Dynamic and Evolutionary Updates of Classificatory Schemes in Scientific Journal Structures

Loet Leydesdorff
Science & Technology Dynamics, Amsterdam School of Communications Research (ASCoR), Kloveniersburgwal 48, 1012 CX Amsterdam. E-mail: loet@leydesdorff.net; www.leydesdorff.net

Can the inclusion of new journals in the *Science Citation Index* be used for the indication of structural change in the database, and how can this change be compared with reorganizations of relations among previously included journals? Change in the number of journals (*n*) is distinguished from change in the number of journal categories (*m*). Although the number of journals can be considered as a given at each moment in time, the number of journal categories is based on a reconstruction that is time-stamped ex post. The reflexive reconstruction is in need of an update when new information becomes available in a next year. Implications of this shift towards an evolutionary perspective are specified.

Introduction

Because the sciences develop dynamically, one expects to find change in trend lines of scientometric indicators. For example, scientific productivity changes over time, and it is also expected to differ among research groups. The variation among research groups at each moment in time may interact with the processes of change over time. A policy analyst, therefore, may wish to ask "what do the results teach us?" Should policies nurture the "weak" units or rather "pick the winners" (Irvine & Martin, 1984)? Does a high score on an indicator predicate for further growth or rather predict relative stability or even decline? In other words: what is the strategic value of the measurement results using scientometric indicators? How do the indicated developments relate to a baseline for the comparison?

The question of the construction of a baseline for the comparison (Studer & Chubin, 1980) has been prevailing in scientometric studies during the 1980s and 1990s without having been solved hitherto. Two important proposals for methodologies were made right at the beginning of the scientometric research program, notably (a) to make comparisons at each moment only in terms of "like with like" (Martin & Irvine, 1983), and (b) to make comparisons over time only in terms of journal sets which are kept fixed ex ante during the period under study (Narin, 1976).

The heuristics of comparing "like with like" can be considered as a definition of research groups in terms of institutional parameters (Collins, 1985), while the definition in terms of journal sets is expected to indicate the intellectual exchange among scholars in a field or specialty (Whitley, 1984). For example, an index of activity can be constructed for the comparison among research groups or other units of analysis (Schubert, Glänzel, & Braun, 1989). The units of analysis of knowledge production can be defined with reference to a relevant environment that one can measure independently, for example, in terms of the journal sets used for the communication (Doreian & Fararo, 1985; Moed, Burger, Frankfort, & Van Raan, 1985; Leydesdorff, 1987).

Can the changing positions of institutional units of knowledge production in changing intellectual environments also be measured? Moed et al. (1985) proposed to normalize output performance measurement results in relation to impact factors of journals used by the groups themselves. In a similar vein, Schubert et al. (1989) developed the instrument of "expected" versus "observed" citation rates. Further questions can be raised here both methodologically and theoretically. For example, the skewness of the distributions considerably complicates the issue of an appropriate normalization (Bonitz, 1997; Leydesdorff, 1995a).

With other colleagues (e.g., Cozzens & Leydesdorff, 1993; Leydesdorff, Cozzens, & Van den Besselaar, 1994), I have been particularly interested in the measurement of structural change at the network level and how such change potentially redefines the universe (or, in other words, the paradigm) in which practicing scientists assess the relevance and the quality of the contributions of their colleagues. In my opinion, the innovative dimension of the development of science and technology cannot be measured using ex ante fixed journal sets or institutional units; the institutions can be expected to aggregate both standardized routines and innovative activities.

Received June 4, 2001; Revised January 3, 2002; accepted May 1, 2002

JOURNAL OF THE AMERICAN SOCIETY FOR INFORMATION SCIENCE AND TECHNOLOGY, 53(12):987–994, 2002

From Ex Ante Classification to a Dynamic Baseline

How are the baselines of science indicators changing when the (techno-)sciences further develop (Callon, 1998; cf. Callon, Law, & Rip, 1986)? In a study of aggregated journal–journal citations in three cases of rapid scientific developments during the 1980s ("AIDS," "Superconductivity," and "Oncogene"), Susan Cozzens, Peter van den Besselaar, and I concluded that one can track these developments by defining "central tendency journals" as the outcome of an iterative procedure (Leydesdorff et al., 1994). Specialties constitute domains which only at certain places (e.g., *Science* and *Nature*) are related to the larger journal–journal citation matrix, but otherwise relate internally in terms of restricted discourses, interrelations of readership, and citations (Bernstein, 1971; Blauwhof, 1995; Coser, 1975). Relevant pieces of the large matrix of journal–journal citations can thus be considered as "nearly decomposable" (Simon, 1969, 1973).

