement in multiple disciplines. With interdisciplinary knowledge background, Leydesdorff made contributions to research topics requiring interdisciplinary knowledge. His publications involve 47 disciplines across the natural sciences, engineering, social sciences, and humanities, with most of them (82.0%) being in library and information science and computer science (Figure 5, right). Computer science took the second position in Leydesdorff's research because knowledge, especially methods, technologies, and tools, have increasingly been applied to solving problems in library and information science. In fact, the development of interdisciplinary research has resulted in increasingly newer knowledge generated at the "trading zones" (**Thagard**, 2005) of knowledge. A typical case of Leydesdorff's interdisciplinary research was to explain and simulate the development of information society by constructing mathematical models and applying computer technologies, which lasted for nearly 30 years (1995-2022) (e.g., **Leydesdorff**; **Ivanova**, 2021). Knowledge mapping was Leydesdorff's other important contribution: he wrote approximately 100 programs and made them all free access. A large number of his papers were based on his programs, especially those regarding knowledge mapping (e.g., **Leydesdorff**; **Bornmann**; **Wagner**, 2021). In addition, publishing mostly in library and information science and computer science, Leydesdorff was also involved in 36 other disciplines, for example, environmental science, the history and philosophy of science, business, economics, public administration, management science, social sciences, interdisciplinary and communication, and so on, which featured in 17.1% of his publications.

Leydesdorff's publication history in terms of disciplinary distribution (Figure 5, left) proves that he was most active in two disciplines: library and information science and computer science. His publication activities in these two disciplines were synchronous, and his research was also related to management science, social sciences, and communication science, although with relatively fewer publications.

The indicators in Table 1 are applied to measure the interdisciplinarity of Leydesdorff's research. The results (Figure 6, left) show a rapid upward trend from 1997 to 2001, followed by a long period of fluctuation. The variety of his studies fluctuated from 1997 to 2023, which implies a transformation of his research focuses. For example, the proposition and development of the TH model in 1997-2002 were based on the absorption of knowledge from different fields, such as statistics, sociology, informatics, and complex systems. During 2010-2021, Leydesdorff focused on bibliometric indicators (e.g., impact factor, diversity, citation impact, the H index, etc.) and their applications, resulting in a reduced trend in the Variety value. The Balance value declined slowly from 1997 to 2013 and then fluctuated slightly at a higher level

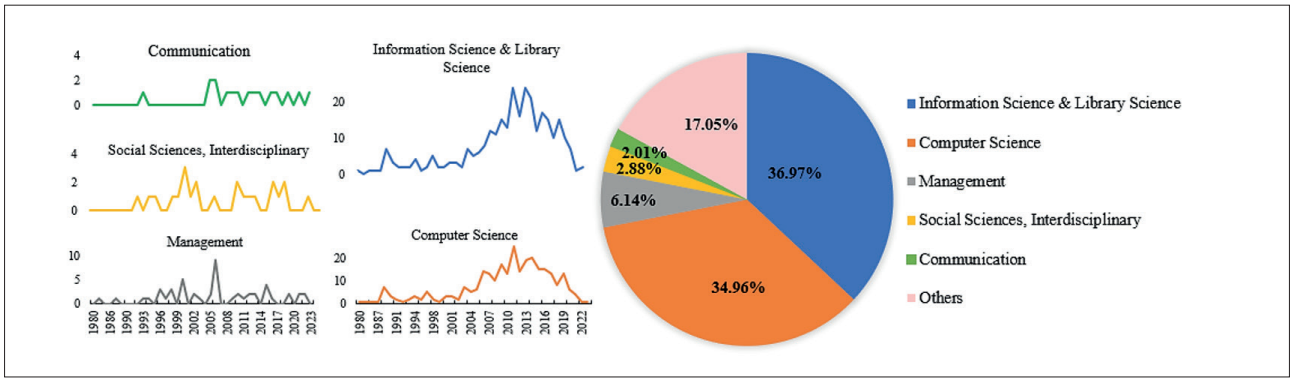

Figure 5. Publication distributions among disciplines in which Leydesdorff was most active.

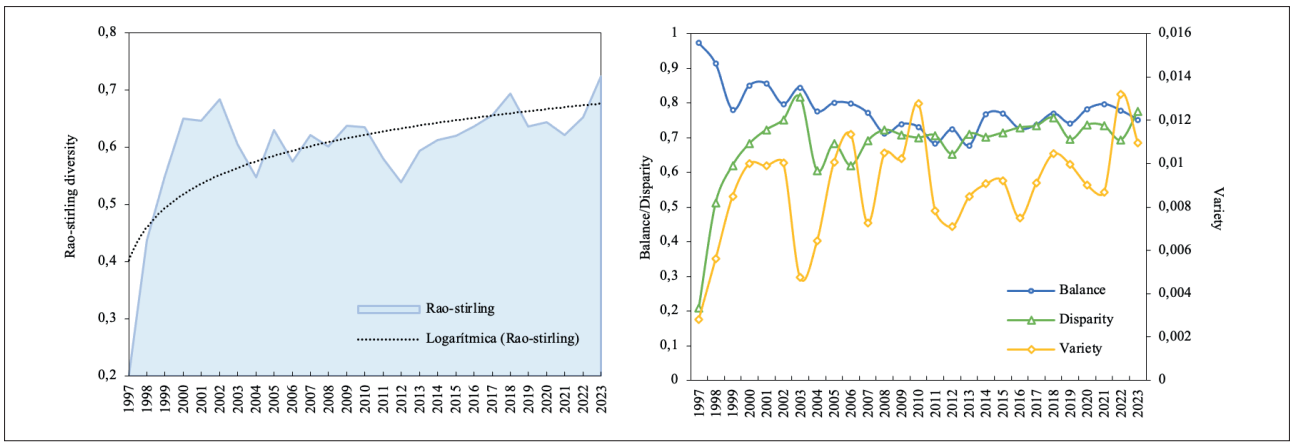

Figure 6. Annual trend of Leydesdorff's interdisciplinary studies.
Note: Detailed reference information of publications before 1997 is incomplete. Only interdisciplinarity values of publications from after 1997 are calculated.

