The citation culture
Wouters, P.F.

Citation for published version (APA):
Wouters, P. F. (1999). The citation culture

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: http://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.

UvA-DARE is a service provided by the library of the University of Amsterdam (http://dare.uva.nl)
Chapter 5

The signs of science

we need to know more than is yet known about what references and citations do and do not represent if citation analysis is to provide further understanding of how science is socially and cognitively organized and practised. (Merton 1977)

5.1 Introduction

citation, citations N COUNT; a rather formal word. A citation is
1. an official document or speech which praises a person for having done something brave or special.
2. a summons to appear before a court or law; a legal term.
3. a quotation from a book or other piece of writing.
cite, cites, citing, cited V+O; IF+PREP; a rather formal word.
1. If you cite something,
   (a) you mention it, especially as an example or as proof of what you are saying.
   (b) you quote from a written work, especially as an example or a proof of what you are saying.
2. To cite someone or something in a legal action means to officially mention or name them.
3. To cite someone means
   (a) to officially summon them to appear before a court of law.
   (b) to officially praise them in a report or other document because they have done something brave or special.

(Wil 1991, 243)

This chapter deconstructs a number of exemplary scientometric indicators in order to better understand the nature (or even better, culture) of the citation. The creators of the SCI, Eugene Garfield and Irving Sher, with the help of Joshua Lederberg and Gordon Allen, translated the juridical concept of citation indexing into a new one, applicable to science (chapter 2). This translation entailed the
creation of a new sign (chapter 1). The resulting new symbolic possibilities stimulated quantitative research within the sociology of science and, furthermore, its exploration according to the science of science tradition (chapter 4). This was only the beginning. The citation has also become the basic building block of aggregate indicators of science. Together they form an intricate maze of signs that provide for a new representation of the sciences. This citation representation is partly, but crucially, influenced by the way the citation is produced. Of course, it is also determined by the distribution of references in the processed literature. To gauge the precise relationships between these two domains it is necessary to probe more deeply into the way the new signs of science have been, and are being, constructed.

5.2 Basic properties of the citation

All citations are equal. (Smith 1981, 89)

Chapter 1 and chapter 2 showed that the production of citation indexes leads to the transformation of the reference into the corresponding citation. Thereby a new quality is created: “All citations are equal” (Smith 1981). This handy property enables the addition of citations of a given article resulting in the so-called citation frequency. The sign citation does not share this feature with its parent, the sign reference. References are not equal: they have different functions in the citing text, and their underlying motives are various. It is true, indeed, that the reference can be added too: this gives the number of references of the citing article. But this is its least important feature. The reference functions predominantly as a pointer. With the citation it is the other way around. This sign can function both as a pointer and as a number, but it is the latter function, not the former, that carries the day. Moreover, in as much as the citation points, it does this on behalf of its role as the fundamental unit of the citation frequency. Pointing is, in other words, auxiliary to counting in citation analysis. Not only can the citation frequency of a certain article be measured, this frequency can also be summed up at higher levels of aggregation to obtain the citation frequencies of research groups, institutions, journals, countries and even of disciplines and scholarly fields in their entirety.

Consequently, the citation seems to have a universal quality. Since the citation frequency of every article can be measured — if it is not cited, it can be given a citation frequency of zero — any article can be compared with any other, independently of the subjects involved. Should the citation not have this property, a citation index would be less useful as a bibliographic instrument:

Another reason why citation indexes are so useful is their independence of topic-descriptors, avoiding the imprecision and inconsistency inherent in the use of such topic-descriptors. (Egghe & Rousseau 1990)

In other words, citations play the role of language: “citations serve as a kind of language system, which can be deployed with greater flexibility than ordinary
language” (Small & Griffith 1974). The role of the citation might also be compared with that of money, especially if the evaluative use of scientometrics is taken into account\(^1\). Whenever the value of an article is expressed in its citation frequency, the citation is the unit of a “currency of science”.

The central point here is the universality, created by a double move. First, the local context of the citing document is removed, in the inversion of reference to citation. Then the local context of the indexing institution is deleted, albeit imperfectly. Citation analysis is in this respect like standardization (Latour & Woolgar 1986): “Nothing so marks the creation of universality as the dropping of local subscripts from units that are nevertheless produced in different physical locales” (O’Connell 1993). The citation shares still another property with the signs of money and language: it can only function properly in the midst of other citations. Therefore, citations need to be mass-produced. A lone citation does not make sense. It derives its function mainly from its relations to other citations. In other words, it is self-referential. Whether one tries to map science or to evaluate it, one needs large amounts of citation data. This self-referential property is well-known of indicators like the I.Q. (Woolgar 1991). Luukkonen (1990) signals this as follows: “The basic problem ... is that the ’quality’ of work is measured by citations, an indicator to be tested and studied. This implies a circular reasoning: the most highly cited scientists are highly cited because they are highly cited (=good as indicated by the high citation counts)”. From this study’s point of view, however, this is less a problem than part of the explanation of the power and culture of citation.

As mentioned, a lone citation does not really count. Seen as an isolated sign, it does not possess many qualities. Virtually the only one is its fundamental equality to all other citations. The more interesting qualities arise from the interactions among citations and those between citations and references. A great deal of scientometric and bibliometric research has dealt with both uncovering and realizing the potential patterns in the citation and reference networks in science.

One of these topics is the way in which “time” is present in the citation representation of science. Again and again, SCI’s inventor Eugene Garfield has stressed an important advantage of the citation index as a search tool: if one takes a publication one can track its “descendents” (the articles which cite the publication at hand) up to the present. Whereas snowballing by using references only leads one further and further into the past (because with this method one can only track its “ancestors”—the articles which have been cited by the publication at hand), a citation index brings one closer to the present. The reason for this is obvious: a citing text is necessarily more recent than the related cited one\(^2\). Because of this, the citation frequency of an article is a dynamic property. It may change at any moment. This raises two points. First, citation networks are always drawn with hindsight; they are by definition a posteriori. Second, existing

---

\(^1\)At the Technical University of Ankara, the relationship between the citation frequency and money is even more direct. Researchers there earn money by receiving citations. When one has collected a specific number of citations, one is even entitled to become a professor (Prof. Ali Azun, Ankara Technical University, personal communication June 1997, Jerusalem).

\(^2\)The only exception to this rule are references to forthcoming publications.
CHAPTER 5. THE SIGNS OF SCIENCE

literature that gives rise to citations is implicitly treated as a static whole. Any article, no matter how old, can in principle be cited. Time is visible in the citation network, not as something that flows nor as movement of the network, but as the absence of certain citation relations (more recent articles not getting citations from older ones), in other words as structure. This is the consequence of the constraints the reference imposes on the citation.

