Sleeping Beauties and their Princes in Solid Waste Research

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Sleeping beauties and their princes in solid waste research

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Abstract: A "sleeping beauty" (SB) is a paper that goes unnoticed for a long time, and then, almost suddenly, is awakened by a "prince" (PR), attracting from there on a lot of attention in terms of citations. Although there are some studies on the SB and PR phenomena in science, little research on the awakening mechanisms between them has been conducted. Based on a comprehensive dataset with more than 10000 papers published in solid waste research from 1956 to 2010, we compared three typical methods of identifying SBs, and the parameter-free criterion worked better than the average-based and quartile-based criterion in some aspects. Besides, through a case study of the top 10 in SBs, we applied three criteria to discover the candidate PRs with high citation, high co-citation, and publication time close to the awakening time. Moreover, we discussed the mechanisms involved in the SBs and PRs, which were divided into three types: the synergistic effect, leading effect, and hysteresis effect. This work develops and validates a bibliometric framework for identifying the SBs and PRs in solid waste research, to figure out the awakening mechanisms, and promote potentially valuable research in other fields.

Keywords: Bibliometric, Sleeping Beauty, Prince, Solid Waste, Awakening mechanisms, Citation

1 Introduction

Citation analysis is an increasingly popular bibliometric tool to evaluate the performance of individual scholars, countries, journals, etc. in the academic and scientific arena (Radicchi et al. 2008). Numerous indices have been developed for such analysis, including the *h*-index, *m*-quotient (Hirsch 2005), *g*-index (Egghe 2006), *A*-index (Jin B. 2006), *R*-index (Jin B. H.; Liang, L. M.; Rousseau, R.; Egghe, L. 2007), and h_w-index (Egghe;Rousseau 2008), which seek to assess the productivity of academics or countries. However, these indices have some drawbacks. First, most of them focus on the number of citations (Hirsch 2005) (Healy et al. 2011) (Ball 2005) instead of the more dynamic measure of citation record or fail to combine the number of publication and citation count data in a balanced way. Also, few indices can predict future scientific achievements (Hirsch 2007). Finally, for calculation, most of the indices require specialized software (van Eck;Waltman 2014; Comins;Leydesdorff 2016) or complex methods (Garner et al. 2018), which hinders their widespread application.

Here SB study may provide a new idea in the evaluation of institutions or individuals. An SB is a paper that goes largely unnoticed for a long period and then suddenly gets attention and a high number of citations (van Raan 2004). SBs generally increased understanding of citation dynamics in Wang's study (Wang D. S. et al. 2013). Zavrsnik compared the total number of citations of an SB with the number of papers published in the scientific area defined by the keywords given in that SB (Zikmund;Stanton 1971). According to Kokol, understanding the citation patterns of SBs may facilitate analysis of the scientific evolution of a given field (Kokol 2017). Furthermore, based on mass data analysis, van Raan suggested that SBs may gain insight into innovation delays (van Raan 2015).

In 1865, Mendel pioneered the study of SBs (Mendel 1865). The definition of such articles has changed over time. In the early 1960s, Barber (Barber 1963) tried to draw a more accurate picture of the "resistance phenomenon" in the process of scientific discovery. Later, Cole (Stephen 1970) operationally defined resistance or "delayed recognition" intending to estimate the frequency of these papers. Wyatt (Wyatt 1975) defined "premature discovery" based on the concept that such papers cannot be extended experimentally for technical reasons. More recently, van Rann (van Raan 2004) studied a number of examples following a bibliometric approach and first proposed the term "sleeping beauties", which refers to papers that go unnoticed for a long time and then, almost suddenly, attract a lot of attention.

Subsequently, many researchers have studied SBs in different disciplines using various approaches. There are three main methods for identifying SBs in science, namely, citation curve fitting (Du 2018), arbitrary thresholds setting (Garfield, 1980, van Raan, 2004), and using parameter-free index (Li 2014) (Ke et al., 2015). Each of the three methods has advantages and disadvantages.

A PR is indispensable for the awakening of an SB, because it is the fundamental piece that leads the SB to attract much more attention (Wambu;Ho 2016). There are various definitions of the rediscovering paper based on the citation network of an SB (Song 2018). However, finding a PR is a common difficulty among studies and it is not always easy to decide which paper might be considered as the PR (Li 2014). According to van Raan (van Raan 2004), the PR is the first paper to quote the SB (self-citing excluded) before a "citation boom." Braun (Braun et al. 2010) sought the candidate PR among those that first cited the SB papers. The co-citations and spontaneous citations should also be taken into account.

The generation of solid waste has increased dramatically in the world, owing largely to the rapid development and expansion of the economy. The management of solid waste is critical and becoming a challenge for some countries in the world (Wang M. X. et al. 2020) (Obiora et al. 2021). Based on the case study of solid waste, this study aims to: 1) examine the defects of the three typical methods used for distinguishing the SBs; 2) discover the candidate PRs and 3) explore the potential mechanism between the SBs and

PRs. This contribution will further validate and detect early signs of the awakening of SBs.

2 Materials and methods

2.1 Datasets

For the bibliometric analysis, the online version of the Science Citation Index Expanded (SCIE) and Social Science Citation Index (SSCI) bibliographic databases were searched with the keywords ("solid waste*") as the topic for all years of publication between 1956 and 2010. Thus, 2010 is the last year for publications having in total a ten-year time span until 2020. All records were manually checked to exclude unrelated topics. A total of 10361 papers related to this topic were included in the following analysis.