In another study, Van den Besselaar and Leydesdorff (1996) were able to use these delineations for testing theoretically specified assumptions about the intellectual development of the emerging specialty of "artificial intelligence." In this changing environment the fixation of a relevant journal set ex ante can no longer be legitimated. For example, an innovative research group may explore the set at its dynamic margins and, therefore, exhibit less visible performance than the year before, while another institution may play "safe" and increase its performance within an established core set. Using an ex ante defined indicator, one would erroneously rate the latter group higher than the former. This would be an artifact of the indicator.

The bias introduced by using the ex ante fixed set of journals as an indicator has also been one of the origins of the debate of the "scientometric" decline of the UK performance during the 1980s. In a dynamic journal set the UK is less declining than in an ex ante fixed one, because the UK at each moment in time contains units of knowledge production that are highly innovative and thus also changing the delineations used for the measurement (Anderson, Collins, Irvine, Isard, Martin, Narin, & Steven, 1988; Braun, Glänzel, & Schubert, 1991; Irvine & Martin, 1985; Leydesdorff, 1988, 1991; Martin, 1991, 1994).

The dynamic delineation of the journal sets in terms of relevant citation environments can be improved by using "central tendency journals." A central tendency journal is defined (Leydesdorff & Cozzens, 1993) as a journal that exhibits highest factor loading on its factor in a matrix that is constructed using this same journal as the seed journal and given a citation threshold (e.g., of 1%). These relatively fixed points can be used for the delineation of clouds in the multidimensional space of journal–journal citations. This dynamic definition of the relevant environments enables us, in principle, to compare "like with like" over the time dimension, because the central tendency is defined as a property at the level of the network.

For example, to delineate the specialty of "artificial intelligence" in the noted study we used the journal *Artificial Intelligence* as the seed journal. First, one can construct a citation matrix of a limited number of journals by using a threshold (because of the near decomposability of the overall journal structure). Second, one can factor analyze this citation matrix, and then find, third, whether this journal leads the factor on which it loads highest in the cited and/or the citing dimension. If the seed journal can be considered as a central tendency journal, the initial choice for this journal as an indicator is legitimated.

Central tendency journals often exhibit a lot of stability over time, while journals relevant for the comparison at the margins may change position from year to year in terms of their factorial complexity (Van den Besselaar & Heimeriks, 2001). Thus, the analysis in terms of central tendency journals provides us with a dynamic baseline for the comparison, for example, of institutional contributions.

From a Historical Baseline to Ex Post Delineation

Whereas the dynamic baseline enables us to change the definition of a relevant journal set "on the fly," the development of institutional performance and citation behavior can be expected to anticipate and/or to lag behind developments at the level of journal–journal structures. How can one select a journal set to measure changes in performance in a changing environment?

By definition, the journal set that describes a changing situation cannot be chosen ahead of time, but instead must be selected with hindsight, that is, after the change has occurred. Thus, the analyst who wishes to make a statement about performance according to the *current* understanding of the field should choose the content of the category according to current, that is, a posteriori standards, and backtrack on the basis of this hypothesis.

The analysis of "artificial intelligence" can again be used to illustrate this point. There is no reason that later papers in journals that were closely related to *Artificial Intelligence* in the mid-1980s (e.g., *JASIS*), should be counted as belonging to this specialty with hindsight. In the latter half of the 1980s "artificial intelligence" became stabilized as a set of journals around *Artificial Intelligence*, including, for example, *AI Magazine* and *IEEE Expert*. With hindsight, we know that papers in *JASIS* belonged mainly to specialties and subspecialties other than artificial intelligence. Given the later data, and the corresponding understanding of the specialty, a 1984 paper in *JASIS* should not be classified as a contribution to the further development of artificial intelligence.

Given changes in the baseline of the emerging specialty, one would come to a different weighting of articles in the journals which were relevant a priori, than on the basis of an a posteriori delineation (Nederhof, 1988). The use of a journal set that is fixed ex ante for performance measurement is ill advised in the case of a research question which looks for, or even wishes to take account of, structural change at the journal level. The a posteriori perspective enables us to interpret results based on different journal sets. It legitimates the choice for a "fixed journal set" in some research designs, but not in others.

The "Citing" and the "Cited" Dimensions

Like other citation matrices, journal–journal citation matrices are asymmetrical, because there is no mutuality implied in a citation relation. Some journals may act as sources for other journals, and vice versa (Noma, 1982). In other words, a journal–journal citation matrix contains a "citing" journal structure and a "cited" journal structure that can be exhibited by Q- and R-factor analysis, respectively. Correspondingly, one can meaningfully distinguish between "central tendency journals" in the "citing" or in the "cited" dimension.