From the early days of the SCI citations and references have been turned into composite indicators. Many of these indicators are supposed to capture a specific phenomenon in science. They represent the reality of science. Raw citation counts dominated scientometrics in the early years. In the course of the seventies and eighties, they gave way to more refined science indicators. For example, the chance of being cited varies greatly per scientific specialty, depending on its size and specific citing culture. To deal with this, several types of normalized citation frequencies were constructed. Citation counts were created at various levels of aggregation, from the individual researcher to countries. To gauge the citation frequencies of scientific journals, the so-called Impact Factor was developed. It is seen as a measure of a journal’s impact on subsequent scientific work. Inspired by the concept of bibliographic coupling in the field of library science, the co-citation frequency was almost simultaneously and independently created by the American Henry Small (Small 1973) and the Russian Irina Marshakova (Marshakova 1973). This indicator records the number of times two publications are cited together, and is taken to be a measure of similarity of the two publications. Because one can measure co-citations at several levels of aggregation, the co-citation frequency can be used as a building block of scientific cartography: the mapping of science on the basis of co-citation links between publications (Starchild et al. 1981, Garfield et al. 1984). Before these more complex indicators can be deconstructed, however, it is useful to take a closer look at the symbolic processes underlying the production of the citation itself.

5.3 Producing citations

It seems to me a great pity to waste a good technical term by using the words citation and reference interchangeably. I, therefore, propose and adopt the convention that if Paper R contains a bibliographic footnote using and describing Paper C, then R contains a reference to C, and C has a citation from R. (Price 1970)

Chapter 1 argued that the signs reference and citation should be distinguished from each other. The latter results from the former. This means that the semiosis of the citation is a second order operation with respect to creation of the reference by the scientist. Various interventions in this production process will therefore influence the outcome. First of all, it is impossible to process every reference made in every scientific article in the world. Hence, a selection must be made, which of course influences the resulting index. The way in which the index represents the literature is also modified by the way in which the reference represents the cited text. For most purposes, it really does matter whether or not the citation is a
“correct” inversion of the reference: the semiosis of the citation is a precision operation. The actors involved, whether scientometricians or indexers, usually relate to this in terms of the identity of reference and citation: they should be the same. From the point of view developed in this study, it is not a matter of identity but of “true inversion”, meaning an inversion without any other changes. No operation can proceed perfectly\(^3\), and this is also true of citation indexing. Therefore, the indexes inevitably contain numerous “mistakes”. How serious these are depends on the use of the index. Any citation analysis that processes large amounts of citation data will end up with considerable numbers of these “errors”, which cannot easily be identified as all citations look alike. As a consequence there is continuous discussion on the “quality of the data” in the field of scientometrics. In fact, three different topics have been discussed under this one heading: the quality of the reference (section 5.3.1, page 111); the selection of the reference (section 5.3.2, page 112); and the integrity of the inversion (section 5.3.3, page 114).

5.3.1 The quality of the reference

It is possible for the scientist to refer to nonexistent texts, simply by typing the wrong page number or year or making a spelling mistake. Whenever this happens the citation indexer may create a citation as an attribute of a non-existing text. The act of making the citation is reflexive towards the giving of reference. Therefore, it is possible to refer back to the reference in order to detect or correct some of these mistakes. For example, Moed and Vriens (1989) found recurring problems by comparing different databases:

Roughly speaking, for every ten citations containing a bibliographic description identical to that of a particular article in our target dataset, one citation shows some kind of discrepancy. (...) the major part of the discrepancies in our dataset are due to errors or variations in cited references that are present in the original text.

These authors attribute this deficiency in the references to certain habits of citing authors: “we found evidence that copying references from other articles may be a cause of the observed multiplication of errors in cited references”. Another, major, problem is the spelling of journal names. At ISI, journal titles were often found to be abbreviated differently: “there were more than 100,000 different abbreviations for the 12,000 individual journal titles cited in the 3-month sample. Inconsistency was made worse by inaccuracy” (Garfield 1970). Correction of these inconsistencies and inaccuracies has even become common practice wherever they can be traced by comparing citations, for example where journal titles show discrepancies:

ISI’s data unification process can result in a more accurate presentation of the citation data than presented in the original journal literature. (SCI Guidelines for Interpretation of ISI Citation Data)

\(^3\)With the possible exception of digital copying.
This underlines the recursive character of the production of citations. If the reference were the citation, ISI’s correction procedure would be sheer magic. It is precisely because of the difference between them, that comparison and correction is possible.

### 5.3.2 The selection of reference

Selecting references entails choosing which type of textual references to process as references, as well as deciding which journals to use as sources. With the exception of the *Arts & Humanities Citation Index*, which also processes implicit references, only clearly identifiable footnotes and endnotes have been used. This practice has been criticized by Hicks & Potter (1991) who, as only few authors have done, have paid special attention to “the way a citation is produced as a separable, countable category” (Hicks & Potter 1991). In their opinion, the SCI does not give a fair representation of the texts by which scientists have been influenced. It only makes use of a thin slice of potential references. Since every text should be seen as “suspended in the network of all others”, any part of any text is some kind of unacknowledged reference. These implicit references are not utilized by the SCI. At the same time, the most recent, informal, influences on scientists are not transformed into footnotes at all, for the very reason they are informal. Therefore:

> Citations form just a thin but glistening band, sandwiched between the rock of eons. And it is this highly limited, highly unrepresentative, yet alluringly available band of rock that the ISI has fetishized and turned into a highly desirable and marketable commodity. (Hicks & Potter 1991)

Hicks & Potter (1991) have still identified the reference with the citation. Seen from the perspective of this study, their geological metaphor needs to be interpreted in a somewhat different way. Actually, these authors are not so much discussing the geology of citation itself as the geology of its raw materials, the references. ISI’s digging up of only a part of the potential reference source is not a coincidence but a consequence of the constraints imposed by the economics of the production of citations. Hicks & Potter’s (1991) metaphor is now especially relevant, digging up the other types of references would simply be too expensive:

> The production of citation indexes is more involved than is generally appreciated. Although citation indexing eliminates the expensive intellectual effort associated with traditional subject-term indexing ... producing a citation index of appreciable size is a massive materials-handling and information-processing job. (Garfield 1979)

Therefore, to be converted into a scientometric citation, a reference must exist in an easily recognizable format. The mass production of citations depends on standardization. Not coincidentally, Garfield, Price and their colleagues frequently campaigned for changes in referencing policies of scientific journals. They tried for example to convince editors of the increasing importance of the
reference format: “Now that citation indexing has become a valuable and integral part of the computerized systems by which we gain access both to archival and to research-front literature, the editorial practices regarding citations may need re-examination” (de Solla Price 1969). This was not only in the interest of the researchers but of the indexers as well. The more standardized the reference, the less costly the production of the citation.