2.2 Methods

2.2.1 Average-based criterion

In the last century, Garfield (Garfield 1980) (Garfield 1989b) (Garfield 1989a) (Garfield 1990) proposed that several parameters should be used to determine true delayed recognition. Later, Glanzel et al. (Glanzel W. et al. 2003) began the systematic and quantitative study of this phenomenon by describing a paper published in 1980 as an example. In 2004, Garfield and Glanzel (Glanzel W.; Garfield, E. 2004) defined papers with delayed recognition as those that were initially rarely cited but then became highly cited over time.

Soon after, the term “sleeping beauty” was proposed by van Raan (van Raan 2004), who summarized the three classical parameters that distinguish SBs:

(1) Length of sleep (s), or the duration of the sleeping period;

(2) Depth of sleep (C_s), where publications receive at most one citation per year on average (deep sleep) or between one and two citations per year on average (less deep sleep);

(3) Awakening intensity (C_w), or the number of citations per year over four years following the sleeping period.

As noted by van Rann (van Raan 2004), different results could be obtained by assigning different values to these parameters. In general, if these three parameters were lower, more SBs would be identified (van Raan 2004). Thus, the number of SBs depends on these variables.

2.2.2 Quartile-based criterion

The quartile-based criterion was originated in 2010 when Costas et al. (Costas et al. 2010) put forward a methodology to classify papers according to the “durability” of their citations. For each document, he identified the year after publication in which the paper received for the first time at least 50% of its citations (Year50%). For all papers of the same year of publication, he calculated the percentile 25 and 75 of the distribution function of the value of the new indicator “P25” and “P75”. Though comparing the relative value for

these three indicators, the general criterion for the classification of papers is as follows (Costas et al. 2010):

(1) Flashes in the pan: $Year50\% < P25$

(2) Normal papers: $P25 \le Year50\% \le P75$ (1)

(3) Delayed papers: $Year50\% > P75$

Besides, other authors also observed a similar phenomenon. Van Dalen (van Dalen 2005) and Henkens called the third type as “sleeping beauties”. Aversa (Aversa 1985) found two general patterns: “delayed rise-slow decline,” which coincides with the delayed type. According to this criterion, 25% of papers could be considered delayed papers.

2.2.3 Parameter-free criterion

To overcome the heavy dependence on identification methods based on arbitrary threshold parameters for the sleeping time and the number of citations, in 2015, Ke et al. (Ke et al. 2015) created the beauty coefficient index, denoted as *B*, to quantify how much a given paper can be considered an SB. There is a continuous spectrum of delayed recognition where both the hibernation period and the awakening intensity are taken into account. The *B* for a given paper is based on the comparison between its citation history and a reference line l_t, which is described by the equation:

$$l_t = \frac{c_{t_m} - c_0}{t_m} \cdot t + c_0 \quad (3)$$

where t is the age of the paper, C_t is the number of citations received in the ith year after publication, and C_0 is the number of citations received in the year of its publication. The paper receives the maximum number C_{tm} of yearly citations at time t_m. The straight line l_t connects the points (0, C_0) and (t_m, C_{tm}) in the time-citation plane.

The beauty coefficient B is defined as:

$$B = \sum_{t=0}^{t_m} \frac{\frac{c_{t_m} - c_0}{t_m} \cdot t + c_0 - c_t}{\max\{1, c_t\}} \quad (4)$$

This criterion reveals that the SB phenomenon is not exceptional, and emphasizes a complex feature of citation dynamics. Similar to van Raan' (van Raan 2004) criterion, although it examines how the citation curve reaches its peak, it fails to explain how it decreases thereafter.

2.2.4 Criteria for uncovering PRs

However, how to identify the rediscovering paper from the citation networks of the SB remains controversial (Song 2018). To discover the PRs that awake SBs, the citation network of an SB, with co-citations and spontaneous citations to the SB being considered, Braun (Braun, Glänzel, & Schubert, 2010) proposed that candidates for being a PR meet the following three criteria:

(1) Be published near the year when the SB began to attract a lot of citations;

(2) Be highly cited papers themselves;

(3) Receive many co-citations with the SB.

As a result, this procedure gives the rediscovering papers that have high spontaneity, a large co-citation number, and was published no later than the recognized time.

3 Results and discussion

3.1 Procedure to find the Sleeping Beauties

As described in section 2.2, three types of criteria, namely the average-based, quartile-based, and parameter-free criterion were used to identify SBs. The advantages and disadvantages were also discussed here.

3.1.1 Average-based criterion

Table 1 presents a typical example of the results of the number of papers (N) of our measurements for s = 10 (sleeping period: 1956-2010), for both "deep sleep" ($C_s \in [0,10)$) and "less deep sleep" ($C_s \in [10,20]$) cases. We set the five awakening intensity classes c_W = [10,20), [20,30), [30,40), [40,50), [>=50].