In established fields, the two structures of a citation matrix often coincide to a large extent. Thus, one finds a cluster of "biochemistry" journals or "solid-state physics" journals in each year with mainly variations at the margin. However, the "citing" dimension of the citation matrix refers to the active operator that both introduces change and reproduces existing structures, whereas the "cited" dimension exhibits the prevailing structure as perceived by the citations in the present. This structure can be considered as a "given" from the perspective of the actively citing units that originally (and sometimes "innovatively") produce the variation. In a next year, the main structures can be expected to be reproduced unless structural change was generated by the aggregated citations on the citing side (Giddens, 1984).

Structural change can be made visible in the reproduction of structure, that is, on the "cited" side. Although variation can be volatile and perhaps selected away, the stabilization of variation in the structure of the citation matrix provides authors with an update of the order "given" in their relevant universe of possible citations (Leydesdorff, 1995b). When a new element of structure is added, the journal citation horizons of the citing agencies may have changed.

The Case of *JASIS* and the "Information Sciences"

Let us take the citation environment of this journal [*JASIS(T)*] itself as an empirical example for analysis, because the history of the position of this journal illustrates developments in the field. *JASIS* has been embedded in a turbulent environment that has witnessed the emergence of "artificial intelligence" in the 1980s and the advent of Internet technologies during the 1990s.

We begin the analysis with the most recent year for which the ISI-data is available, namely in the *Journal Citation Reports 2000*. With a default threshold of one percent (of the total cited or citing), only 11 journals are drawn into the analysis. This result is a remarkably low number. It indicates a specific and pronounced citation pattern in the relevant citation environments of this journal. Furthermore, the citation mapping of *JASIS* is almost identical in the cited and in the citing dimension, and *JASIS* is a "central tendency journal" in both these dimensions.

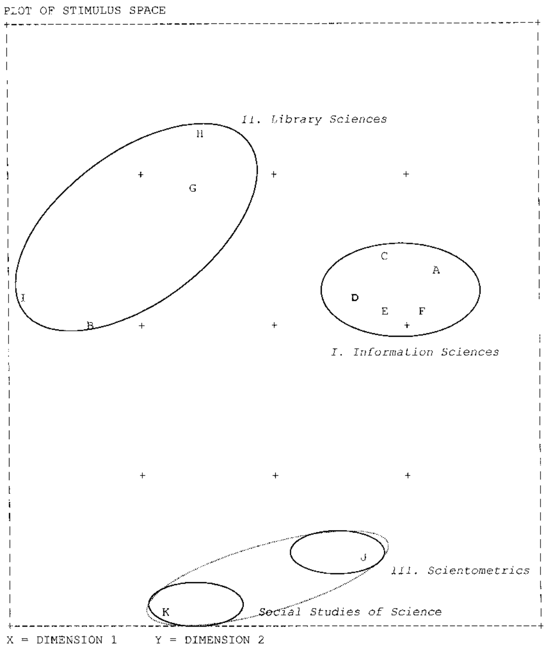

FIG. 1. Factor analysis and MD-SCAL for the *Journal of the American Society for Information Science, JASIS*, citing patterns (2000; threshold = 1.00%).

I. Information science	II. Library science	III Science studies
A. Aslib Proc	B. Coll Res Libr	J. Scientometrics
C. Inform Process Manag	G. Libr Inform Sci Res	K. Soc Stud Sci
D. J Am Soc Inform Sci	H. Libr Quart	
E. J Doc	I. Libr Trends	
F. J Inform Sci		

The distinction between "information science" and "library science" journals prevails in the factor solution to such an extent that these two factors explain 64.8% of the variance in the matrix. A third factor is "science studies" as expressed in the citation patterns of *Scientometrics* and *Social Studies of Science.* These two journals are considered as a single cluster (factor) in the cited dimension, but they load with different signs when their active citation patterns are analyzed from the the citing perspective. I have pencilled this difference into Figure 1.

Furthermore, the citation patterns between the first (information science) and the second (library science) clusters exhibit factorial complexity. *Library and Information Science Research* and *Library Quarterly* are citing as information science journals in addition to belonging to the library science cluster, whereas *College & Research Libraries* and *Library Trends* exhibit a negative factor loading on the first factor. In the cited dimension the differences are more gradual, with *Library and Information Science Research* and *College & Research Libraries* in the extreme positions. The *ASLIB Proceedings* exhibits a negative factor loading (r

= −0.56) on the library science cluster in the cited dimension.

The 1999 pictures are not very different, although four additional journals are drawn into the analysis. *Library Trends* belongs to the information science cluster in this year, and the library science cluster is further subdivided in the factor solution. Another cluster is retrieved consisting of *Libri* and *Educational Techology Research & Development (ETR&D)*. This cluster is positively associated with the *ASLIB Proceedings* in the cited dimension.