(Balance > 0.7) in the rest of the period. The Disparity value grew rapidly during 1997-2004 (from 0.2 to 0.6) and then fluctuated slightly during the rest of the period owing to a noticeable transformation in knowledge sources. From 2003, Leydesdorff focused more on bibliometric studies, such as citation analysis, research evaluation, knowledge map, co-occurrence analysis, and social network analysis. Accordingly, the disciplines involved changed from physics, sociology, and management science to library and information science and computer science. In the last decade, his research focus had gradually fixed upon interdisciplinary research, including indicators and research evaluation, resulting in relative stable values of Disparity.

Next, we applied topic classification to define Leydesdorff's discipline/field involvement. By inputting the title, abstract, author keywords, and keywords plus of Leydesdorff's publications into *VOSviewer*, five distinct clusters were obtained: research evaluation, citation analysis, interdisciplinary study, innovation systems, and communication studies (Figure 7). Three clusters –citation analysis, interdisciplinary study, and research evaluation– are closely linked to each other because of their common knowledge foundation, with bibliometrics and citation analysis lying at their core. Thus, the three clusters can be generalized as one cluster, viz. the bibliometric cluster. The other two clusters –innovation systems (TH model) and communication studies– are related to each other but are independent from the bibliometric cluster. Leydesdorff's broad scope of knowledge is well displayed in Figure 7.

Leydesdorff was most productive in bibliometrics, a field in library and information science, and invested his energy in this field throughout his academic life. His research focuses in bibliometrics included theoretical (**Leydesdorff**; **Zhang**; **Wouters**, 2023) and methodological (**Leydesdorff**; **Ràfols**, 2012) issues, citation analysis (e.g., **Bornmann**; **Leydesdorff**,

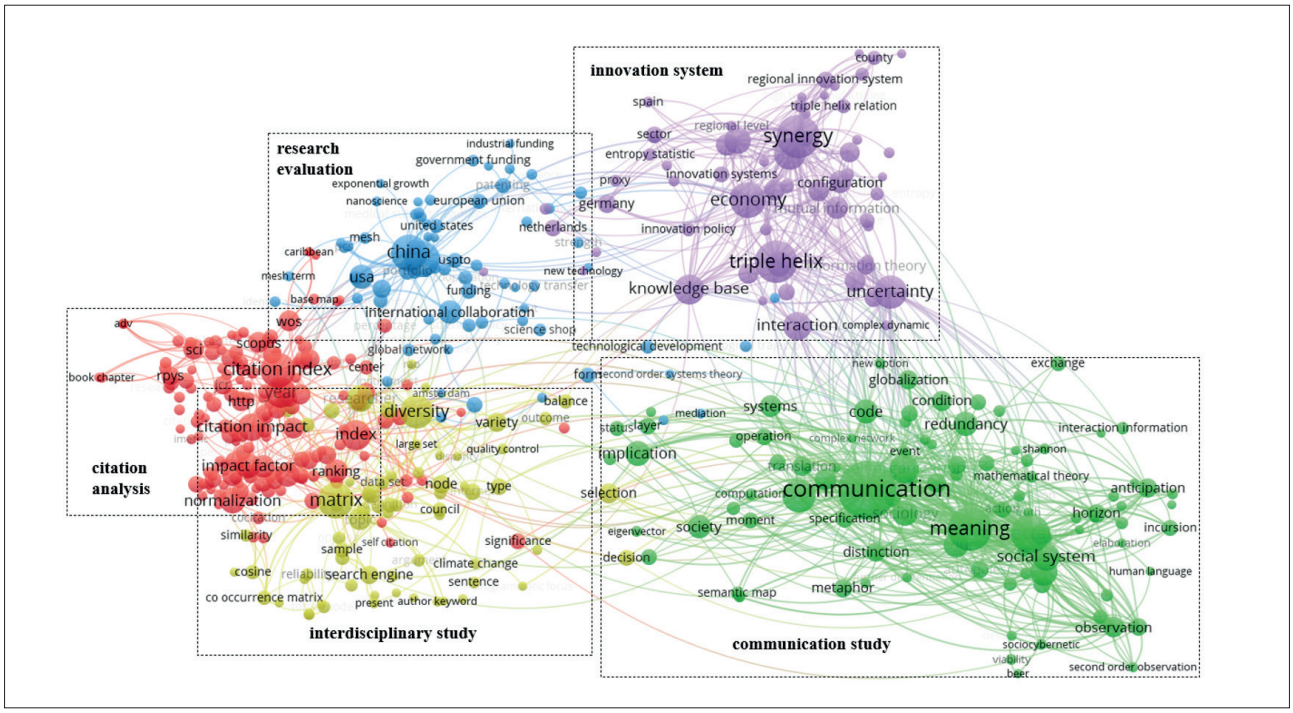

Figure 7. Co-occurrence network map of Leydesdorff's academic contributions.

2017), indicators (e.g., **Leydesdorff**; **Tekles**; **Bornmann**, 2021; **Leydesdorff**; **Bornmann**, 2021), research evaluation (e.g., **Leydesdorff**; **Milojević**, 2015), and knowledge mapping (e.g., **Chen**; **Leydesdorff**, 2014). Price (e.g., **Price**, 1965; **Price**, 1970), Garfield (e.g., **Garfield**, 1972; **Garfield**; **Merton**, 1979), and Merton (e.g., **Merton**, 1968) were Leydesdorff's important knowledge sources.

> "Leydesdorff's international collaborations were spread widely across 36 countries, with Germany, the USA, the UK, China, Russia, and South Korea being the most significant"

With great concern placed on research evaluation, Leydesdorff reviewed classical theory such as Bradford's Law (**Bradford**, 1934), and systematically optimized existing evaluation methods (**Ràfols**; **Leydesdorff**, 2009). With his co-authors, he carried out many evaluation studies on countries, institutions, journals, and disciplines (e.g., **Zhou**; **Su**; **Leydesdorff**, 2010; **Zhou**; **Tijssen**; **Leydesdorff**, 2016; **Leydesdorff**; **Zhou**, 2014; **Leydesdorff**; **Bornmann**, 2016; **Zhou**; **Leydesdorff**, 2011; **Wagner**; **Whetsell**; **Leydesdorff**, 2017). In interdisciplinary study, Leydesdorff proposed the concept of diversity and its measurement in the paper titled "Diversity and interdisciplinarity: how can one distinguish and recombine disparity, variety, and balance?" (**Leydesdorff**, 2018). By inducing the Gini coefficient into the Rao-Stirling index, he made it possible to measure the diversity of interdisciplinary research, and thus received a high citation impact (28 citations in *WoS* and 38 citations in *Google Scholar*, retrieval date: September 13, 2023).