For instance, after a "deep sleep" of 10 years, we could find that 340 papers were cited an average of 10 to 20 times per one during the next four years (awakening period). By comparing the N of the "deep sleep" cases with those of the "less deep sleep" cases for the same c_W values between 10 and 20, it is clear that the "deep sleep" cases with 340 papers were more than the "less deep sleep" cases with 97 papers. On the other hand, with the increase of c_W, the N of the "deep sleep" cases were a little lower than those of the "less deep

sleep" cases, which means the probability of awakening after deep sleep is smaller for a longer sleeping period. Moreover, when we changed the values of s, C_s, and c_W, the N would change with them, which suggests the dependence of N on these variables. In total, approximately 5.37% of the papers were found as SBs from 1956 to 2010.

3.1.2 Quartile-based criterion

In **Fig. 1**, we present a general description of papers, considering different bibliometric properties of papers classified in the three durability classes (equation (1)). From the figure, we observe that the increasing trends for flashes in the pan and delayed papers were almost in sync and much slower than the normal ones. According to this criterion, the proportion of delayed papers namely SBs accounted for 18.4 % of all papers published from 1956 to 2010, much higher than that identified with the average-based criterion. Thus, such a high percentage makes the phenomenon of SB normal rather than rare.

A further important interesting observation is that the distribution of papers among the three types does not reach a 25-50-25 distribution (Flashes in the pan accounted for 20.3%, and Normal accounted for 61.3%). The reason for this is that we used the "threshold equals", which tends to favor normal documents.

3.1.3 Parameter-free criterion

Fig. 2 shows the survival distribution functions of B for all papers in the datasets. To further investigate the distribution of B in this field, we divided the papers into three disjoint subsets with high, medium, and low values of B. Here, the boundaries of 2.5 and 7.0 were the percentiles equal to one-third and two-thirds of B for 10361 papers, respectively. According to Ke (Ke et al. 2015), B increases with both the length of the sleeping period and the awakening intensity, namely papers with higher B values are more likely to be SBs. From the figure, we could find a dramatic increase in the number of papers with high B values, which maintained the dominant role in these three subsets since 1996 and reached the peak in 2001 (almost 51.3%). On the whole, the papers with high B values accounted for 34.6% from 1956 to 2010. Simultaneously, the number of papers with low B values decreased gradually, and there was a slow growth in the number of papers with medium B values.

In contrast to previous methods, it does not rely on the arbitrary choice of age or citation thresholds, and this fact puts the papers with extreme values of B as a common phenomenon from the macroscopic point of view. Meanwhile, the result implicitly suggests that the SB phenomenon could be in principle described via a simple mechanism with statistical significance. Based on these criteria, we found that the SBs are not exceptional outlines, but simply the extreme cases in very heterogeneous but otherwise continuous distributions (Ke et al. 2015).

However, the major drawback of this method is that there is no clear demarcation value that allows us to separate SBs from "normal" papers, which means that SBs occur on a wide and continuous range (Ke et al. 2015).

Then, **Table 2** listed basic information about the top 10 SB papers in statistics and mathematics, respectively. It was interesting to note that the number of authors in these papers was very small, and half of the papers were done by a single author, which means there is less collaboration among authors in the SB phenomenon. Also, we could see that the top 10 SBs identified by *B* were all landmark publications of *Engineering* (SB1, SB4, SB5, SB9, SB10); *Environmental Sciences & Ecology* (SB4, SB9, SB10); *Agriculture; Biotechnology & Applied Microbiology; Energy & Fuels* (SB3, SB6). According to Hawkins (Hawkins 1973), research quality is often based on a journal's impact, which is of major importance because it explains both the journal's reputation and its relevance to society. The SBs were published in highly renowned journals in the fields of *Business (SB2:5.266 (IF, namely impact factor)); Agricultural engineering (SB3:3.551, SB6:7.539); Chemistry, Applied (SB7:5.825); Multidisciplinary Sciences (SB8:9.412); Engineering Environmental (SB9:9.083, SB10:7.864).* And all the journals are the best in their fields. A particularly interesting fact is that 80% of the top 10 papers were "waken up" after 15 years, and the longest length of sleep was almost 30 years (the SB2 sleep from 1992 to 2015). Finally, the whole citation histories of the top 10 papers were shown by the graphs.

3.2 Steps for identifying the prince (PR)

The exercise undertook demonstrates that finding the PRs of the SBs is a far more complicated endeavor than what the extant literature has been positing (Aurora 2016). Summing up, the procedure involves 4 main steps : (1) to extract the list of articles that cited the SB and were published near the year in which the SB began to awake; (2) to extract all those articles with a large number of citations; (3) to analyze the co-citations and leave out the relatively lower value for co-citations/Citation; and (4) to reduce the subsequent analysis to the PRs with a higher value for co-citations/Citation, taking into account the sleep/waking moments of the SB. (Aurora 2016) According to the above procedure, the 10 candidate PR papers were found and the results were shown in **Table 3**. Here, several basic bibliometric indicators of PRs for the top 10 SBs were demonstrated, including the title, author, journal, and co-citations/Citation.