If we go back to 1994—the first year for which the *Journal Citation Reports* are available in electronic format—the picture is different (see Fig. 2). The "information science" cluster is now much larger and includes several journals that we would consider library journals from our current perspective. The interface with the library journals is diffuse, and it shifts depending on whether we take a citing (solid lines) or a cited (dotted lines) perspective.

In addition to "science studies," various new technologies were relevant in the citation environment in 1994, but these journals did not provide clear citation structures. *The Canadian Journal of Information and Library Sciences* seems to occupy a position at the interfaces of the library and information sciences with these new developments.

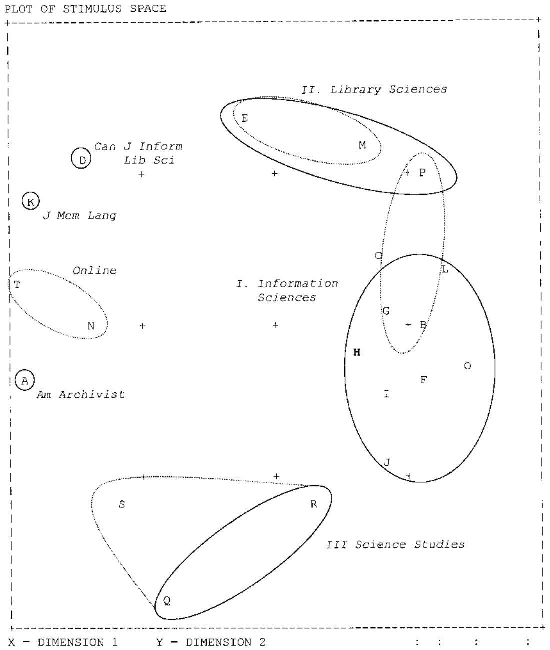

FIG. 2. Factor analysis and MD-SCAL for the *Journal of the American Society for Informaiton Science, JASIS*, citing patterns with cited patterns aded as dotted lines (1994; threshold = 1%).

Information science	Library science	Science studies new technologies
B. Annu Rev Inform Sci	E. Coll Res Libr	Q. Research Policy
F. Inform Process Manag	M. Libr Resour Tech Ser	R. Scientometrics
G. Inform Technol Libr	P. P Asis Annu Meeting	S. Social Studies of Science
H. J Am Soc Inform Sci		D. Can J Inform Lib Sci
I. J Doc		K. J Mem Lang
J. J Inform Sci		N. Online
L. Libr Quart		T. Telecommun Policy

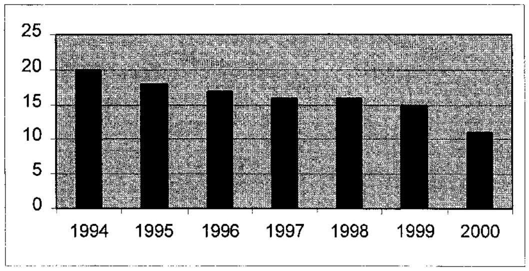

FIG. 3. Number of journals drawn into the analysis when using *JASIS* as a seed journal and with a 1% threshold of total citations.

If we look 6 years further back to 1988, "information science" is only a second factor in relation to a "library science" factor, both in the cited and the citing dimensions. *Information Processing & Management* was the central tendency journal for the "information science" cluster in the citing dimension in 1988. In the cited dimension, however, *JASIS* was already leading at that time.

In 1988, the *Journal of Academic Librarianship*, *College & Research Libraries*, and *Library Resources & Technical Services* exhibited highest factor loading on the factor "library science," both in the cited and the citing dimension. The *Canadian Journal of Information Science* (at that time still under its previous name) and *Scientometrics* showed as parts of the "information science" cluster when *JASIS* was used as the seed journal.

In sum, we can witness a gradual change in the hierarchy between library and information science journals: the borderlines between these two discourses have been reorganized over time. Although a much more diffuse structure of "library and information sciences" was emerging in the early 1990s, "information science" has more recently become specialized. Its citation patterns are now very restricted. This indicates a restricted and codified discourse.

Figure 3 exhibits this trend by showing the decrease in the number of journals that were drawn into the analysis when *JASIS* was used as the entrance journal. Within the "library sciences" themselves a further differentiation has occurred—which I will now not discuss—between library and information systems usage, on the one hand, and collection maintanance and management, on the other. This differentiation, however, is not so visible from the more restricted perspective of the "information sciences."

The further specialization of "information science" seems to be enhanced by the development of the new information and communication technologies. These new developments are not visible in the citation environment of *JASIS* in 2000, while they were evident in 1994. However, if we lower the threshold for inclusion in the matrix to 0.25% of the total cited/citing, the journal *Online Information Review* becomes visible.

