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Integrating scientometric indicators into sociological studies: methodical and methodological problems

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This article discusses the methodological problems of integrating scientometric methods into a qualitative study. Integrative attempts of this kind are poorly supported by the methodologies of both the sociology of science and scientometrics. Therefore it was necessary to develop a project-specific methodological approach that linked scientometric methods to theoretical considerations. The methodological approach is presented and used to discuss general methodological problems concerning the relation between (qualitative) theory and scientometric methods. This discussion enables some conclusions to be drawn as to the relations that exist between scientometrics and the sociology of science.

A methodological no man's land

Whoever tries to construct sociological explanations by using scientometric methods must cross a methodological no man's land that is circumvented by both the sociology of science and scientometrics. The current sociology of science generally shows little interest in methodological problems such as the range of applicability of different empirical approaches, the reliability and validity of methods, or strategies of generalisation. On the scientometric side of the no man's land there is a much more vibrant methodological discussion. However, this discussion focuses on the field's internal research questions and therefore does not provide a methodological basis that supports the application of scientometric methods to problems outside the field. Thus, neither field offers much advice on applying scientometric methods in sociological investigations. That is why a methodology is needed that facilitates sociologists' application of scientometric methods as well as scientometricians' addressing of sociological problems. In our view, the absence of such a methodology is one of the

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main reasons for the widening gap between the sociology of science and scientometrics that has been detected recently (*Leydesdorff* and *Wouters*, 1996: p. 23; *Leydesdorff* and *Van den Besselaar,* 1997: pp. 163–168; *Van den Besselaar*, 2000).*

With this article, we are endeavouring to contribute to the methodology of science studies by discussing our application of scientometric methods in the context of a sociological investigation of East German science transformation. This investigation will answer the question of how a scientist's integration into his or her community develops under conditions of rapid institutional change. It rests on a theoretical framework that combines a (neo)institutionalist approach to scientists' conditions of action with a synthesis of theoretical considerations on scientists' integration into their communities. These latter considerations have been provided by the older 'Mertonian' sociological approaches to scientific communities that are partially built upon scientometric investigations. That is why many empirical findings about scientists' integration into their communities have been supplied by scientometric investigations and why an application of scientometric methods in a study on scientists' integration into their scientific communities first suggested itself. When we designed the comparative analysis of scientists' integration into their communities, we attempted to integrate scientometric and qualitative sociological methods. In doing so we faced interesting methodological problems but found ourselves wandering into the aforesaid methodological no man's land. We had to develop our own methodological approach that linked our theoretical framework to scientometric indicators. In this article we present that approach in order to demonstrate how sociological theory and scientometric methods can be integrated. At the same time, we will discuss under which conditions (SCI-based) scientometric methods are applicable to the micro and meso-level actor constellations that are mainly addressed by the sociology of science. This discussion leads us on to the question of how scientometric methods can contribute to causal sociological explanations.

Since we report the methodological problems of work in progress here, the presentation of our study is limited to the investigation's theoretical framework, methodology and scientometric methods. We begin with an introduction to the project's research question, the theoretical and general methodological foundation. Thereafter, we provide a detailed discussion of how our theoretical concept 'integration into a scientific community' enables us to develop a strategy for 'measuring' integration by means of scientometric indicators. The application of scientometric methods is exemplified and the correspondence between scientometric and qualitative methods is discussed. Finally,

* Another important reason is the neglect of scientific specialties as a cognitive link between scientometrics and the sociology of science (*Gläser,* 2001).

we discuss the abovementioned methodological problems of applying scientometric indicators in sociological investigations and, more generally, of applying scientometrics in the sociology of science.

Empirical subject and theoretical question

The transformation of formerly socialist countries is being accompanied by several simultaneous processes of external integration into international social contexts, among them the integration of scientists into their international scientific communities. This does not mean that scientists in socialist states have not been internationally integrated to any extent. However, as several scientometric studies have shown, international integration under socialist conditions was limited in several respects. Socialist countries were seen to form a separate collaboration cluster in world science (*Braun* and *Schubert,* 1990) and in some subfields of physics (*Braun* et al., 1992). However, Eastern bloc scientists gave most citations to Western bloc scientists (*Lancaster* et al., 1992). Studies of language use in several subfields have found that the GDR and the USSR published more than expected in their domestic language (*Jagodzinski-Sigogneau* et al., 1982; *Lancaster* et al., 1992). For the GDR, weak international perception and domestic orientation have been observed by scientometric studies (*Braun* and *Glänzel*, 1990; *Grupp* and *Hinze,* 1994; *Czerwon,* 1997: pp. 140–141). The impact of political and financial restrictions has been retrospectively confirmed by several sociological studies (*Gläser* and *Meske,* 1996; *Meske* et al., 1997; *Gläser,* 1998).