The second aspect of the selection of raw materials for the mass production of citations is the choice of source journals. This has been given considerable attention by the creators of the SCI. It should be remembered, however, that they were building a bibliographic tool, i.e. a search instrument. To function as a search tool for science as a whole, the SCI should be able to provide access to scientific literature in its entirety. This does not mean, however, that it should contain a representative sample of the literature, in fact the reverse is true. The distribution of characteristics is often skewed in bibliometric and scientometric research. According to “Bradford’s law” (Bradford 1953), the distribution of scientific literature in a certain domain spreads out over many neighboring fields. Garfield (1979) compares this phenomenon with a comet having a concentrated core as well as a widely fanned out tail. “Garfield’s law” expands on this by stating that the tails of disciplines show a very significant degree of overlap. This means that there should be a core of all scientific literature, which receives the majority of references. It is Garfield’s explanation of why the science citation index is technically feasible in the first place.

So large is the overlap between disciplines, in fact, that the core literature for all scientific disciplines involves a group of no more than 1000 journals, and may involve as few as 500. In less abstract terms, this means that a good general science library that covers the core literature of all disciplines need not have any more journals than a good special library that covers all the literature of a single discipline. (Garfield 1979)

Griffith et al. (1977) report on the same issue:

The quality and quantity of the scientific literature ‘channelizes’. That is, a combination of social and probabilistic mechanisms ensure that most documents of a discipline, and nearly all documents of the highest quality, appear in a limited number of resources (i.e., journals in the natural sciences). Furthermore, all such important sources may be readily recognized and ranked along this quality dimension by citation counts. (Griffith et al. 1977).

Interestingly, this ranking is used to gauge the selection of source journals:

The selection of journals is crucial to the success of a citation index because it is a strategy quite different from the usual librarian’s striving for completeness. ... the ultimate test is provided as feedback from the journals which are cited by such sources. For many years the list of cited journals has provided a higher criticism of which journals to accept and which to reject as sources. (...) Thus although it [the SCI] is derived from only $\frac{1}{10}$ of the source papers, it includes $\frac{1}{4}$ of the cited literature. (Price 1979)
CHAPTER 5. THE SIGNS OF SCIENCE

Not surprisingly, the citation quickly evolved into an indicator of the appropriateness of the selection of source journals in the production of citation indexes: “The list of most frequently cited journals shows that the SCI has been remarkably successful in covering all ‘significant’ and ‘important’ journals, insofar as citation counts can be considered a reliable measure of ‘importance’ and ‘significance’” (Garfield 1970). This relates to the self-referential property of the citation index. Often, the use of citation indicators can only be justified in terms of these indicators themselves. For example, the question of whether the Science Citation Index uses the appropriate source journals has been answered by measuring the citation frequency of these source journals. This is a different criterion from the representativity of the source journals, if only because ISI selects the highly cited journals, while most journals are, by definition, less cited. In fact, if the citation index is to function well as a bibliographic search tool, its selection of source journals should not be a representative sample of science as a whole.

5.3.3 The integrity of the inversion

The third topic is the inversion process itself. This process may create additional problems, which didn’t exist with the original reference. Again, the import of irregularities depends on the later use of the citation. Nevertheless, scientometricians have repeatedly compiled long lists of problems encountered while using ISI’s data. Most of these arise because of the inherent uncertainty of the inversion. Smith (1981) gives an overview of the difficulties that may be created by the production process of the citation. They vary from ISI’s policy of registering only the first authors of cited texts, and the regular occurrence of identical names for different entities, to field-dependent differences and plain errors. Egghe & Rousseau (1990) give some additional problems, like the incompleteness of the ISI database, the dominance of English as a scientific language, and the American and sex bias. Cleaning up the data sets is common practice at scientometric indicator and research centres like the Centre for Science and Technology Studies in Leiden, CHI (the company led by patent analysis pioneer Francis Narin) in New Jersey and the Information and Scientometrics Research Unit of the Library of the Hungarian Academy of Sciences in Budapest. Given the labour intensive character of recursively improving the quality of the data, these databases are jealously guarded by their proprietors: access to clean data is a strategic opportunity in scientometrics.

Errors may have quite unpredictable consequences because of the skewed distributions of bibliometric data: “citation data are extremely positively skewed. (...) This leads us to a second point. The presence of errors is a nontrivial factor. (...) a random error rate of nearly 20% was probably present in our study (...) How does the ‘signal’ retained vary with the type of citation count performed? If one loses 33% of an individual’s citations (co-authored ones), fails to cull 5% co-author self-citations, and adds a substantial random error rate, what does one have? Automated search may surrender 25% of the sample. Further, estimates of the proportion of ‘perfunctory’ citations in high-energy physics range from about 20 per cent to 40 per cent. The value of a citation count is thus a complex function of the type of counting and the intended uses; it cannot be taken at simple face value” (Porter 1977).
5.4 Building upon the citation

Raw citation counts have given rise to more sophisticated indicators. They are too numerous to discuss individually, and neither would it be particularly enlightening. There is, however, a pattern in the construction of aggregate indicators. First, all are built on the basis of varying combinations of the signs reference and citation. The way these two dimensions (the citing and the cited) are combined determines important characteristics of the resulting indicator network. Second, they all aim to represent reality in a more reliable way than competing indicators, or qualitative descriptions. Third, they build upon one another.

5.4.1 The Price Index

The Price Index is the simplest aggregate scientometric indicator.

\[
PI = \frac{N_1}{N_2} \times 100
\]

where \(N_1\) is the number of references which were published less than six years before the citing publication, and \(N_2\) is the total number of references.

In other words, as it represents the number of references to the last (five) years as a percentage of the total number of references, the Price Index is a measure of the recency of the literature cited by a given article, journal or specialty. The Price Index can be computed for a given year (Price 1970), or alternatively on a per article basis (Moed 1989). The Price Index is a pure reference indicator. It is indicative of citing behaviour. Whereas Derek de Solla Price took this measure as a rather straightforward means of distinguishing the hard sciences from “the soft ones and from non-science” (Price 1970), more recent research has shown this to be an oversimplification (Moed 1989). Although the index itself is very simple, its sociological interpretation is not without ambiguities.