Figure 4 exhibits the configuration when the journal *Online Information Review* is taken as the seed journal in

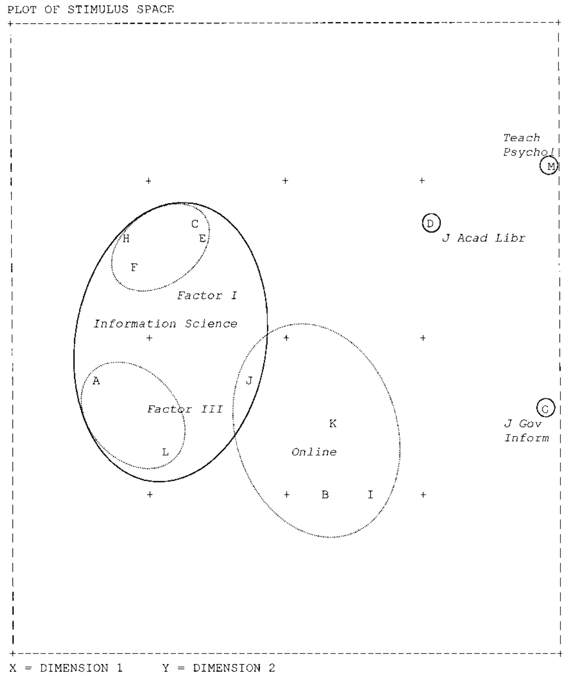

FIG. 4. Factor analysis and MD-SCAL for *Online Inform Rev*, citing patterns indicated with solid lines; cited patterns with dotted lines (2000; threshold = 1%).

Information science	Online	Other (isolates)
A. ASLIB Proc	B. Database	D. J Acad Libr
C. Inform Process Manag	I. Online	G. J Gov Inform
E. J Am Soc Inform Sci	J. Online CDRom Rev	M. Teach Psychol
H. J Inform Sci	K. Online Inform Rev	
L. J Program-Electron Lib		

2000. "Information science," with *JASIS* as the leading journal, remains the first factor in this environment. The journal loads on a second cluster that can be designated as "on-line" research. The factor is led by the journal *Online* in the citing dimension and by *Online & CDRom Review* in the cited dimension. This latter journal, however, is not processed "citing." (For this reason, Fig. 4 provides the picture from the "cited" perspective. In the citing dimension the two "information science" factors that can be distinguished as "cited" are merged, as indicated.)

In summary, the new developments can be made visible as a structure in 2000, but hitherto they have remained subsidiary to their relations with the "information science." However, this structure was not clearly differentiated in 1994, although the journals were already included in the database. In 1994, these journals were still a part of the larger field of "library and information sciences" that since has become more specialized in different subfields.

Relation to Information Theory

In the above analysis I have drawn on notions that are derived from information theory, communication theory, and systems dynamics. For example, the idea of finding a solution by iterative approximation is typical for information theory (Krippendorff, 1986); the problem of relating units at different levels of aggregation is central to statistical decomposition analysis (Theil, 1972); and the choice of the a posteriori perspective in the reconstruction is typical for communication theory, because it focuses on the question of what what one can learn from the information which the communication process has made available (Shannon, 1948).

Citations are a substantive, but composite unit of analysis: they contain information that may reflect novelty, codification, and evaluation in different respects (e.g., Cozzens, 1989; Leydesdorff & Amsterdamska, 1990). However, the aggregated journal–journal citation system here under study is at a level of abstraction such that one does not have to open the "black box" of each citation to examine the information that is communicated. One analyzes only the number of messages. The analysis at the level of the citation network is reconstructive with respect to content (Leydesdorff, 2001).

The abstraction of content in analyzing the multidimensional construct of messages has an analogy in the time dimension. The science system produces change naturally over time when it operates. At the network level, however, one does not focus on the substantive changes that are a normal consequence of the operation of the system, but on the possible effects of this lower level change on the reconstructed communication network. In summary, we analyze an abstract problem that can be considered as content-free with respect both to the various dimensions of the network at each moment in time, and with respect to the system's development over time. Because of this abstract character, one is allowed to make the problem subject to the mathematical theory of communication (Leydesdorff, 1995a; Shannon, 1948).

Aggregated journal–journal citations form a huge communication network that develops over time. At each moment, the system and its nearly decomposable subsystems contain a reference to their previous states, and they reflect change in their respective environments by, among other things, internal differentiation. Thus, the journal systems are self-referential, but in the reproduction they also refer to relevant contexts. In other words, each (sub)system has two incoming arrows at each stage, one from the previous situation and one from relevant communication systems in a continuously changing environment of interactions and recursions.