On the basis of the theory of information entropy (**Shannon**, 1948; **McGill**, 1954), statistical decomposition analysis methods (**Theil**, 1972), and social system theory (**Luhmann**, 1984), Leydesdorff proposed the TH model with Henry Etzkowitz and made it possible to explain and quantify interactions among industries, universities, and governments in a communication system of knowledge economy (e.g., **Leydesdorff**; **Zhou**, 2014; **Park**; **Leydesdorff**, 2010; **Kwon** *et al.*, 2012; **Leydesdorff**; **Sun**, 2009; **Leydesdorff**; **Strand**, 2013). The TH model has been widely accepted in multiple disciplines and fields, for example, bibliometrics, management science, sociology, and public administration (e.g., **Buligina** *et al.*, 2014; **Kim**; **Park**, 2012).

Time-slice analysis of research topics helps to trace the historical evolution of Leydesdorff's research focuses (Figure 8). In 1980-1990, his interests were theoretical issues in communication science, statistics, social systems, self-organization, and information entropy. His research in this period laid the foundation for his significant contributions in later years. In 2000-2007, his research involved theoretical and application issues of the innovation system (TH model), citation analysis, and knowledge mapping. In 2008-2015, his focuses included topics relevant to synergistic effects based on the TH model and bibliometric topics such as indicators and research evaluation. In 2016-2023, his interests were in innovation systems and applications of the TH model (i.e., university–industry–government interactions and multiple sectors in knowledge production). With the increasing need to tackle complex scientific problems, studies on interdisciplinary research attracted Leydesdorff's attention. He studied the interdisciplinarity of different objects and entities such as publications, journals, countries, regions, disciplines, fields, authors, organizations, and so on by conducting citation analysis, co-occurrence analysis, and social network analysis.

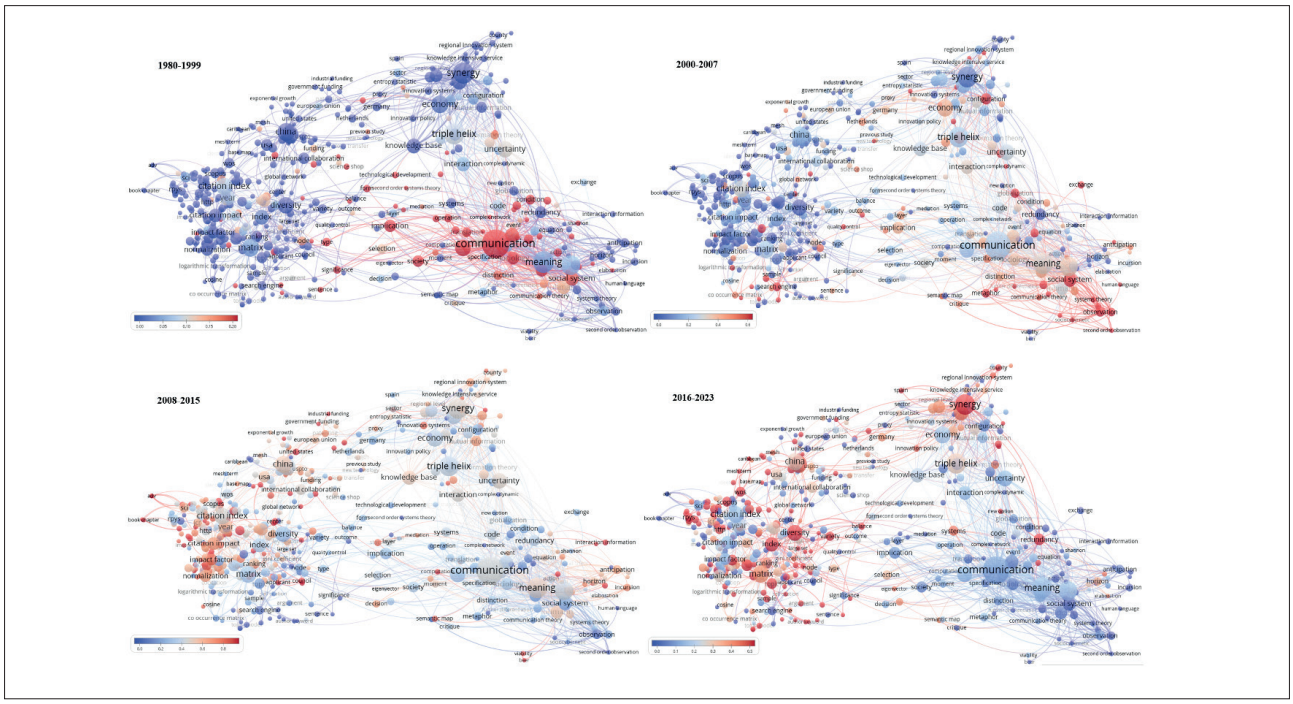

Figure 8. Time-slice analysis of research topics.
Note: The terms marked with red nodes occur more frequently than those marked with blue.