5.4.2 The Impact Factor

Garfield’s Impact Factor is an example of a purely citation based indicator.

\[
IF = \frac{C}{N}
\]

where

- \(C\) is the number of citations a scientific journal begets in a certain period,
- \(N\) is the number of publications in that journal during the same period.

In most cases a period of two years is standard as the basis for the computation. This seems to have been decided, rather casually, on the basis of a general impression of the first raw data on the variation of citation frequencies with the age distribution of cited articles (Interview with Irv Sher, Philadelphia, 1992).
**Citation Reports.** Of course, different choices of time periods give rise to different values of the Impact Factor. This is the main reason that, simple as the indicator may seem, the application and construction of the Impact Factor has been a point of contention in scientometrics (Moed & van Leeuwen 1995). The Impact Factor was created to be able to compare scientific journals with respect to the probability of their being cited, and is an example of normalization:

Citation frequency is, of course, a function of many variables besides scientific merit. ... Citation frequency of a journal is thus a function not only of the scientific significance of the material it publishes ... but also of the amount of material it publishes. (Garfield 1955)

A journal’s Impact Factor represents the probability of being cited if one is published in that journal. Therefore, this index creates the citation frequency as a property of the journal. The division by the number of citable items enables one to compare journals with widely differing publication frequencies or number of articles.

### 5.4.3 Co-citation clustering

Co-citation analysis (Small 1973, Marshakova 1973) was the principal instrument in ISI’s Atlas of Science project (Starchild et al. 1981, Garfield et al. 1984), and is widely used by scientometricians (Some of the early studies are discussed in Small & Sweeney 1985b, Small & Sweeney 1985a, Small & Griffith 1974, Small 1977, Hicks 1987, Hicks 1988, Franklin 1988, Sullivan, White & Barboni 1977, Edge 1977, Oberski 1988, Oberski 1987). Its basic entity, the co-citation frequency, is the number of times a certain pair of cited articles are cited together.

\[
CCF_{i,j} = C_i \cup C_j
\]

where \(C_i\) is the set of citations to article \(i\).

Basically, the co-citation frequency is the common occurrence of two references in a bibliography of a citing article. In this sense, the co-citation frequency is built upon the reference. As Egghe & Rousseau (1990) show, the co-citation frequency can also be computed by taking both sets of citations of the two cited articles and measuring the intersection of these two sets. In this case, the co-citation frequency is the number of citations in this intersection. Like the citation frequency, the co-citation frequency is a number. It is supposed to be a measure as well as proof of the existence of a symmetrical relationship between two cited documents.

The whole point of co-citation clustering is its capacity to create maps of science that can be interpreted by scientists, science managers or science policy officials. This does not mean that co-citation clustering straightforwardly reflects the true nature of science. The reality of co-citation clusters is, on the contrary, the very consequence of built-in inconsistencies and “ontological gerrymandering” (Woolgar 1991). In this respect, co-citation clustering tells an important part of
The co-citation procedure starts with the selection of highly cited articles (Small & Griffith (1974) mention a threshold of 10 citations). This list of highly cited articles is then inverted to retrieve the articles that cited them. This results in a selection of lists of highly cited references and their citing articles from all references processed by the citation index. Then the number of times each pair of these references co-occurs in a bibliography is counted, and the whole file is resorted. This gives a long list of pairs of cited articles and their co-citation frequency. The citing articles are subsequently discarded. This transforms the co-citation frequency from the number of times two independent, asymmetrical citing relations appear together, into a measure of a new symmetrical relationship between the two cited documents. With this inversion, we have entered a new domain, the world of co-citation.

The next step is a clustering procedure. Small & Griffith (1974) use the so-called “single link clustering” in which one co-citation link between documents is enough to include that document in one cluster:

Typically, a cluster would be generated by selecting a starting document and listing all other documents with which is was paired. These new documents were added to the cluster, and the documents they were with were, in turn, added to the cluster. This process was continued until all documents which were linked with those already in the cluster had been identified. (Small & Griffith 1974)

Thresholds are used in this clustering procedure to distinguish different levels of co-citation relationships. At the lowest level, all clusters are connected. Setting the threshold higher, gives the effect of “zooming in” on a certain cluster. The rest is a matter of display. Lists of clusters can be generated; alternatively, multi-dimensional scaling techniques can be used to generate maps. Recently, ISI even developed software to enable the drawing of these maps with desktop computers.

Thus, several translation steps are involved in co-citation clustering, the inversion of the co-occurrence of two references into the co-citation frequency being the crucial one. It should be stressed that this inversion is essentially the same one we have already seen in citation analysis. Again, a consequence of citing behaviour is transformed into a property of cited documents. Depending on the algorithm used, this inversion can be performed as an early or a late step in the computations. If Small & Griffith’s (1974) procedure is used, inversion is one of the later steps. If we compute the co-citation frequency according to Egghe & Rousseau (1990), we start with the inversion. The end result is the same.

The science maps based on this co-citation clustering have been seen as the “true reflection” of the structure of science. Small & Griffith (1974) report that the clusters they found consist of:

- a relatively small group of co-cited documents and a larger group of documents, each of which cites two or more of the co-cited documents. These two sets of documents are believed to form the basis of a research area, a group
of researchers engaged in the joint exploration of related problems. (Small & Griffith 1974)

This interpretation is based on the assumption that the existence of a co-citation link indicates some kind of transfer of information or cognitive relatedness: “We will assume that the larger the number of co-citing documents, the greater the amount of transfer and exchange of information within and between specialties”. Small & Griffith (1974) found a large number of biomedical documents, forming one overwhelming cluster. It was interpreted in a realist way: “These findings reflect, on the one hand, the strong representation of the biomedical literature in the SCI and, on the other, the pervasive use of certain standard methods and procedures in biomedical work”. Subsequently, they broke up this big cluster into 65 smaller ones by raising the threshold and, at the same time, removed the linking method papers before reclustering: “It appears, from these data, that the biomedical literature presents a structure that is quite different from the physical sciences; and, secondly, that some comparatively simple strategies can be employed to break up clusters which are pulled together by papers whose use is not confined to a single specialty”.