From this perspective, the initial research question about structural change in the dynamics among journals can be reformulated as the specification of the consequences when the incoming arrow (from the external "world") is more important than the self-referential one (corresponding to the system's previous state). In this case, the network is expected to change its structure. How can communication networks in general acquire new structural elements? Under which conditions does the addition of a new element (that is, journal) also lead to a change of the organization among elements (that is, at the network level)? As I have shown, one can also expect changes in the organization at the network level without necessarily involving new elements to be included.

Structural Change

Structure reduces the uncertainty that prevails in the network. In general, a network can only reduce the uncertainty within the system by increasing its redundancy. However, the uncertainty in the network has to increase because of the system's operation in accordance with the second law of thermodynamics or its probabilistic equivalent (Theil, 1972). The increase in the redundancy can only be generated by extending the maximum information content of the network system more than the increase of its expected information content (Brooks & Wiley, 1986). (The maximum information content is by definition equal to the sum of the expected information content and the redundancy.)

The maximum information content of the system is equal to the logarithm of the number of categories. At the lower level of aggregation of only journals, the number of categories is equal to the number of journals (n)—and the maximum information content is therefore $\log(n)$—but if one includes a grouping of these journals (m), the number of categories is n times m. The maximum information content is then $\log(n \times m)$, that is, $\log(n)$ plus $\log(m)$. Thus, the redundancy at the network level can be increased by either increasing the number of journals or the number of journal categories. Although the number of journals included is a given at each moment in time, the number of categories for the classification is dependent on the analysis. As noted, this latter number can be changed over time reflexively.

In contrast to this abstract consideration—which assumes a continuous flux—the journal–journal citation networks are so constructed that they contain an absorbing barrier of entropy by the introduction of a citation threshold in addition to the primary selection of journals by the editorship of the *ISI* (Garfield, 1990). At this end, "probabilistic noise" is continuously removed from the system by the exclusion of journals. This selection does not invalidate the above considerations about the generation of structure at the network level: *new* structure has to be based on an increase in redundancy. Redundancy can be added to the network by the introduction of new journals (n) or new journal categories (m).

The relevant questions are then: (1) have new journals been added and/or have new journal categories emerged? and (2) what type of change is involved in either case? As noted, the change in the number of journal categories remains based on a reconstruction. Therefore, it matters whether we approach the problem from a historical perspective (that is, "following the actors" on the basis of ex ante assumption) or from an evolutionary perspective (that is, on the basis of a reconstruction ex post).

Further Perspectives

Because there is a (noncomputable) multitude of possible forms of change expected if the categories themselves can change, one has to assess empirically what type(s) of change occurred. This information enables us to reduce our uncertainty and thereby it may help us to reduce the amount of computation needed. For example, one is able to assess whether the inclusion of new journals indicates structural change in terms of introducing and then also stabilizing a journal category. This can be measured in terms of the "central tendency" properties (see above).

Furthermore, one is able to distinguish between historical change using Latour's (1987) heuristics of "following the actors" versus evolutionary assessment of change, that is, by backtracking from the current situation into its origins. In the latter case, one assumes that an emerging order may feed back on a redefinition of the relevant universes. However, this raises methodological questions about design, because one then reconstructs *given* the events at a later moment in time (e.g., Riba-Vilanova & Leydesdorff, 2001).

It is possible to distinguish new journals that belong to existing journal classifications from new journals that do not belong to such previously existing groupings by using the citation behavior of journals in the network environment (Leydesdorff et al., 1994). The latter category of new journals may be particularly useful as early indicators of emerging journal groupings, because they indicate not only change in the system (n), but one is able to assess whether they also indicate change in the organization of the journal network (m). What type of change may follow, can only be assessed with hindsight (i.e., in a later year): the instrument provides us with an indicator only, because we deliberately abstracted from contents. We suggest that this indicator can be routinized by using the new journal list as input to a central tendency analysis in the cited dimension.

Let me emphasize that the empirical results remain reconstructive indicators, and therefore, the inferences drawn on the basis of this data provide us only with hypotheses about what to expect on the basis of the information contained in this data. The delineation is a prediction based on the scientometric data at a certain moment in time. But as the system itself operates, this prediction has to change, too, because new information becomes available that needs to be taken into account. In other words, the number of journal categories m has the epistemologic status of a hypothesis, and accordingly the maximum information content of the distribution ($m \times n$) remains an expectation. The information content of the matrix is *expected* to be communicated. The indicator provides only our best prediction given the information available in the current state.

If a system is not in equilibrium, but developing, any classification system remains a hypothesis for the next round(s) of operation. If the classification would not be able to "learn" from the operation of the system by updating, it might make itself obsolete in short order. This reasoning holds true for any taxonomy (e.g., a thesaurus, classification, index system, etc.), which is not defined in terms of its coevolution with the system that it is supposed to monitor (Leydesdorff, 1997).