Usually, the authors must recognize the importance of the sleeping paper and have profound impacts on it to bring a great number of citations to the SB (Song 2018). For these 10 SB papers, except for the PR1 that shared the same authors with SB1, all the other authors were the new ones who rediscovered the sleeping paper. And the number of authors was generally larger than those for SBs. The majority of PRs were published in well-renowned journals with equal or higher impact factors than the journal where the corresponding SB

was published, which help “free” the SB from her wasted unnoticed sleep. For instance, SB7 published in *CATALYSIS TODAY* was awakened by PR7 published in *ENERGY & ENVIRONMENTAL SCIENCE* with *IF* of 30.289, this indicated that editors and contributors of these journals were relatively far-sighted and pioneering, being able to accept and/or understand the overlooked contributions of SBs (Huang 2015). It was also interesting to point that about 50% of the PRs were published in journals whose main research areas did not coincide with the research area of the journal where the SB was published. The SB5 was in the categories of *Engineering; Public Administration* and *Urban Studies*, while the PR5 was in the category of *Environmental Sciences & Ecology*. The SB8 and PR8 were in the category of *Science & Technology - Other Topics* and *Biotechnology & Applied Microbiology* respectively. This, to a large extent, reflects the multidisciplinary characteristics of research in solid waste studies (Aurora 2016).

3.3 Mechanisms involved in SBs and PRs

The key scientific issue of the study toward SBs is to figure out the mechanisms for awakening (Wang J.; Ma, F.; Chen, M.; Rao, Y. 2012) (Fang 2015). Here, we further explored the relationships between SBs and PRs in solid waste studies between 1956 and 2010. By drawing the citation distribution map for the top 10 SBs and their PRs, the results could be divided into three types: synergistic effect, leading effect, and hysteresis effect.

The synergistic effect holds approximately 40% in the top 10 papers with high *B* values. As shown in **Fig. 3**, it demonstrated the typical pattern of synergistic effect. After awakening, both the SBs and PRs followed parallel citation trends, similar to the symbiosis applied in biology, where two organisms live together for mutual benefit and cannot survive without one or the other, which is a highly developed relationship between organisms. In this type, both the SBs and PRs could help each other to increase the citations. In other words, their co-citation accounted for the high rate of the total citations of SBs and PRs. In 1974, the SB5 introduced an equity trade-off model for solid waste management and was used by Chang NB in PR5 to support the insight that a good management plan for environmental risk reduction and control was the key to the success in modern solid waste management systems. In this part, the PR5 needed the theoretical basis of SB5, and the SB5 can't "live" without the optimization from PR5. Nearly 50% of the value of co-citation/citation testified the symbiotic relationship between them. And SB4/PR4, SB6/PR6, SB10/PR10 all belonged to this type.

It could be observed that the leading effect was common in the samples, with 40%, including SB-dominated type (10%) or PR-dominated type (30%). As could be seen from **Fig. 4a**, the PRs were always under the shadow of their respective SBs during their citation history, and then there was significant exponential growth for the citations of SBs after the revival. For instance, the SB1 proposed a grey linear programming (GLP) model for the planning of

solid waste management systems under uncertainty, and according to its algorithms, the PR1 developed and showed the superiority of the interval-parameter fuzzy-robust programming (IFRP) model. Meanwhile, they shared the same academic team and 59 references. In this relationship, the SB1 was the basic research and played the leading role, PR1 and many other papers were the extension and application of the SB1.

Oppositely, SBs and PRs switched their leading role, as shown in **Fig. 4b**. As a review of the channels of distribution, the SB2 discussed the major alternative channels to recycle solid waste and identifies some of the marketing problems in this procedure. After sleeping for 29 years, it was awakened by the PR2, a highly cited paper, which raised a fairly new concept in logistics based on the case study of distribution (SB2). He said, “they are important and involve significant cost and time, neither of which should be ignored in any well-implemented reverse-logistics system”. Thus, due to the emergence of PR2, the SB2 had drawn wide attention. This phenomenon could be explained by the ecological parasitic effect, namely, the parasite always depends on its host to grow and reproduce, and brings a strong or weak effect to the host. Moreover, this could be used to interpret the higher citations of PRs than their SBs, which we discussed before.

Finally, **Fig. 5** showed the third one - a hysteresis effect. This was a relatively less popular type (20%), with two subtypes – PR-lagged type or SB-lagged type, which was not presented in this study. **Fig. 5**. indicated that the

SBs rose to their peaks ahead of the PRs, and the PRs reached the peaks several years after the first citation. This phenomenon is suggestive of an obvious lag effect in ecological predation. The change in quantity for the preying ones usually causes a change in the numbers of the predator, and which is relatively backward. For example, the SB3 and PR3 were both reviews of literature, focusing on the anaerobic digestion of solid substrates. Thus, authors may choose to cite only one of SB3 and PR3, which leads to a competitive relationship between them. From the figure, it could be seen that they hold a similar growth trend, and the PR3 lagged behind SB3 a little because of the later publication year than SB3.

In general, for an SB and PR, there is always more than one mechanism at work, and the graphs for the citation histories of the SBs and their PRs are good tools to find out the SBs' awakening secret. The study of the SB and PRs has been considered "a rather useful and instructive model in studying the mechanisms of scientific information flow through citations." (Braun et al. 2010) and is likely to contribute to the understanding of citation dynamics in general.