The “ontological gerrymandering” of co-citation analysis (and citation analysis at large) is clearly demonstrated in the reflexive improvement of the technique developed in 1985. What was seen by Small & Griffith (1974) as the reflection of the reality of science, is perceived by Small & Sweeney (1985b) and Small & Sweeney (1985a) as a methodological problem to be solved by changing the method of co-citation clustering. Far from being the result of science itself, the large biomedical cluster appears to be an artefact of the clustering method: “it proved difficult to obtain an adequate representation for fields such as mathematics and engineering within the broad mix of biological and physical sciences. ... These facts pointed strongly to a biomedical over-representation in the annual SCI clusters”. This is caused by the higher referencing level in biomedical literature: “in two ways: 1: by increasing the number and proportion of biomedical items which fall in the highly cited range ... and 2: by increasing the strength and intensity of co-citation links formed among biomedical items”. After the methodological improvement, the goal of clustering is stated as follows:

A reasonable objective seems to be that the number of clusters for a field be proportional to its source article representation in the data base. If five percent of the articles in a year are in mathematics, then five percent of the clusters should be on mathematical topics. The problem becomes how to compensate for the differences in referencing patterns from field to field and indeed from article to article.

Interestingly enough, the epistemological status of ISI’s journal selection is fundamentally altered in this argument. While Garfield and his colleagues never pretended to draw a representative sample of science, the proportionate composition of the source journals of ISI is used by Small & Sweeney (1985b) and Small & Sweeney (1985a) as a baseline for the validation of the clustering technique in precisely such a way.
Small & Sweeney (1985b) and Small & Sweeney (1985a) reach their goal in two steps. In the first place, they introduce fractional citation counting to get a “better” representation of the disciplinary structure of science. This is a subtle but important innovation: no longer does every citation count as being equal. Instead, every citing article is assigned a value of 1 to be evenly distributed over its references. Every reference, therefore, gets the value of the inverse of the number of references.

The important concept here is that all source items have but a single unit of credit to dispense. (Small & Sweeney 1985b, Small & Sweeney 1985a)

The reference transfers this value to its corresponding citation. The citation frequency is then the sum of these different fractions. The citation frequency is based on: the equality of the citing articles; the relative equality of the references of a given citing article; and the possibility of adding the resulting values of the citations. Where the propensity of the citation to be added was based on the citation itself as the fundamental unit (with a value of 1), fractional citation counting takes as its fundamental unit the citing article (which can distribute a value of 1 over its references). The co-citation frequency is thus a hybrid entity composed of the citing and the cited context. Since it relates the number of citations of cited articles to the number of references per citing article, it diminishes the domination of highly citing fields, like biomedicine, in co-citation based science maps.

The second innovation introduced in co-citation clustering is the replacement of fixed thresholds as cluster criteria by variable ones. Small & Sweeney (1985b) and Small & Sweeney (1985a) note that the single-link clustering algorithm, with its low demand of only one link, leads to “chaining”, the creation of large macro-clusters. Whereas Small & Griffith (1974) saw this as proof of the interconnectedness of science, Small & Sweeney (1985b) and Small & Sweeney (1985a) speak of it as a technical problem in need of repair by a new cluster-defining technique. Instead of a fixed threshold, a fixed upper value of the cluster size is defined with a reference to Price’s invisible colleges (Price 1965a). Whenever this cluster size is exceeded, the clustering procedure starts anew with a higher threshold. This has the advantage that it “also prevents the formation of amorphous macro-clusters by chaining, which is a problem with the single-link method when low co-citation levels are used”.

In the selection of highly cited items, fractional citation counting is used, but integral counts are the basis of the co-citation frequency itself. The authors, wishing to use the two methods independently, even stress this point: “it is important to note that we did not use the fractional counts for the normalization of integer co-citation counts. The fractional counts were used only in the initial selection of cited items”.

It is therefore possible to go one step further and apply an analogous fractioning procedure to co-citation counts. And this is indeed what the authors speculate on:

fractional co-citation would assign a single unit of co-citing strength to each citing paper among all the pairs of references cited by that paper. If, for
example, a paper cited “n” highly cited items, each pair of cited items would be assigned a weighted co-citation equal to \( \frac{1}{2n(n-1)} \). The summation of all such fractional co-citation contributions from all citing papers for a given pair of cited items would constitute the fractional co-citation count for that cited pair. (Small & Sweeney 1985b, Small & Sweeney 1985a)

The authors expect that using this would further extend the “balanced” representation of science, “to structural features of the fields as well, e.g. the density of links”. With these fractional co-citation counts, the fractioning is only over the number of highly cited references, not over all of them. Its resulting fractional co-citation frequency is based neither on the equality of all citations (as the integral co-citation and citation frequency are) nor on the equality of the citing articles (as the fractional citation frequency is). It is founded on: the relative equality of all articles that co-cite at least one pair of highly cited articles; the relative equality of the co-occurrences of highly cited references in a given bibliography; and the possibility to add the resulting fractional co-citation counts. This last capacity is neither based on the citation nor on the citing article, but on the article-that-co-cites-highly-cited-articles as the fundamental unit with a value of 1. This further increases the relative inequalities of citations.

In summary, co-citation analysis liberally juxtaposes elementary references and citations to build an intricate network of complex indicators and relations. Its central feature is the inversion of the co-occurrence of pairs of references to the co-citation of pairs of cited documents. This inversion creates additional degrees of freedom of the sign cocitation frequency and gives the technique the flexibility to develop on the basis of its own results and shortcomings. This leads to the ingenious construction of ever more elaborate and abstract indicators, in which the citing and the cited dimensions of scientific literature are freely mixed. In no way is there a fixed boundary between the hard reality of scientific literature and its representation in co-citation clusters. On the contrary, this boundary is the result of the application and interpretation of the technique.

The method seems to develop itself in two ways. First by extension through analogy, as we have seen with the expanding domain of fractional citation counting. Second through deconstruction of parts of the foundations of co-citation analysis and reconstruction of new ones without the method becoming invalid in the eyes of its proponents. In other words, it is not the consistency of the method that gives it its power (Ziman 1979) but the very lack of it. Co-citation analysis flourishes on its contradictions. What was an interesting part of the reality of science in 1974, was an artefact of deficiencies of the technique in 1985. This improvement resulted in a reconstruction of the boundary between reality and representation. Of course, this process is infinite.

This improved co-citation clustering has indeed been deconstructed by another indicator building group. First these authors reiterate the existing state of affairs from their point of view:

Main problems in co-citation analysis concern the occurrence of artefacts (clusters are mainly the result of the applied technique), the stability of cluster structure (continuity over time) and the interpretation of the results. ...
Both decisions (setting threshold levels for citations and for co-citations) may influence the clustering results, and the rather arbitrary way in which these decisions are made, leads to severe problems of interpretation and evaluation of the results. (van Raan 1988)

The authors wonder whether the cluster structure created by the existing co-citation methods is indeed the most appropriate one when compared to other possible cluster structures:

"What criteria can be used to specify thresholds in a less arbitrary way? A choice can be made experimentally by looking at the interpretability of the resulting cluster structures, or by applying some a priori criteria. At the present moment there is no definite method for either of these approaches.