An evolutionary perspective differs from a taxonomic perspective, in that a taxonomy is usually hypothesized ex ante, and not capable of signaling relevant change other than as disturbance or unspecific noise; the need for an update is not systematically derived from change in the data becoming available over time. In an evolutionary model, the classification remains provisional, based on the information currently available, and can reflexively be updated and improved with the operation of the system under study.

Conclusions

One can replace taxonomic models with evolutionary designs. However, the evolutionary models do not only affect the methodologies—by changing the perspective to an a posteriori one—but also the theoretical understanding of what one measures with scientometric indicators. As depictions of a science system under study, scientometric mappings should not be reified. They contain only a pattern that the analyst can propose hypothetically for the further analysis of, for example, performance in the specified domains.

If one does not systematically account for redelineation in the groupings over time but uses "fixed journal sets" instead, one risks making a prediction of performance with reference to an outdated unit. Van den Besselaar and Leydesdorff (1996) used the case of artificial intelligence to show empirically that the choice of the a priori or the a posteriori perspective has important consequences for scientometric applications like publication counting in performance measurement, but the approach remained historically. The evolutionary perspective radicalizes the priority of the ex post reconstruction by backtracking from the most current understanding of the field (Leydesdorff, 2002).

Because of this orientation towards the current understanding, the kind of analysis we described above can contribute to the development of scientometric tools with management and policy relevance. Unlike the comparative static designs that lead to trend lines in indicators reports, but follow the axis of time, the indicators based on the evolutionary form of evaluation, that is, taking the ex post situation for the benchmark, can help decision makers with the very real problems of responding to increasingly rapid change in science. The focus shifts from the mapping of the past and the comparisons among static snapshots from the past to the expectation in the present. Are new clusters emerging and if so, to what extent have they been able to redefine the discourse of what is considered relevant or not, by the citing actors involved?

References

Anderson, J., Collins, P.M.D., Irvine, J., Isard, P.A., Martin, B.R., Narin, F., & Stevens, K. (1988). On-line approaches to measuring national scientific output—A cautionary tale. Science and Public Policy, 15, 153–161.

Bernstein, B. (1971). Class, codes and control, vol. I. Theoretical studies in the sociology of language. London: Routledge & Kegan Paul.

Blauwhof, G. (1995). The non-linear dynamics of technological developments: An exploration of telecommunications technology, Ph.D. Thesis, University of Amsterdam.

Bonitz, M. (1997). The scientific talent of nations. Libri, 47(4), 206–213.

Braun, T., Glänzel, W., & Schubert, A. (1989). Assessing assessments of British science. Some facts and figures to accept or decline. Scientometrics, 15, 165–170.

Braun, T., Glänzel, W., & Schubert, A. (1991). The bibliometric assessment of UK scientific performance—Some comments on Martin's reply. Scientometrics 20, 359–362.

Brooks, D.R. & Wiley, E.O. (1986). Evolution as entropy: Towards a unified theory of biology. Chicago: University of Chicago Press.

Callon, M. (1998). The laws of the market. Oxford, MA: Blackwell.

Coser, R.L. (1975). The complexity of roles as a seedbed of individual autonomy. In L.A. Cosser (Ed.), The idea of social structure. Papers in honor of Robert K. Merton (pp. 237–264). New York: Harcourt Brace Jovanovich.

Callon, M., Law, J., & Rip, A. (Eds.). (1986). Mapping the dynamics of science and technology. London: Macmillan.

Collins, H.M. (1985). The possibilities of science policy. Social Studies of Science, 15, 554–558.

Cozzens, S.E. (1989). What do citations count? The rhetoric-first model. Scientometrics, 15, 437–447.

Cozzens, S.E., & Leydesdorff, L. (1993). Journal systems as macroindicators of structural change in the sciences. In A.F.J. Van Raan, R.E. De Bruin, H.F. Moed, A.J. Nederhof, & R.W.J. Tissen (Eds.), Science and technology in a policy context (pp. 219–233). Leiden: DSWO Press/Leiden University.

Doreian, P., & Fararo, T.J. (1985). Structural equivalence in a journal network. Journal of the American Society of Information Science, 36, 28–37.

Garfield, E. (1990). How ISI selects journals for coverage: Quantitative and qualitative considerations. Current Contents, 28, 5–13.

Giddens, A. (1984). The constitution of society. Cambridge: Polity Press.

Irvine, J., & Martin, B.R. (1984). Foresight in science: Picking the winners. London: Pinter.

Irvine, J., & Martin, B.R. (1985). Charting the decline of British science. Nature, 316, 587–590.

Krippendorff, K. (1986). Information theory. Structural models for qualitative data. Beverly Hills, CA: Sage.