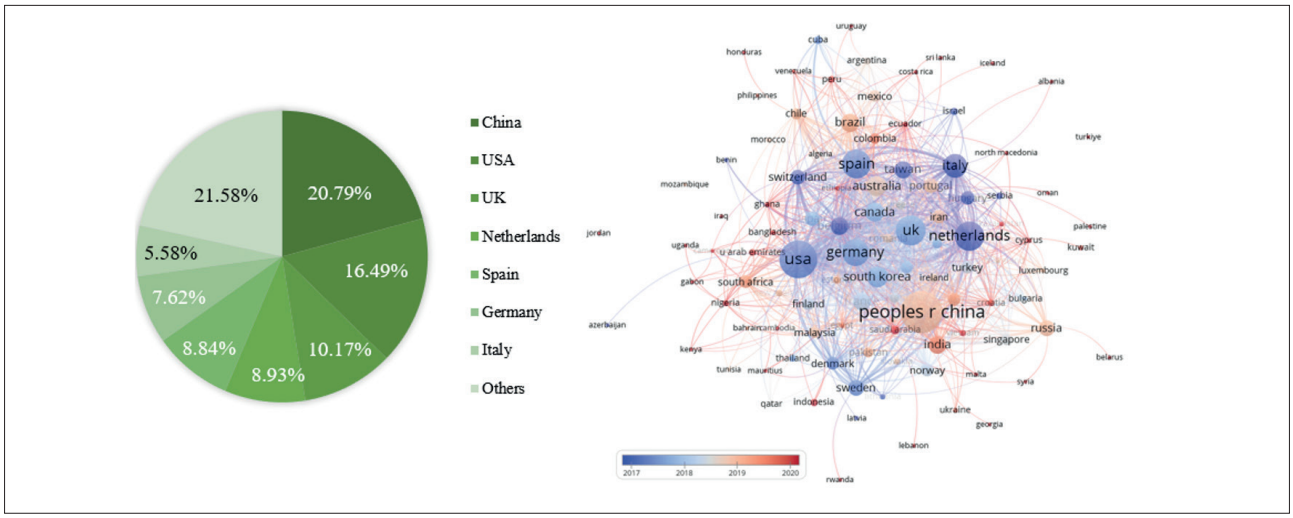

Figure 9. Country distribution of citing publications of Leydesdorff's research.

3.4. Citation impact

Citation impact is an important dimension that measures scholarly contribution. In this section, we use citations from each publishing year, citing discipline, and country/region, to respectively measure Leydesdorff's impact on said publishing years, disciplines, and countries/regions.

Leydesdorff's citation impact can be seen across 120 countries, with China, the USA, the UK, and Spain being the most significant (Figure 9). Among the citing publications, China has 1,639, accounting for 20.8%, followed by the USA (1,312 publications, 16.4%) and the UK (721 publications, 10.2%). In the early years, Leydesdorff's impact was mainly seen in North America (e.g., the USA and Canada), Europe (e.g., Italy, Spain, Germany, Switzerland, Sweden, Denmark), South Korea, and Australia. In the middle and late periods, his academic impact spread gradually to China, Russia, India, Singapore, Africa (e.g., South Africa), and South America (e.g., Brazil, Chile).

Leydesdorff's citation impact is spread across 221 disciplines and fields. His publications are cited most frequently in computer science (21.99%) and library and information science (20.39%), followed by environmental science (5.94%), management science (5.70%), and business (3.91%) (Figure 10). The time distribution of the citing disciplines shows that Leydesdorff's early impact was on library and information science, computer science, and electrical and electronic engineering, and then expanded to education and educational research, public health, green and sustainable development sciences and technology, and environmental science. This phenomenon further confirms the interdisciplinary characteristics of Leydesdorff's academic contributions.

In 42 years (1982-2023), Leydesdorff's most influential contributions were made in 1996, 1998, 2000, 2005, 2006, and 2012 (Figure 11). Given that Leydesdorff published more than one paper per year, we only mention the paper receiving the most citations in the focal year. In 1996, he and Etzkowitz first published the paper introducing the Triple Helix model to illustrate the relationship between universities, industries, and government (**Leydesdorff**; **Etzkowitz**, 1996). It should be noted that the TH model was first announced at the 1995 ESST conference (**Etzkowitz**; **Leydesdorff**, 1995), but published in a journal in 1996 (**Leydesdorff**; **Etzkowitz**, 1996). This paper had 1,731 citations.

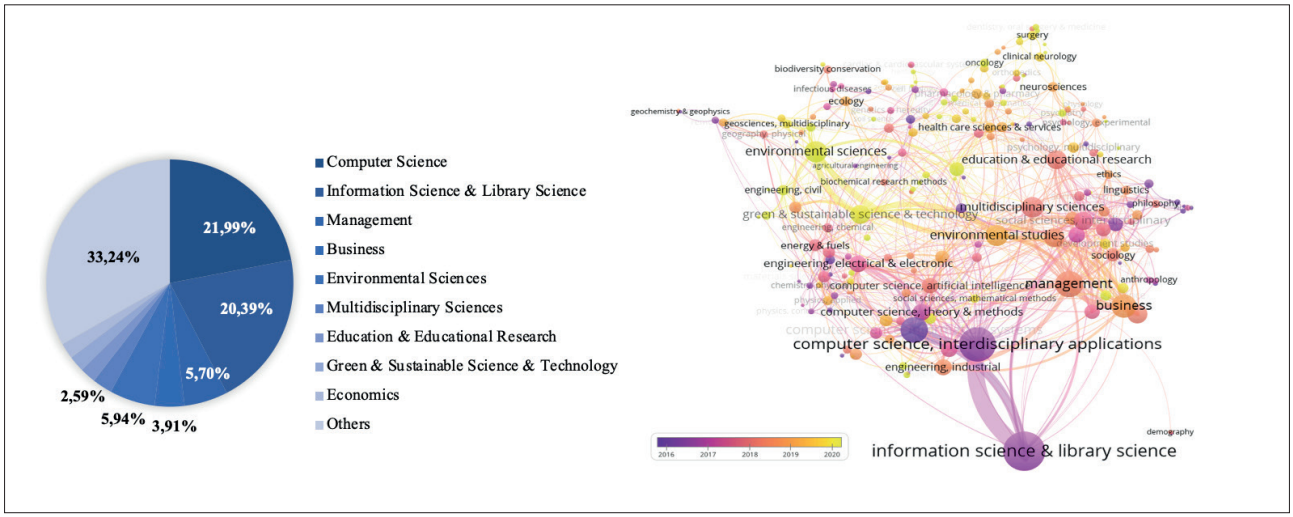

Figure 10. Disciplinary distribution of citing publications of Leydesdorff's research.

The 1998 publication (**Leydesdorff**; **Etzkowitz**, 1998, 1,397 citations) introduced the topics discussed at the second Triple Helix conference held in New York the same year. The 2000 publication (**Etzkowitz**; **Leydesdorff**, 2000) enriched the TH model with theoretical foundations and thus had the highest number of citations (3,382). The 2005 publications with high citations co-authored with Caroline Wagner (then Leydesdorff's PhD student) (**Wagner**; **Leydesdorff**, 2005, 1,349 citations) focused on principles and mechanisms of international collaboration in scientific research. Although 2006 was also the year that Leydesdorff produced papers with high citations, the count was an accumulative result, with three publications being the most representative (**Zhou**; **Leydesdorff**, 2006, 379 citations; **Leydesdorff**; **Vaughan**, 2006, 265 citations; **Leydesdorff**; **Meyer**, 2006, 202 citations).