These authors find that, contrary to Small’s experiences, journals do not discriminate very well between clusters, whereas indexing terms do. They conclude that a much lower threshold than normally applied should be used; they did not find macroclusters with low thresholds, “at least as long as it is not very low”. Getting relatively stable results, the authors are able to reconstruct a new boundary between their results and their method: “This means that, at least in our case, the cluster structure is not a simple artefact of the technique”.

Part and parcel of this reconstruction of the difference between the reality of science and the artefacts of the method of co-citation analysis is the subsequent validation of the results. From the very beginning of co-citation analysis the clusters have been related to the perception of the citing scientist. This is no coincidence, for the origin of the co-citation frequency is the co-occurrence of two references in a bibliography, put there by an author of a scientific article. Small & Griffith (1974) saw the appearance of clusters as proof of the existence of specialties or invisible colleges. More precisely, they thought that co-citation clustering recreated the structure of science as scientists themselves perceive this structure:

Assuming that highly-cited items reflect the significant concepts in a field, then co-citation associations between them represent clusters of related concepts. (...) Using the cluster maps in this volume, one can, at a glance, trace the historical developments of an area of research, and identify the papers that made the most important contribution to its growth. (Starchild et al. 1981)

At the same time, co-citation clusters are supposedly robust, thanks to the selection of highly cited documents from the wealth of scarcely cited texts as starting point of the technique: “The idiosyncratic citation behavior of some scientific authors is likely to have little effect upon the patterns being observed here”. This robustness has been underlined by validation of the co-citation clusters, which has been done in various ways. Again, these methods exemplify important traits of scientometrics at large. The most direct way is noting, as Braam et al. (1988) have done, that earlier problems have disappeared, e.g. the macro-clusters that plagued Small and his colleagues. Secondly, the resulting clusters can be compared with other, independent criteria, like the title words in the citing or in the
cited articles of the cluster (Small & Griffith 1974). Thirdly, scientific experts in the fields involved may be asked to take a look at the maps of their specialties and give their own post-hoc interpretation. Of course, these validation methods frequently give only partial validation. In its turn this may give rise to a new round of partial deconstruction of the technique in order to get rid of the pertinent problems. The essentially partial and contradictory nature of these validation procedures is illustrated by Sullivan et al. (1977). In writing the history of a specialty, they found that co-citational history and plain historical intellectual history did not produce inconsistent results, but they did convey some different kinds of information. In particular, the cocitation analyses provided dramatic indicators of shifts in the dominant foci of intellectual activity that were harder to see in the data we used to write our intellectual history (Sullivan et al. 1977).

Combined, the two methods proved “very useful”: “Cluster formation, in other words, signals the broad acceptance of a line of research, not necessarily its actual inception ... The assumption that articles which define clusters share in the research tradition of the clusters would therefore seem justified”. However, articles were missed by co-citation because they cited only one document in a cluster, or they cited none of the articles.

Ironically, the more important, salient, and accepted the problem focus, perhaps the less accurate the retrieval of papers via co-citation.

The articles retrieved were, according to these authors, neither representative, nor a constant fraction of the literature of the specialty. Therefore, co-citation analysis was an unreliable measure of the growth of a specialty, because the thresholds are held constant, while the focus of the intellectual activity influences both the size of the clusters and the fraction of the total population. The claim that “the mechanical production of co-citation analyses of scientific literature will lay bare the structure of science” is in the view of Sullivan et al. (1977) “too strong”.

A well-known critique of co-citation analysis has been written by Edge (1977). “If”, argues Edge (1977), “co-citation analysis gives an objective account of science, then why bother to ‘validate’ co-citation studies? Differences between the co-citation results and those derived from other sources are only to be expected, and it is implicit in the method that preference, in such cases, should be given to the former over the latter. However, co-citation practitioners lose nerve at this point: not only do they undertake validations, but they allow errors.

Interestingly, Edge’s critique is based on the same assumptions with respect to the citation as co-citation analysis itself, especially his supposition of consistency. Edge tries to keep co-citationers to their own words, criticizing them for not being courageous enough. What is seen by the co-citation analists as an argument for the reality of their clusters, is seen by Edge (1977) as a reason to strongly oppose this type of research.
This deconstruction of co-citation analysis confirms the conclusion that the validation procedures contribute to the reality of co-citation clusters, but for different reasons. The construction of co-citation indicators is neither simple nor self-evident. Validation has been shown to occur not to a robust reality “out there”. Rather, this is done by comparing one representation of science with another, often an expert’s. This results in a mixture of difference and sameness. By stressing either one or the other, different realities are constructed by juxtaposing these different representations. It also enables the incorporation of criticism in new techniques and methods, at the same time defying the ultimate grounding of co-citation analysis on some definite truth as well as evading a kind of definite critique that mistakes scientometric ideology for its practice.

The difference between different representations is illustrated by the representation of time in co-citation analysis. As noted, time is represented in the citation network by missing citation relations. Co-citation analysis, if applied in writing the history of a specialty, must be carried out for several consecutive years. However, there is no given continuity between these years, contrary to more traditional ways of writing the history of science. After all, every co-citation map is drawn with hindsight from a given citing year to all previous, potentially cited, literature. Even if the clusters were to directly represent the perception of scientists, the writing of a co-citational history would be like a flickering series of flashbacks in a movie without there necessarily being any connection in between. Although co-citation analysis is justified as giving the collective perception of the active research community, it is at the same time supposed to enable the continuous history of science. In the first statement the origin of the co-citation frequency is stressed, whereas in the latter the robustness of the resulting clusters is emphasized. Co-citation analysis results in successive slices of frozen science literature, each slice being reconstructed with hindsight from a given year. In a way, co-citation analysis therefore results in a successive, but discontinuous, series of histories of science. No wonder clusters are prone to sudden changes (Sullivan et al. 1977) that may or may not be found in other historical representations.