4 Conclusions

In the present study, we compared three existing criteria for finding SBs, and the parameter-free criterion proved that the papers with extreme values of B could be a common phenomenon, because they did not rely on arbitrary

thresholds placed on the SBs. And these findings show that a paper with fewer authors, more diverse fields, more popular journals, and longer "sleeping" is more likely to be the SB. Meanwhile, based on the three criteria proposed by Braun, we identified the candidate PRs for the top 10 SBs, and the characteristics for PRs were also discussed. Like SBs, their PRs are usually published in multidisciplinary fields and journals with high *IF*, while the difference is that PRs have more authors. Moreover, the formation of the synergistic effect, leading effect, and hysteresis effect constituted the dominant types of relationship identified between PRs and SBs. The discovery of SBs, and their PRs, in the solid waste field, as well as the analysis of the reasons for their emergence/awakening, provides us with a distinct and rich overview of the evolution of the literature in the area, offering a better understanding of the reasons for their late recognition and why the "information sleeps". Therefore, it is imperative for us to spare no effort to avoid delayed recognition and to detect SBs as early as possible, in order to promote potentially valuable but not readily accepted solid waste research.

Declarations

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Author contribution: Zheng Tang was the major contributor in writing the manuscript, including conceived and designed the research method, collected and analyzed the data and so on. All authors read and approved the final manuscript.

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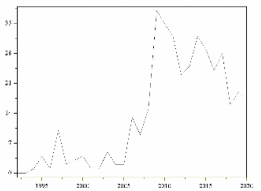
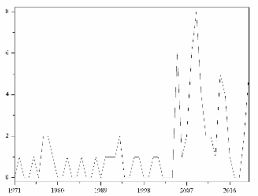
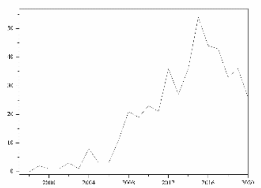
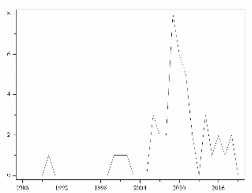
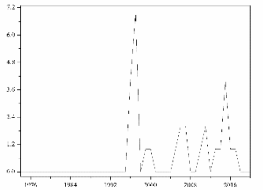
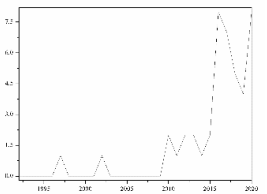
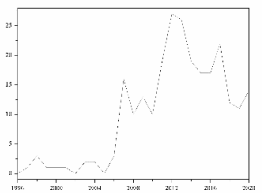
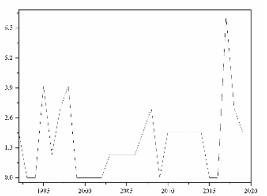
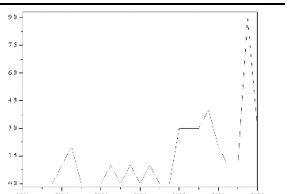
Table 1 SBs calculated based on average-based criterion.

C_w	$C_s \in [0,10)$	%	$C_s \in [10,20]$	%
[10,20)	340	3.28	97	0.94
[20,30)	21	0.20	59	0.57
[30,40)	3	0.03	30	0.29
[40,50)	1	0.01	6	0.06
[>=50]	0	0.00	0	0.00
Total	365	3.52	192	1.85

Table 2 The top 10 SB papers in solid waste.

	Title	Authors (Year of publication)	Journal	Awakening year (length of sleep)	Total citations	Graph
SB1	A gray linear-programming approach for municipal solid-waste management planning under uncertainty	Huang, GH; Baetz, BW; Patry, GG (1992)	*CIVIL ENGINEERING SYSTEMS*	2007 (15)	391	
SB2	Recycling solid wastes - channels-of-distribution problem	Zikmund, WG; Stanton, WJ (1971)	*JOURNAL OF MARKETING*	2000 (29)	68	
SB3	Anaerobic digestion of biomass for methane production: A review	Gunaseelan, VN (1997)	*BIOMASS & BIOENERGY*	2012 (15)	452	
SB4	Long-term planning for solid-waste management	Wilson, DC (1985)	*WASTE MANAGEMENT & RESEARCH*	2006 (21)	41	

	Title	Authors (Year of publication)	Journal	Awakening year (length of sleep)	Total citations	Graph
SB5	Solid waste management - equity trade-off models	Fuertes, LA; Hudson, JF; Marks, DH (1974)	*JOURNAL OF THE URBAN PLANNING & DEVELOPMENT DIVISION-ASCE*	1996 (22)	29	
SB6	Relationships between organic-carbon and total organic-matter in municipal solid-wastes and city refuse composts	Jimenez, EI; Garcia, VP (1992)	*BIORESOURCE TECHNOLOGY*	2015 (23)	44	
SB7	Production of high grade fuels and chemicals from catalytic pyrolysis of biomass	Bridgwater, AV (1996)	*CATALYSIS TODAY*	2009 (13)	247	
SB8	Polymer recycling - opportunities and limitations	Stein, RS (1992)	*PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA*	1998 (6)	47	
SB9	Plastic incineration versus recycling: A comparison of energy and landfill cost savings	Lea, WR (1996)	*JOURNAL OF HAZARDOUS MATERIALS*	2012 (16)	35	

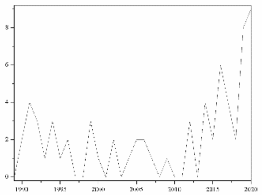
	Title	Authors (Year of publication)	Journal	Awakening year (length of sleep)	Total citations	Graph
SB10	Acid digestion for sediments, sludges, soils, and solid-wastes - a proposed alternative to epa sw 846 method 3050	Kimbrough, DE; Wakakuwa, JR (1989)	*ENVIRONMENTAL SCIENCE & TECHNOLOGY*	2015 (26)	67	

Table 3 The candidate PR papers in solid waste.