Latour, B. (1987). Science in action. Milton Keynes: Open University Press.

Leydesdorff, L. (1987). Various methods for the mapping of science. Scientometrics, 11, 291–320.

Leydesdorff, L. (1988). Problems with the "measurement" of national scientific performance. Science and Public Policy, 15, 149–152.

Leydesdorff, L. (1991). On the "scientometric decline" of British science: One additional graph in reply to Ben Martin. Scientometrics, 20, 363–368.

Leydesdorff, L. (1995a). The challenge of scientometrics: The development, measurement, and self-organization of scientific communications. Leiden: DSWO/Leiden University; at http://www.upublish.com/books/leydesdorff-sci.htm.

Leydesdorff, L. (1995b). The production of probabilistic entropy in structure/action contingency relations. Journal of Social and Evolutionary Systems, 18, 339–356.

Leydesdorff, L. (1997). Why words and co-words cannot map the development of the sciences. Journal of the American Society for Information Science, 48(5), 418–427.

Leydesdorff, L. (2001). A sociological theory of communication: The self-organization of the knowledge-based society. Parkland, FL: Universal Publishers; at http://www.upublish.com/books/leydesdorff.htm.

Leydesdorff, L. (2002). Indicators of structural change in the dynamics of science: Entropy statistics of the SCI Journal Citation Reports. Scientometrics 53(1), 131–159.

Leydesdorff, L., & Amsterdamska, O. (1990). Dimensions of citation analysis. Science, Technology & Human Values, 15, 305–335.

Leydesdorff, L., & Heimeriks, G. (2001). The self-organization of the European Information Society: The case of "biotechnology." Journal of the American Society for Information Science & Technology 52(14), 1262–1274.

Leydesdorff, L., & Cozzens, S. (1993). The delineation of specialties in terms of journals using the dynamic journal set of the *SCI*. Scientometrics, 26, 133–154.

Leydesdorff, L., Cozzens, S.E., & Van den Besselaar, P. (1994). Tracking areas of strategic importance using scientometric journal mappings. Research Policy, 23, 217–229.

Martin, B.R. (1991). The bibiometric assessment of UK scientific performance—A reply to Braun, Glänzel and Schubert. Scientometrics, 20, 333–357.

Martin, B.R. (1994). British Science in the 1980s—Has the relative decline continued? Scientometrics 29, 27–57.

Martin, B.R., & Irvine, J. (1983). Assessing basic research: Some partial indicators of scientific progress in radio astronomy. Research Policy, 12, 61–90.

Moed, H.F., Burger, W.J.M., Frankfort, J.G., & Van Raan, A.F.J. (1985). The use of bibliometric data for the measurement of university research performance. Research Policy, 14, 131–149.

Narin, F. (1976). Evaluative bibliometrics. Cherry Hill, NJ: Computer Horizons, Inc.

Nederhof, A.J. (1988). Changes in publication patterns of biotechnologists: An evaluation of the impact of government stimulation programs in six industrial nations. Scientometrics, 14, 475–485.

Noma, E. (1982). An improved method for analyzing square scientometric transaction matrices. Scientometrics, 4, 297–316.

Riba-Vilanova, M., & Leydesdorff, L. (2001). Why Catalonia cannot be considered a regional innovation system. Scientometrics, 50(2), 215–240.

Schubert, A., Glänzel, W., & Braun, T. (1989). World Flash on basic research. Scientometric datafiles. A comprehensive set of indicators on 2649 journals and 96 countries in all major science fields and subfields 1981–1985. Scientometrics, 16, 3–478.

Shannon, C.E. (1948). A mathematical theory of communication. I and II. Bell System Technical Journal, 27, 379–423 and 623–656.

Simon, H.A. (1969). The sciences of the artificial. Cambridge, MA: MIT Press.

Simon, H.A. (1973). The organization of complex systems. In H.H. Pattee (Ed.), Hierarchy theory: The challenge of complex systems (pp. 1–27). New York: George Braziller.

Studer, K.E., & Chubin, D.E. (1980). The cancer mission. Social contexts of biomedical research. Beverly Hills, CA: Sage.

Theil, H. (1972). Statistical decomposition analysis. Amsterdam: North-Holland.

Van den Besselaar, P., & Heimeriks, G. (2001). Disciplinary, multidisciplinary, interdisciplinary? Concepts and indicators. Paper presented at the ISSI Conference for Scientometrics and Informetrics, Sydney, July 2001.

Van den Besselaar, P., & Leydesdorff, L. (1996). Mapping change in scientific specialties: A scientometric reconstruction of the development of artificial intelligence. Journal of the American Society for Information Science, 47, 415–436.

Whitley, R.D. (1984). The intellectual and the social organization of the sciences. Oxford: Oxford University Press.