5.4.4 Normalization procedures

Normalization is a very common procedure in citation analysis and scientometrics. Several ways of normalizing citation counts have already been shown in this study. Garfield’s Impact Factor is one example, normalizing the citation counts to the number of publications; Small’s fractional citation counting is another one, relating it to the number of references of citing articles. A different type of normalization is used to relate the citation to itself. Then, the raw citation counts are divided by some weighted average number of citations in a certain domain. These methods stick strictly to the perspective of the cited article and see citations something like raindrops falling on articles. In environments where it often rains citations, articles tend to have a higher citation frequency than in other environments. Hence, if one wishes to distinguish articles on an individual basis, it makes sense to construct relative citation counts by dividing the raw number of citations by the number of background citations. The resulting indicators are
especially relevant to evaluations of scientific articles, journals, institutions and scientists. As has been shown, they also play a minor role in co-citation analysis: if the analyst wishes to normalize the co-citation counts to the number of citations of each cited article, the so-called Jaccard coefficient — the co-citation counts of a pair of cited articles divided by the root of the product of the citation counts of each article — is one of the possible indicators.

\[
J_{C_{i,j}} = \frac{CCF_{i,j}}{\sqrt{C_i \times C_j}} = \frac{C_i \cup C_j}{\sqrt{C_i \times C_j}}
\]  

(5.4)

In other words, the Jaccard coefficient shows the co-citation frequency, the intersection of the two sets of citations, as related to the two sets. Co-citation is then seen as contingent upon citation, the last providing the background for the first.

The citation frequency is, however, not the only possible frame of reference for normalization. This procedure may also be applied to other dimensions in science. The most frequently used are the number of citing publications, the number of co-authors of the cited articles, and the number of references of the citing texts. The normalization of the citation frequency to the number of co-authors is especially relevant if authors are to be evaluated on the basis of the citation frequency of their work, or if these citation counts are to be used at a higher level of aggregation like in comparisons between countries. In both cases the question arises of how to divide the citation counts over multiple authors of cited articles. Within scientometrics, three solutions of this problem have been devised (Egghe & Rousseau 1990): counting only the first author; giving each author the full credit; and dividing the credit over the authors. The first method is based on the fact that the SCI used to list only the first authors. The second method is based on the notion that all citations are equal, as well as all authors, and transfers the whole citation frequency from the cited article to every author. The third and last one is based on the equality of all co-authoring authors in dividing the citation frequency of their article among themselves. Consequently, citations are not identical anymore; they are less valuable if they refer to articles with multiple authors. This is an example of fractional counting from the cited perspective, whereas Small’s fractional counting is an example of fractioning from the citing perspective.

The coupling of the cited and the citing dimension plays an important role in the methodology developed in the Science Indicators Project of the United States National Science Foundation. In this policy context, the Influence Methodology has been developed by the group of the physicist Francis Narin (Narin 1976). This method starts with the construction of a citation matrix in which the value of cell \(i\) is determined by the number of references \(i\) gives to \(j\).
where $C^i_j$ is the number of references unit $i$ gives to unit $j$. The units can be any “publishing entity”, like articles, authors, journals or specialties. Narin (1976)’s method is based on the following assumption:

The citation matrix is the fundamental unit which contains the information describing the flow of influence among units. ... The citation matrix may be thought of as an ‘input output’ matrix with the medium of exchange being the citation. Each unit gives out references and receives citations; it is above average if it has a ‘positive citation balance’, i.e. receives more than it gives out. (Narin 1976)

In this matrix reference and citation are identical, signalling the transfer of a fundamental unit of “influence”. Every unit in the matrix starts with an individual weight that is obtained by dividing the number of citations it gets from all other units in the matrix by the number of references it gives to all other units.

$$W^i_j = \frac{\sum_k C^k_i}{\sum_k C^k_j}$$ (5.6)

This is only the beginning, however. The central notion of the “Influence Methodology” is the relative character of influence. The weight of each unit (its influence balance) is supposed to determine the weight of the references it gives to other units. In other words, each citing unit conveys its influence weight to every reference, which again transfers it to the cited units. In this second step, the initial equality of all citations and references is abolished and replaced by a weighted set of values, determined by the initial distribution of citations and references. As a consequence, the weight of every unit is dependent on the weights of all other units and must be determined in an iterative procedure of many more steps. The influence weight of a unit is defined as the product of the citations to the unit and the relative weight of the citing units, summed over all citing units, and divided by all references from the unit.

$$WW^i_j = \frac{\sum_k (C^k_i \times W^k_j)}{\sum_k C^k_j}$$ (5.7)

The $n$ equations, one for each unit, provide a self consistent ‘bootstrap’ set of relations in which each unit plays a role in determining the weight of every other unit. ... This procedure is closely related to the standard method for finding the dominant eigenvalue of a matrix. (Narin 1976)
On the basis of this network indicator, hierarchies of journals and maps of specialties have been constructed by ordering according to influence. Narin’s influence measure is related to Small’s fractional citation counting, which is the first order approximation of Narin’s measure if articles are the units in the citation matrix. The difference is in the goal of the method. Whereas Small only wished to correct a specific problem within his technique, Narin wanted to construct a general measure of influence, applicable to all levels of aggregation and different types of entities. Apparently, different techniques and contradicting theoretical assumptions concerning the nature of the citation and the reference can go together smoothly.

To sum up, normalization, born out of the desire to obtain statistically more significant results, is at the same time a crucial way of connecting the citation with other signs or indicators. It facilitates the construction of indicators for science policy at every conceivable level of science.

5.5 Other signs of science: co-word analysis

In this chapter, the foundations and uses of citations and references in the specialty of scientometrics have been discussed. Scientometricians are like “heterogeneous engineers” (Callon 1986, Latour 1987), mixing various elements in their construction of representations of science. The incorporation of different representations of science into citation analysis, e.g. the validation procedures in cocitation analysis has been shown. This translation of various representations can, however, be carried even further by creating bibliometric representations of science not based on the citation. This is what happens in co-word analysis, created by the French sociologist of science Michel Callon and his colleagues. According to this group, there is a fundamental problem with citation analysis:

The study of citations limits the scope of the analysis to one of the numerous means used by an author to identify, mobilize or turn aside for his own profit earlier results, institutions and authors. (Callon, Courtial, Turner & Bauin 1983)

In this argument, the citing author is the central unit of analysis and the inversion implicated in the SCI, citation analysis and co-citation analysis is consequently rejected. Ironically, Callon et al. (1983) return to a representation of the literature discarded by citation indexing: subject indexing. Whereas Garfield rejected subject indexing as too rigid (and slow), preferring the newspeak of citation, Callon turns the flexibility of citation against its use: “Depending on the different disciplines, circumstances and audiences, he [the scientist] could have recourse to citation in different ways”. Callon et al. (1983) prefer the old-fashioned subject indexing terms, precisely because of its rigidity:

at least three factors tend to ‘objectivate’ the work of indexers: 1: the organizational stability of the documentation service; 2: the contact that the indexers have with the users of the documentation service when handling
their requests for information; 3: the form of the scientific text itself with its double-mouth funnel-like structure which facilitates identification of the macro-terms.