	Title	Authors (Year of publication)	Journal	Citations	Co-citations	Co-citaitons/Citations (%)
PR1	IFRP: A hybrid interval-parameter fuzzy robust programming approach for waste management planning under uncertainty	Nie, XH; Huang, GH; Li, YP; Liu, L (2007)	*JOURNAL OF ENVIRONMENTAL MANAGEMENT*	131	59	45.04
PR2	Developing a theory of reverse logistics	Dowlatshahi, S (2000)	*INTERFACES*	327	6	1.83
PR3	Anaerobic digestion of solid organic substrates in batch mode: An overview relating to methane yields and experimental procedures	Raposo, F; De la Rubia, MA; Fernandez-Cegri, V; Borja, R (2012)	*RENEWABLE & SUSTAINABLE ENERGY REVIEWS*	253	14	5.53
PR4	Environmental management under uncertainty - An internal-parameter two-stage chance-constrained mixed integer linear programming method	Li, YP; Huang, GH; Baetz, BW (2006)	*ENVIRONMENTAL ENGINEERING SCIENCE*	37	7	18.92
PR5	Comparative risk analysis for metropolitan solid waste management systems	Chang, NB; Wang, SF (1996)	*ENVIRONMENTAL MANAGEMENT*	26	13	50.00
PR6	Optimization of solid state anaerobic digestion of the OFMSW by digestate recirculation: A new approach	Michele, P; Giuliana, D; Carlo, M; Sergio, S; Fabrizio, A (2015)	*WASTE MANAGEMENT*	23	1	4.35
PR7	The critical role of heterogeneous catalysis in lignocellulosic biomass conversion	Lin, YC; Huber, GW (2009)	*ENERGY & ENVIRONMENTAL SCIENCE*	289	13	4.50

	Title	Authors (Year of publication)	Journal	Citations	Co-citations	Co-citaitons/Citations (%)
PR8	Molecular cloning, sequencing and expression in Escherichia coli of the poly(3-hydroxyalkanoate) synthesis genes from Alcaligenes latus DSM1124	Genser, KF; Renner, G; Schwab, H (1998)	*JOURNAL OF BIOTECHNOLOGY*	10	1	10.00
PR9	Recycling and recovery of post-consumer plastic solid waste in a european context	Brems, A; Baeyens, J; Dewil, R (2012)	*THERMAL SCIENCE*	57	3	5.26
PR10	Phosphorus Leaching from Agricultural Soils of the Delmarva Peninsula, USA	Kleinman, PJA; Church, C; Saporito, LS; McGrath, JM; Reiter, MS; Allen, AL; Tingle, S; Binford, GD; Han, K; Joern, BC (2015)	*JOURNAL OF ENVIRONMENTAL QUALITY*	32	1	3.13

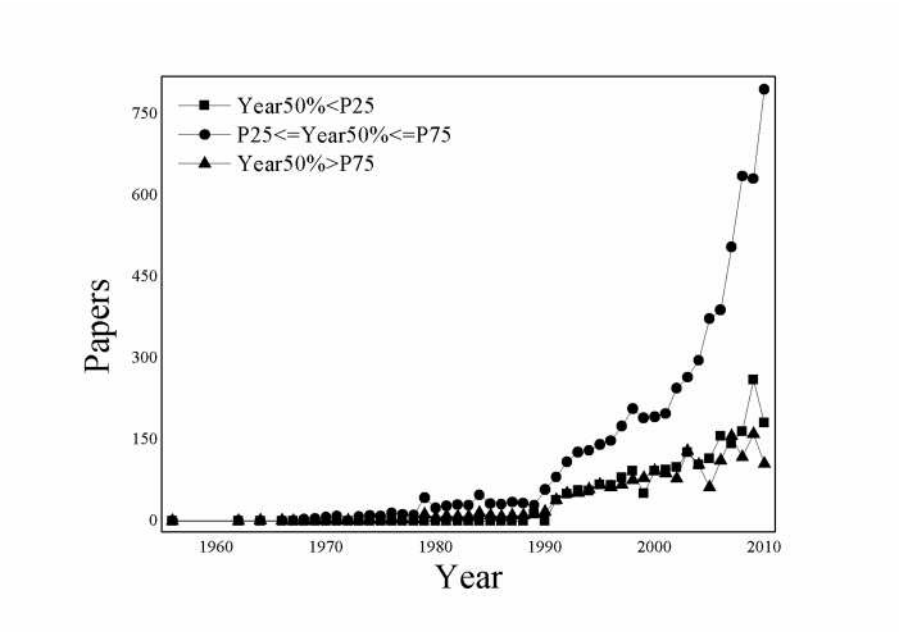


Fig. 1 Distribution of papers calculated by quartile-based criterion.