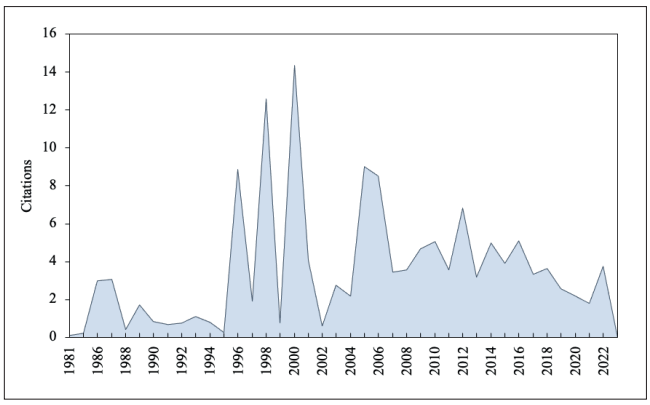

Figure 11. Number of citations in publication years (retrieval date: May 30, 2023).

4. Summary

By tracing the academic contribution of Loet Leydesdorff from different perspectives, the current paper provides a quantified portrait of him.

In 44 years (1980-2023), Leydesdorff published more than 500 *WoS*-indexed publications, with the years 2004-2021 being the most productive, with more than 10 publications per year. More than half of his papers were published in informetrics journals such as *Scientometrics*, *Jasist*, and *Journal of Informetrics* as well as the management journal *Research Policy*.

Leydesdorff was an active practitioner of international collaboration, with nearly half of his publications being co-authored. The scholars who collaborated with him were spread across 36 countries, including Germany, the USA, the UK, China, Russia, and South Korea. The year 2005 was when his international collaboration began to proliferate. In later years (2019, 2022, and 2023), almost all his publications featured international collaborations. It is no exaggeration to say that he is an internationally distinguished scholar. The importance of international collaboration in promoting science development is well illustrated by Leydesdorff's practices and achievements. International collaboration contributed to his academic achievement, and he also contributed to his international partners' achievements through collaboration.

On the basis of *WoS* journal categories, Leydesdorff published in, and thus had impact across, multiple disciplines and fields. His publications engage with 47 different disciplines and fields, including library and information science, computer science, management science, communication science, business, economics, and public administration. Topic clustering identified five disciplines/fields that Leydesdorff engaged with the most: research evaluation, citation analysis, interdisciplinary study, innovation systems (TH model), and communication studies. Using bibliometrics to generalize research evaluation, citation analysis, and interdisciplinary study because of their connections to each other, three distinct disciplines/fields are obtained (bibliometrics, innovation system (TH model), communication studies) with which Leydesdorff engaged most frequently.

Leydesdorff's far-reaching impact is unparalleled. His work was cited in more than 120 countries and 221 *WoS* subject categories. China, the USA, the UK, and Spain were the top four countries in which citations of his work are found. The disciplines citing Leydesdorff most frequently are library and information science and computer science. Over the course of 44 years, most of Leydesdorff's publications amounted to a high citation impact, which is remarkable given his extreme productivity. Another unusual phenomenon is the number of highly cited papers he produced through international collaboration on various research topics, with those on the TH model for innovation systems being the most influential.

The current study is based on *WoS* data without inclusion of Leydesdorff's four books: *A sociological theory of communication: The self-organization of the knowledge-based society* (2000); *The challenge of scientometrics: The development, measurement, and self-organization of scientific communications* (2001); *The knowledge-based economy modeled, measured, simulated* (2006), and

The evolutionary dynamics of discursive knowledge (2021). A more comprehensive profile of Leydesdorff's academic contribution might be carried out by including his books for both the quantitative and qualitative study of his output, in addition to the publications already referenced in this paper.

> "With profound knowledge in a wide range of disciplines, such as philosophy of science, social network analysis, communication science, informatics, and sociology, Leydesdorff was able to make innovative contributions to a variety of subjects."

5. References

Bornmann, Lutz; **Leydesdorff, Loet** (2012). "Statistical tests and research assessments: A comment on Schneider". *arXiv preprint arXiv*: 1210.3477.

Bornmann, Lutz; **Leydesdorff, Loet** (2017). "Skewness of citation impact data and covariates of citation distributions: A large-scale empirical analysis based on Web of Science data". *Journal of informetrics*, v. 11, n. 1, pp. 164-175.
https://doi.org/10.1016/j.joi.2016.12.001

Bornmann, Lutz; **Tekles, Alexander**; **Leydesdorff, Loet** (2019). "How well does I3 perform for impact measurement compared to other bibliometric indicators? The convergent validity of several (field-normalized) indicators". *Scientometrics*, v. 119, n. 2, pp. 1187-1205.
https://doi.org/10.1007/s11192-019-03071-6

Bradford, Samuel C. (1934). "Sources of information on specific subjects". *Engineering*, n. 137, pp. 85-86.

Buligina, Ilze; Sloka, Biruta; Dzelme, Juris; Tora, Ginta (2014). *Triple Helix for VET: New challenges for public administration in Latvia*. Economic Science for Rural Development. ISBN: 978 9934 8466 2 5

Chen, Chaomei; **Leydesdorff, Loet** (2014). "Patterns of connections and movements in dual-map overlays: A new method of publication portfolio analysis". *Journal of the Association for Information Science and Technology*, v. 65, n. 2, pp. 334-351.
https://doi.org/10.1002/asi.22968

Dusdal, Jennifer; Powell, Justin J. (2021). "Benefits, motivations, and challenges of international collaborative research: a sociology of science case study". *Science and public policy*, v. 48, n. 2, pp. 235-245.
https://doi.org/10.1093/scipol/scab010

Dutta, Bidyarthi (2019). "Biobibliometric portrait of BK Sen: A librarian, information scientist and scientometrician". *Malaysian journal of library & information science*, v. 24, n. 1.
https://doi.org/10.22452/mjlis.vol24no1.1

Etzkowitz, Henry; **Leydesdorff, Loet** (1995). "The Triple Helix of University-Industry-Government relations: A laboratory for knowledge based economic development". *EASST Review*, v. 14, n. 1, pp. 11-19.