This preference is partially inspired by the prevailing access to databases: the most important French scientific database Pascale did not include citations but did have a highly developed subject indexing system, whereas the inverse was true for the SCI. This does not mean that the French would not have learned from the experiences with citation analysis. In more than one respect, co-word analysis is the analogue of co-citation clustering applied to a different database and with a different elementary concept. As before, “extension by analogy” is the applied procedure. What the citation is in citation analysis, is the indexing term in co-word analysis. Then, co-occurrences are measured, just as in co-citation analysis: “two key words, i and j, co-occur if they are used together in the description of a single document” (Callon et al. 1991). Because of the never-ending possibilities of indexing terms, “It is clear that a simple counting of co-occurrences is not a good method for evaluating the links between co-words”. Therefore, a normalized coefficient has been constructed which relates the co-occurrence of each pair of indexing terms to the general occurrence of each term, like the Jaccard coefficient in co-citation clustering. This is the equivalence index:

\[
E_{ij} = \frac{C_{ij}^2}{C_i \times C_j}
\]  

(5.8)

where \(C_i\) is the number of occurrences of keyword i and \(C_{ij}\) is the number of co-occurrences of keyword i and j. This index is calculated for every possible word pair. On this basis clusters are constructed “with variable thresholds, characterized by the value of the first link refused, which is called the saturation threshold of the cluster. These thresholds are automatically determined in such a way that no cluster contains more than ten words”. So, this clustering algorithm is based on a fixed upper size of the word clusters. Then these clusters are classified. If the division seems to be artificial, i.e. if one cluster is simply the continuation of another, a new round of classification is started.

The first stage of the description of a network (we mean the whole network of words for a given file) is the identification of clusters, the description of the links that unite them, and the representation of their internal organization. We then have to characterize the morphology of the network as a whole, and the contribution of each of these clusters to its structure. (Callon et al. 1983)

After clusters have been generated in this way, indicators typifying them are constructed. Each cluster is defined by its centrality (the intensity of its links with other clusters) and by its density (the strength of the links that tie the words making up the cluster together). This double characterization of each cluster makes

---

it subsequently possible to classify them into four quadrants and analyze the development of a network, or the difference between two different networks (which is an identical problem) in terms of the differences between these classifications. This means that clusters are analyzed on the similarities between the values of their densities and centralities. Clusters are moreover compared by computing the number of words they share, the so-called transformation index. Since this is the number of items in the intersection of the clusters, this is again a co-occurrence measure but at the higher, cluster, level.

As will be clear, co-word analysis, like citation analysis, rests upon several translations that are neither self-evident nor necessarily consistent. It takes the indexing terms to be adequate representations of the content of the scientific literature and is moreover based on the assumption that these terms remain stable over time and in different contexts. These co-occurrences are then translated into relative measures as input into clustering methods which have, as in co-citation clustering, several degrees of freedom. Different threshold criteria, for example, will lead to different clusters, as will other cluster criteria. Furthermore, the technique is based on relational analysis, like co-citation clustering, and does not take the relative positions of the words into account (for positional analysis of networks see Burt (1982)). This is borne out in the choice of relational indicators characterizing the clusters, only one of the many possible ways of discriminating between the clusters. Ultimately, co-word analysis resurrects the boundary between the method and reality (de-emphasizing the local context of the origin of the indexing terms):

Co-word analysis, and in this it is in line with the sociology of traduction which gave rise to it, does not rely on a priori definitions of research themes. The subject areas identified are those which are constructed by different actors (researchers, engineers, ...) and which they define and transform in the course of their interactions. Co-word analysis considers the dynamic of interactions to develop as a result of actor strategies. (Callon et al. 1983)

5.6 A maze of indicators

The utility of any particular indicator depends ultimately on the accuracy of the observations on which it is based, on the validity of the unstated assumptions by which it is accompanied, and on the logical consistency of the further processes by which it is reduced to operational form. (Ziman 1979, 261)

Thus, the citation representation of science is an intricate maze of indicators. It developed mainly through the extension of the sign citation, the juxtaposition and combination of the reference and the citation, and the combination with other representations of science. This development consisted of consecutive steps of translation, not necessarily consistent but still building on its own results. The citing and the cited dimensions of science have been thoroughly intermingled.
Translation also occurs whenever the citation representation is mixed with others. The citation culture has even permeated through a competing mode of bibliometric research like co-word analysis. Although based on the old-fashioned subject indexing, co-word analysis is in no way part of the pre-citation world. On the contrary, its methodology is deeply embedded in the established reality of citation analysis. Both the citation and the co-word representation of science are formal representations, contrary to the substantive science representations.

Apparently, the indicators used in citation analysis provide for a rather complicated representation of science. They do not reflect science straightforwardly. Far from simply measuring independent objects “out there”, citation analysis selects and reconstructs objects on the basis of the citation index, on which it capitalizes. The heart of the matter is the semiosis of the citation, a symbolic inversion process. This transformation creates the basic properties of the citation network. The countability, universality, and self-referential nature of the citation are its central attributes. They make extensive new combinations possible as well as the simultaneous use of different, even supposedly incompatible, ways of measuring.

In this process of creating a new representation of science the realist and the constructivist perspective have frequently alternated. Scientometricians are able to use both discourses at the same time, as do scientists (Shapin & Schaffer 1985, Mulkay, Potter & Yearly 1983, Latour 1987) and sociologists of science (Ashmore 1989). In realist rhetoric, the scientometric indicators are depicted as being based on science itself. In constructivist utterances the creative act of making science indicators is stressed. During these activities, scientometricians are engaged in boundary work (Gieryn 1983), though not so much rhetorically as practically: deconstructing and reconstructing the boundaries between their constructs and the reality of science. Scientometricians thereby construct the reality of science within (or in terms of) the representation they have created. This is a general feature of scientifically constructed representations: not only do they represent a phenomenon by a combined reduction-reconstruction translation, but within this whole they also create boundaries between that which is labelled as deliberately constructed (like methods and artefacts) and that which is attributed purely to the phenomenon (results). This labelling can subsequently be swapped as we have seen in the evolution of the co-citation clustering methodology. Scientific representations generally indicate their own construction in a way that enhances their claims to be true. Scientometric representations are no exception.

---

7 This point will be discussed in more detail in chapter 8.