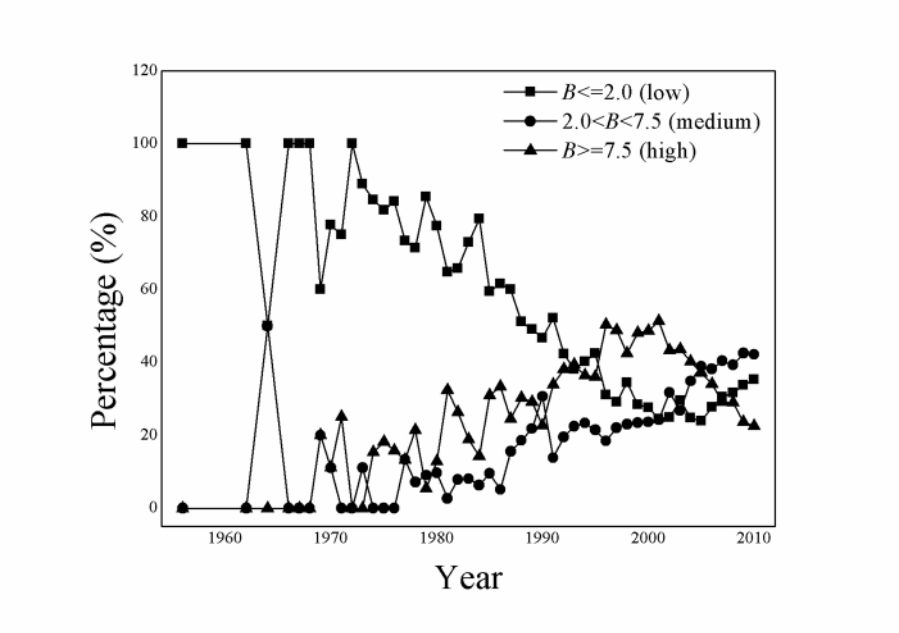


Fig. 2 Distribution of papers calculated by parameter-based criterion.

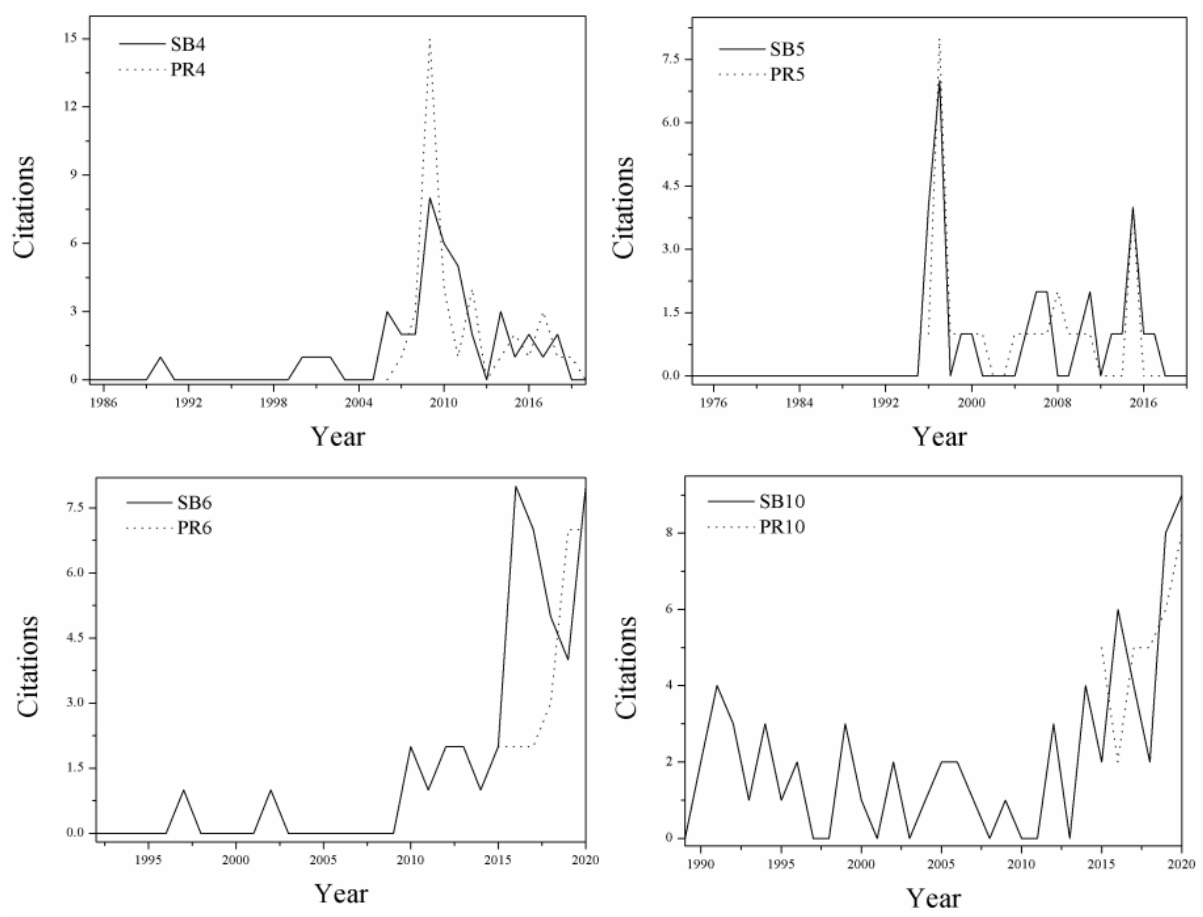


Fig. 3 Synergistic effect between SBs and PRs.