Etzkowitz, Henry; **Leydesdorff, Loet** (2000). "The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations". *Research policy*, v. 29, n. 2, pp. 109-123.
https://doi.org/10.1016/S0048-7333(99)00055-4

Freeman, R. Edward (2010). *Strategic management: A stakeholder approach*. London: Cambridge University Press. ISBN: 978 0 521 15174 0
https://doi.org/10.1017/CBO9781139192675

Garfield, Eugene (1972). "Citation analysis as a tool in journal evaluation: Journals can be ranked by frequency and impact of citations for science policy studies". *Science*, v. 178, n. 4060, pp. 471-479.
https://doi.org/10.1126/science.178.4060.471

Garfield, Eugene; Merton, Robert K. (1979). *Citation indexing: Its theory and application in science, technology, and humanities* (vol. 8). New York: Wiley.

Glänzel, Wolfgang; Abdulhayoğlu, Mehmet Ali (2018). "Garfield number: On some characteristics of Eugene Garfield's first and second order co-authorship networks". *Scientometrics*, v. 114, pp. 533-544.
https://doi.org/10.1007/s11192-017-2623-4

González-Alcaide, Gregorio (2014). "Scientometric portrait of biochemist Santiago Grisolía: Publication productivity, collaboration patterns, and citation analysis". *Research evaluation*, v. 23, n. 2, pp. 150-165.
https://doi.org/10.1093/reseval/rvu003

Gui, Qinchang; Liu, Chengliang; Du, Debin (2019). "Globalization of science and international scientific collaboration: A network perspective". *Geoforum*, v. 105.
https://doi.org/10.1016/j.geoforum.2019.06.017

Halevi, Gali (2020). "The scientific legacy of Judit Bar-Ilan". *Scientometrics*, v. 123, n. 3, pp. 21-32.
https://doi.org/10.1007/s11192-020-03439-z

Hazarika, Tilak; Sarma, Dipak; Sen, B. K. (2010). "Scientometric portrait of Nayana Nanda Borthakur: a biometeorologist". *Annals of library & information studies*, v. 57, n. 1, pp. 21-32.

Ivanova, Inga A.; **Leydesdorff, Loet** (2014). "Rotational symmetry and the transformation of innovation systems in a Triple Helix of university–industry–government relations". *Technological forecasting and social change*, v. 86, pp. 143-156.
https://doi.org/10.1016/j.techfore.2013.08.022

Kademani, Basavaraj Shivappa.; Kalyane, V.; Jange, Suresh (1999). "Scientometric portrait of nobel laureate Dorothy Crowfoot Hodgkin". *Scientometrics*, v. 45, n. 2, pp. 233-250.
https://doi.org/10.1007/BF02458435

Katz, J. Sylvan; Martin, Ben R. (1997). "What is research collaboration?". *Research policy*, v. 26, n. 1.
https://doi.org/10.1016/S0048-7333(96)00917-1

Khan, Gohar-Feroz; Han Woo Park (2011). "Measuring the triple helix on the web: Longitudinal trends in the university-industry-government relationship in Korea". *Journal of the American Society for Information Science and Technology*, v. 62, n. 12, pp. 2443-2455.
https://doi.org/10.1002/asi.21595

Kim, Minjeong; Han Woo Park (2012). "Measuring Twitter-based political participation and deliberation in the South Korean context by using social network and Triple Helix indicators". *Scientometrics*, v. 90, n. 1, pp. 121-140.
https://doi.org/10.1007/s11192-011-0508-5

Koley, Susanta; Sen, B. K. (2018). "Biobibliometric portrait of the astronomer Jan Hendrik Oort". *Annals of Library and Information Studies*, v. 64, n. 4, pp. 217-228.

Kwon, Ki-Seok; Han Woo Park; So, Minho; Leydesdorff, Loet (2012). "Has globalization strengthened South Korea's national research system? National and international dynamics of the Triple Helix of scientific co-authorship relationships in South Korea". *Scientometrics*, v. 90, n. 1, pp. 163-176.
https://doi.org/10.1007/s11192-011-0512-9

Leydesdorff, Loet (2001). *A sociological theory of communication: The self-organization of the knowledge-based society*. u-Publish.com: Universal-Publishers. ISBN: 1 58112 695 6

Leydesdorff, Loet (2001). *The challenge of scientometrics: The development, measurement, and self-organization of scientific communications*. u-Publish.com: Universal-Publishers. ISBN: 1 58112 681 6

Leydesdorff, Loet (2006). *The knowledge-based economy: Modeled, measured, simulated*. u-Publish.com: Universal-Publishers. ISBN: 1 58112 937 8
https://doi.org/10.3395/reciis.v1i1.36pt

Leydesdorff, Loet (2011). "'Structuration' by intellectual organization: the configuration of knowledge in relations among structural components in networks of science". *Scientometrics*, v. 88, n. 2, pp. 499-520.
https://doi.org/10.1007/s11192-011-0397-7

Leydesdorff, Loet (2018). "Diversity and interdisciplinarity: how can one distinguish and recombine disparity, variety, and balance?". *Scientometrics*, v. 116, pp. 2113-2121.
https://doi.org/10.1007/s11192-018-2810-y

Leydesdorff, Loet (2021). *The evolutionary dynamics of discursive knowledge: Communication-theoretical perspectives on an empirical philosophy of science*. Cham: Springer Nature. ISBN: 978 3 030 59950 8
https://doi.org/10.1007/978-3-030-59951-5

Leydesdorff, Loet; **Bornmann, Lutz** (2016). "The operationalization of 'fields' as WoS subject categories (WCs) in evaluative bibliometrics: The cases of 'library and information science' and 'science & technology studies'". *Journal of the Association for Information Science and Technology*, v. 67, n. 3, pp. 707-714.
https://doi.org/10.1002/asi.23408

Leydesdorff, Loet; **Bornmann, Lutz** (2021). "Disruption indices and their calculation using web-of-science data: Indicators of historical developments or evolutionary dynamics?" *Journal of informetrics*, v. 15, n. 4, p. 101219.
https://doi.org/10.1016/j.joi.2021.101219

Leydesdorff, Loet; **Bornmann, Lutz**; **Mutz, Rüdiger; Opthof, Tobias** (2011). "Turning the tables on citation analysis one more time: Principles for comparing sets of documents". *Journal of the American Society for Information Science and technology*, v. 62, n. 7, pp. 1370-1381.
https://doi.org/10.1002/asi.21534

Leydesdorff, Loet; **Bornmann, Lutz**; **Wagner, Caroline S.** (2021). "Improved clusterings and visualizations of 11,359 journals in the JCRs 2015". *Scientometrics*, v. 126, pp. 5353-5354.
https://doi.org/10.1007/s11192-021-03938-7

Leydesdorff, Loet; **Etzkowitz, Henry** (1996). "Emergence of a Triple Helix of university-industry-government relations". *Science and public policy*, v. 23, n. 5, pp. 279-286.