With the political barrier disappearing, a change to this state of mute integration was to be expected.[*] A special case of rapid integration processes occurred in East Germany, where a very fast institutional transformation took place that triggered a simultaneous integration at both the national and the international level. At the national level, East German scientists became members of one of the world's largest national science systems.

International integration has been made possible by disappearing political restrictions, sought by many East German scientists and demanded by German science policy. It has been characterised by high demands being placed on East German scientists and has been accompanied for some scientists by specific institutional and financial support. Studying these special conditions and integration paths should enable

[*] This expectation has only partially become reality. The disappearance of political barriers was accompanied by severe cuts in science funding in all postsocialist countries (*Meske* et al., 1998). These cuts in funding actually overcompensated for the new opportunities provided by political freedom, as for example the declining numbers of publications by the USSR's successors' show (*van Raan,* 1997: pp. 292, 299).

a deeper analysis to be made of scientific communities' structural and cultural prerequisites for scientists' integration into these communities. Thus, the aim of our project is to explore what conditions facilitate or hinder the integration of scientists into their international scientific communities. Special attention is paid to several political and organisational measures that have been introduced in order to promote the integration processes. However, facilitating and hindering conditions might also be found in the scientific communities, in scientists' careers up to the start of the integration process, and in the integration paths themselves.

The project's theoretical starting point was a conceptual clarification of the collectivity into which a scientist is integrated. For nearly 20 years the sociology of science has ignored the meso-level of scientific activities, i.e., the level of scientific communities or specialties.[*] This ignorance is mainly due to the sociology of science's microsociological bent and the constructivists' focus on local practices of knowledge production. Because the sociology of science's mainstream – the sociology of scientific knowledge – is primarily interested in microprocesses of knowledge production, both theoretical and empirical interests in the meso-level of scientific communities have rapidly declined. Knorr-Cetina even deduced from her laboratory studies "the irrelevance, and indeed meaninglessness, of the notion of specialty communities in actual scientific work" (*Knorr-Cetina,* 1982: p. 117; see also *Callon* et al., 1983: pp. 191–192).[**]

In our study we departed from a line of thinking that regards scientific specialties as communities of scientists who directly or indirectly interact in the production of new knowledge about a common subject matter. The common subject matter may be a certain type of phenomenon such as superconductivity, a material or 'system' such as non-crystalline solids, or a type of method or instrumentation (*Whitley,* 1974: pp. 77–78). The idea of collective production was proposed early on by *Polanyi* (1962: pp. 1–3) and has been alluded to by *Merton* (1968: p. 59), but its consequences for understanding scientific work have never been systematically discussed. One important consequence (and the main difference to the mainstream in the sociology of science) is that scientists are seen as contributing components (knowledge claims) to a common

[*] Depending on research interests, empirical methods or pure convenience, the concepts 'scientific community', 'specialty', 'invisible college', or 'network' have been applied to various collectivities in science.

[**] The scientific community is, however, a social context that is strong enough to occur even in microsociological studies that try to avoid it. The two most obvious reflections of this context are the conceptualisation of experiments in High Energy Physics as "movable, semi-detached corporations" (*Knorr-Cetina,* 1995: p. 123) and the concept of "epistemic cultures" (*Knorr-Cetina,* 1999).

product. Peer review, publication and citation activities are attempts to introduce the components in the common body of knowledge by means of negotiating knowledge claims with the other producers, namely research colleagues (*Gläser*, 2001).

By providing 'raw material', 'means of production' and the target for contributions, a specialty's common body of knowledge is also the main 'device' for coordinating scientists' actions. This coordination is partly decentralised because it rests on scientists' individual perceptions of the common body of knowledge.