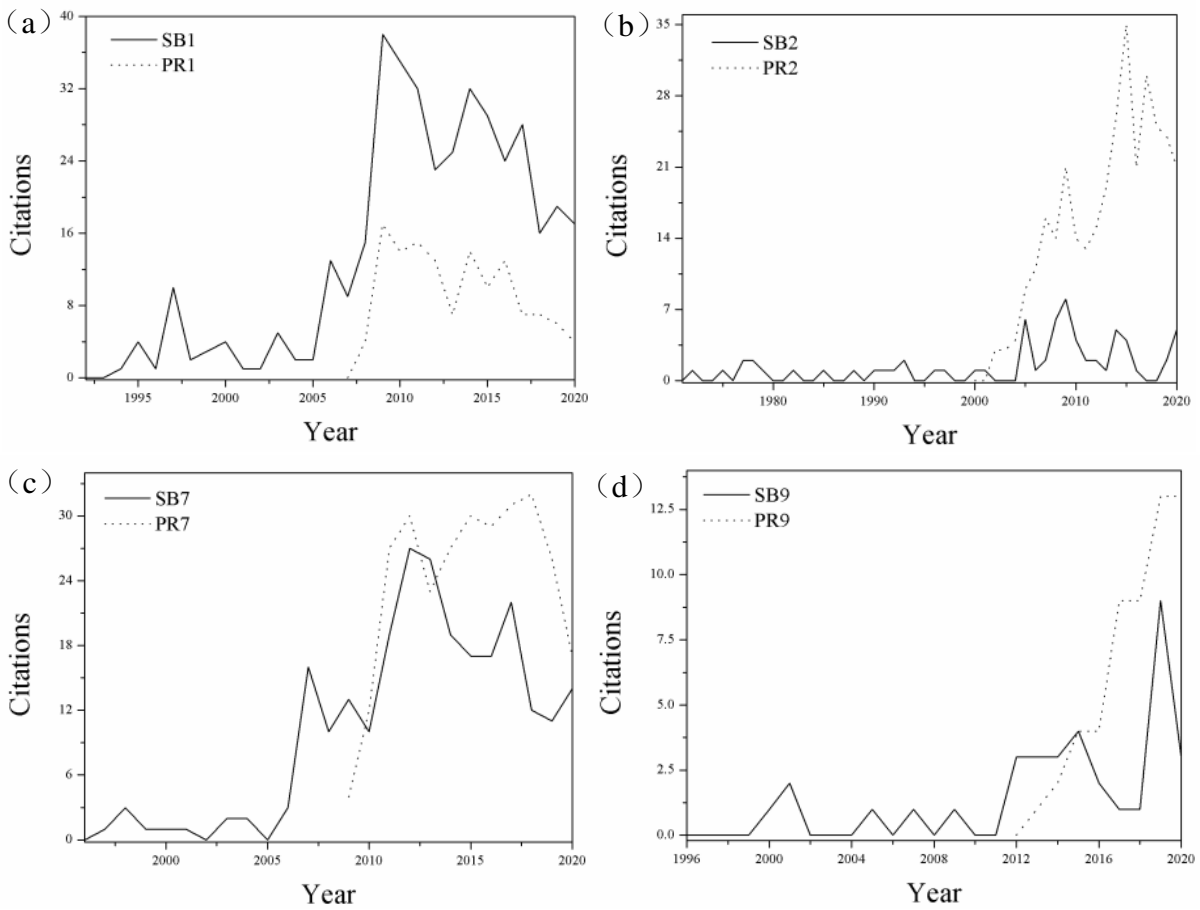


Fig. 4 Leading effect between SBs and PRs. (a) SB-dominated type; (b,c,d) PR-dominated type.

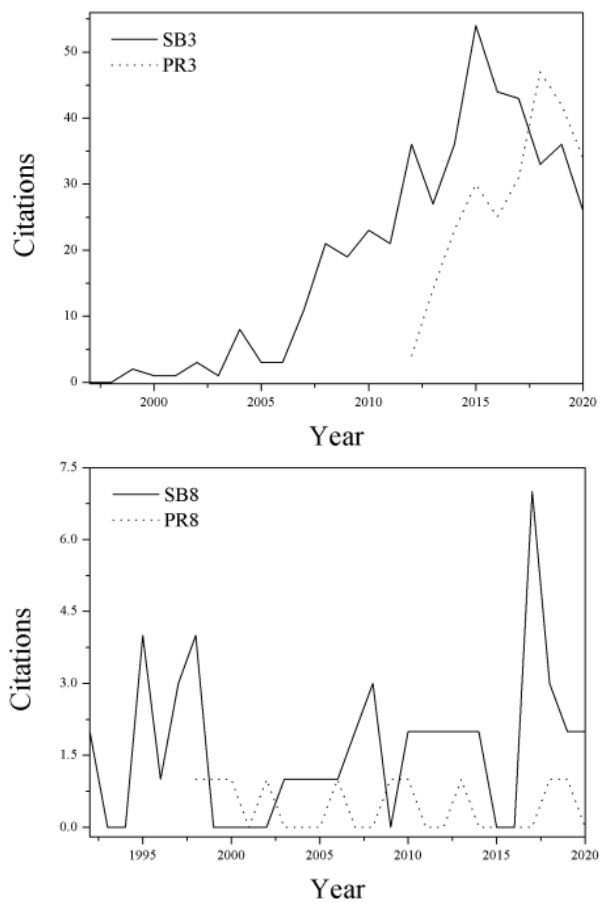


Fig. 5 Hysteresis effect between SBs and PRs.

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