Leydesdorff, Loet; **Etzkowitz, Henry** (1998). "The triple helix as a model for innovation studies". *Science and public policy*, v. 25, n. 3, pp. 195-203.

Leydesdorff Loet; Ivanova, Inga A. (2016). "'Open innovation' and 'triple helix' models of innovation: can synergy in innovation systems be measured?". *Journal of open innovation: technology, market, and complexity*, v. 2, n. 3, p. 11. *https://doi.org/10.1186/s40852-016-0039-7*

Leydesdorff, Loet; **Ivanova, Inga A.** (2021). "The measurement of 'interdisciplinarity' and 'synergy' in scientific and extra-scientific collaborations". *Journal of the Association for Information Science and Technology*, v. 72, n. 4, pp. 387-402. *https://doi.org/10.1002/asi.24416*

Leydesdorff Loet; Ivanova, Inga A.; Meyer, Martin (2019). *Synergy in innovation systems measured as redundancy in triple helix relations*. Cham: Springer handbook of science and technology indicators. ISBN: 978 3 030 02510 6

Leydesdorff, Loet; **Liwen, Vaughan** (2006). "Co-occurrence matrices and their applications in information science: Extending ACA to the Web environment". *Journal of the American Society for Information Science and technology*, v. 57, n. 12, pp. 1616-1628.
https://doi.org/10.1002/asi.20335

Leydesdorff, Loet; **Meyer, Martin** (2003). "The Triple Helix of university-industry-government relations". *Scientometrics*, v. 58, pp. 191-203.
https://doi.org/10.1023/A:1026276308287

Leydesdorff, Loet; **Meyer, Martin** (2006). "Triple Helix indicators of knowledge-based innovation systems: Introduction to the special issue". *Research policy*, v. 35, n. 10, pp. 1441-1449.
https://doi.org/10.1016/j.respol.2006.09.016

Leydesdorff, Loet; **Ràfols, Ismael** (2012). "Interactive overlays: A new method for generating global journal maps from Web of Science data". *Journal of informetrics*, v. 6, n. 2, pp. 318-332.
https://doi.org/10.1016/j.joi.2011.11.003

Leydesdorff, Loet; **Staša Milojević** (2015). "The citation impact of German sociology journals: Some problems with the use of scientometric indicators in journal and research evaluations". *Soziale Welt*, v. 66, n. 2, pp. 193-204.
https://doi.org/10.5771/0038-6073-2015-2-193

Leydesdorff, Loet; **Strand, Øivind** (2013). "The Swedish system of innovation: Regional synergies in a knowledge-based economy". *Journal of the American Society for Information Science and Technology*, v. 64, n. 9, pp. 1890-1902.
https://doi.org/10.1002/asi.22895

Leydesdorff, Loet; **Sun, Yuan** (2009). "National and international dimensions of the Triple Helix in Japan: University-industry-government versus international co-authorship relations". *Journal of the American Society for Information Science and Technology*, v. 60, n. 4, pp. 778-788.
https://doi.org/10.1002/asi.20997

Leydesdorff, Loet; **Tekles**, **Alexander**; **Bornmann, Lutz** (2021). "A proposal to revise the disruption indicator". *Profesional de la información*, v. 30, n. 1, e300121.
https://doi.org/10.3145/epi.2021.ene.21

Leydesdorff, Loet; **Wagner, Caroline S.** (2008). "International collaboration in science and the formation of a core group". *Journal of informetrics*, v. 2, n. 4, pp. 317-325.
https://doi.org/10.1016/j.joi.2008.07.003

Leydesdorff, Loet; **Wagner**, **Caroline S.**; **Bornmann, Lutz** (2019). "Interdisciplinarity as diversity in citation patterns among journals: Rao-Stirling diversity, relative variety, and the Gini coefficient". *Journal of informetrics*, v. 13, n. 1, pp. 255-269.
https://doi.org/10.1016/j.joi.2018.12.006

Leydesdorff, Loet; **Wagner, Caroline S.; Park, Han Woo; Adams, Jonathan** (2013). "International collaboration in science: The global map and the network". *arXiv preprint* arXiv:1301.0801.
https://doi.org/10.3145/epi.2013.ene.12

Leydesdorff, Loet; **Zhang, Lin; Wouters, Paul** (2023). "Trajectories and regimes in research versus knowledge evaluations: Contributions to an evolutionary theory of citation". *Profesional de la información*, v. 32, n. 1, e320103.
https://doi.org/10.3145/epi.2023.ene.03

Leydesdorff, Loet; **Zhou, Ping** (2005). "Are the contributions of China and Korea upsetting the world system of science?". *Scientometrics*, v. 63, pp. 617-630.
https://doi.org/10.1007/s11192-005-0231-1

Leydesdorff, Loet; **Zhou, Ping** (2014). "Measuring the knowledge-based economy of China in terms of synergy among technological, organizational, and geographic attributes of firms". *Scientometrics*, v. 98, pp. 1703-1719.
https://doi.org/10.1007/s11192-013-1179-1

Luhmann, Niklas (1984). *Soziale systeme: grundriss einer allgemeinen theorie*. Suhrkamp.

Luukkonen, Terttu; Persson, Olle; Sivertsen, Gunnar (1992). "Understanding patterns of international scientific collaboration". *Science, technology, & human values*, v. 17, n. 1, pp. 101-126.
https://doi.org/10.1177/016224399201700106

McGill, William J. (1954). "Multivariate information transmission". *Psychometrika*, v. 19, n. 2, pp. 97-116.
https://doi.org/10.1007/BF02289159

Merton, Robert K. (1968). "The Matthew effect in science: The reward and communication systems of science are considered". *Science*, v. 159, n. 3810, pp. 56-63.
https://doi.org/10.1126/science.159.3810.56

Orduña-Malea, Enrique (2020). "Crossing the academic ocean? Judit Bar-Ilan's oeuvre on search engines studies". *Scientometrics*, v. 123, n. 3, pp. 1317-1340.
https://doi.org/10.1007/s11192-020-03450-4

Park, Han Woo (2014). "Transition from the triple helix to N-tuple helices? An interview with Elias G. Carayannis and David FJ Campbell". *Scientometrics*, v. 99, n. 1, pp. 203-207.
https://doi.org/10.1007/s11192-013-1124-3

Park, Han Woo; **Leydesdorff, Loet** (2010). "Longitudinal trends in networks of university-industry-government relations in South Korea: The role of programmatic incentives". *Research policy*, v. 39, n. 5, pp. 640-649.
https://doi.org/10.1016/j.respol.2010.02.009

Price-de-Solla, Derek J. (1965). "Networks of scientific papers". *Science*, v. 149, n. 3683, pp. 510-515.
https://doi.org/10.1126/science.149.3683.510

Price-de-Solla, Derek J. (1970). "Citation measures of hard science, soft science, technology, and nonscience". *Communication among scientists and engineers*, v. 1, 3r22.

Purvis, Andy; Hector, Andy (2000). "Getting the measure of biodiversity". *Nature*, v. 405, n. 6783, pp. 212-219.
https://doi.org/10.1038/35012221

Ràfols, Ismael; Leydesdorff, Loet (2009). "Content-based and algorithmic classifications of journals: Perspectives on the dynamics of scientific communication and indexer effects". *Journal of the American Society for Information Science and Technology*, v. 60, n. 9, pp. 1823-1835.
https://doi.org/10.1002/asi.21086

Ràfols, Ismael; Meyer, Martin (2010). "Diversity and network coherence as indicators of interdisciplinarity: case studies in bionanoscience". *Scientometrics*, v. 82, n. 2, pp. 263-287.
https://doi.org/10.1007/s11192-009-0041-y

Sangam, S.; Savanur, Kiran; Manjunath, M. (2007). "Communication and collaborative research pattern of Sivaraj Ramaseshan: A scientometric portrait". *Scientometrics*, v. 71, n. 2, pp. 217-230.
https://doi.org/10.1007/s11192-007-1670-7

Shannon, Claude E. (1948). „A mathematical theory of communication". *Bell System technical journal*, v. 27, n. 3, pp. 379-423.
https://doi.org/10.1002/j.1538-7305.1948.tb01338.x

Stirling, Andy (1998). "On the economics and analysis of diversity". SPRU Electronic working paper.
http://www.sussex.ac.uk/Units/spru/publications/imprint/sewps/sewp28/sewp28.pdf

Stirling, Andy (2007). "A general framework for analysing diversity in science, technology and society". *Journal of the Royal Society Interface*, v. 4, n. 15, pp. 707-719.
https://doi.org/10.1098/rsif.2007.0213

Sun, Junwei; Jiang, Chunlin (2012). "Ronald Rousseaus academic thought and the academic exchange with Chinese colleague". *Journal of modern information*, v. 32, n. 3, pp. 4-15.

Thagard, Paul (2005). "Being interdisciplinary: Trading zones in cognitive science". *Interdisciplinary collaboration: An emerging cognitive science*, pp. 317-339.

Theil, Henri (1972). *Statistical decomposition analysis: With applications in the social and administrative sciences*. Amsterdam, The Netherlands: North-Holland Publishing Company.

Vellaichamy, A.; Amsan, E. (2016). "Scientometric portrait of Mike Thelwall". *Library philosophy and practice*, p. 1487.

Wagner, Caroline S.; **Leydesdorff, Loet** (2005). „Network structure, self-organization, and the growth of international collaboration in science". *Research policy*, v. 34, n. 10, pp. 1608-1618.
https://doi.org/10.1016/j.respol.2005.08.002

Wagner, Caroline S.; Whetsell, Travis A; **Leydesdorff, Loet** (2017). "Growth of international collaboration in science: revisiting six specialties". *Scientometrics*, v. 110, pp. 1633-1652.
https://doi.org/10.1007/s11192-016-2230-9

Zhang, Yi; Chen, Kaihua; Fu, Xiaolan (2019). "Scientific effects of Triple Helix interactions among research institutes, industries and universities". *Technovation*, v. 86, pp. 33-47.
https://doi.org/10.1016/j.technovation.2019.05.003

Zhou, Ping; Glänzel, Wolfgang (2010). "In-depth analysis on China's international cooperation in science". *Scientometrics*, v. 82, n. 3, pp. 597-612.
https://doi.org/10.1007/s11192-010-0174-z

Zhou, Ping; Leydesdorff, Loet (2006). "The emergence of China as a leading nation in science". *Research policy*, v. 35, n. 1, pp. 83-104.
https://doi.org/10.1016/j.respol.2005.08.006

Zhou, Ping; **Leydesdorff, Loet** (2007). "The citation impacts and citation environments of Chinese journals in mathematics". *Scientometrics*, v. 72, n. 2, pp. 185-200.
https://doi.org/10.1007/s11192-007-1713-0

Zhou, Ping; **Leydesdorff, Loet** (2011). "Fractional counting of citations in research evaluation: A cross-and interdisciplinary assessment of the Tsinghua University in Beijing". *Journal of informetrics*, v. 5, n. 3, pp. 360-368.
https://doi.org/10.1016/j.joi.2011.01.010

Zhou, Ping; Su, Xinning; Leydesdorff, Loet (2010). "A comparative study on communication structures of Chinese journals in the social sciences". *Journal of the American society for Information science and Technology*, v. 61, n. 7, pp. 1360-1376.
https://doi.org/10.1002/asi.21343

Zhou, Ping; Tijssen, Robert; Leydesdorff, Loet (2016). "University-industry collaboration in China and the USA: A bibliometric comparison". *PloS one*, v. 11, n. 11, e0165277.
https://doi.org/10.1371/journal.pone.0165277