Decentralised coordination is closely linked with an interesting feature of specialties that is crucial for the problem of integration, namely the way membership in a specialty is established. Specialty membership is established in the specific way that is characteristic of communities as a type of social order. It is constituted by perception: a member of a community is one who perceives himself or herself to be a member. Thus, a scientist's own perception is sufficient to establish specialty membership. Ultimately, even the perception of one's colleagues is sufficient to establish membership: if a knowledge claim is perceived to be relevant and therefore is used, its creator is perceived as a relevant contributor to that collective knowledge production and thus as belonging to the specialty that makes use of his or her knowledge claim (*Gläser,* 2001).

It is because of the perception-based membership that specialties have "no inherent boundaries" (*Woolgar*, 1976: p. 234; *Chubin*, 1985: p. 224). The consequences for the problem of integration are obvious. A scientist's integration into his or her specialty is a complex relation between the individual and the social contexts provided by the specialty and depends on self-perception as well as on the perceptions of colleagues. Therefore it cannot be measured on a one-dimensional scale by characterising scientists as being 'more' or 'less' integrated. With regard to collective knowledge production, there is always a 'core' of closely interconnected main producers and a periphery of scientists who adjust their work to that of the core and contribute to the common body of knowledge to varying degrees. This relation between core and periphery is shaped by many factors, among them nationally provided resources, language, geographical distance, and culture. Therefore integration varies in several dimensions. Moreover, many scientists do not try to become 'core members' or members of the 'elite'. For these reasons it is obviously impossible to construct a yardstick for 'integration benchmarking'. Scientists strive for different states of integration, and differentiation is constitutive for a specialty.

A theoretical concept of integration must respond to the multidimensional character and the differentiation of the phenomenon. Having focused on the emergence and the growth of specialties, the older sociology of science has contributed little to the problem of scientists' integration into specialties. However, the foregoing theoretical considerations suggest an analytical differentiation of at least five different dimensions of integration:

1) Integration into joint knowledge production. Since specialties are collective producers of knowledge, the scientist's part in the knowledge production is of utmost importance for his or her integration. At this 'functional' level, integration depends on how a scientist's individual work is determined by his or her specialty's body of knowledge, how he or she contributes to that body of knowledge, and to what extent he or she participates in collaborative work.

2) Integration into exchange processes. Exchange in the context of knowledge production is primarily communication about knowledge claims. From the perspective of joint knowledge production, this scientific communication is essentially a dissemination of components. To be integrated into these exchange processes means to publish results that are used by others, to cite colleagues whose knowledge claims are used, and to exchange information with colleagues informally.

3) Integration into the sociostructure. This dimension of integration is described by the concepts 'stratification', 'status' etc. It refers to the social position a scientist has achieved in his or her specialty. This position is at least partly determined by a scientist's membership of informal networks.

4) Integration into decision-making. A specialty governs the work and interactions of scientists by informal, but nevertheless strong, institutions as well as by informal decision-making on the issues of resource distribution and acceptance of results. Integration along this dimension is determined by involvement in peer review processes and other forms of informal and formal decision-making.

5) Integration into culture. Specialties develop a specific culture that is formed by cognitive styles, values, attitudes and belief systems. To be integrated means a scientist has adopted this culture.

The actual state of a scientist's integration depends mainly on his or her actions, that is their knowledge production, decision-making and communication. The conditions that influence these actions are produced by different environments, including at least a local organisational context, a national context and the specialty itself. The organisational and the national context provide the resources necessary for knowledge production and hence integration. Furthermore, they produce sociostructural, institutional and cultural conditions that affect scientists' integrative behaviour. Conditions of actions provided by a specialty are cognitive structures of its common subject matter, informal institutions (rules of experimentation, a specific language, rules concerning co-authorships etc.), social stratification and so on. Relevant conditions of actions are partly described by the degree of integration a scientist has achieved so far. Since further integration depends on achieved integration, integration must be regarded as a path-dependent process.

Beside these different external conditions, a scientist's goals, interests and attitudes affect integration, too. How scientists perceive, evaluate and change their social relations in their specialty depends partly on their prior socialisation, a fact that reinforces the path-dependent character of integration.

The influence of these different conditions on integration is mediated by scientists' actions. Figure 1 gives an overview of the analytical framework that has been developed for studying integration.

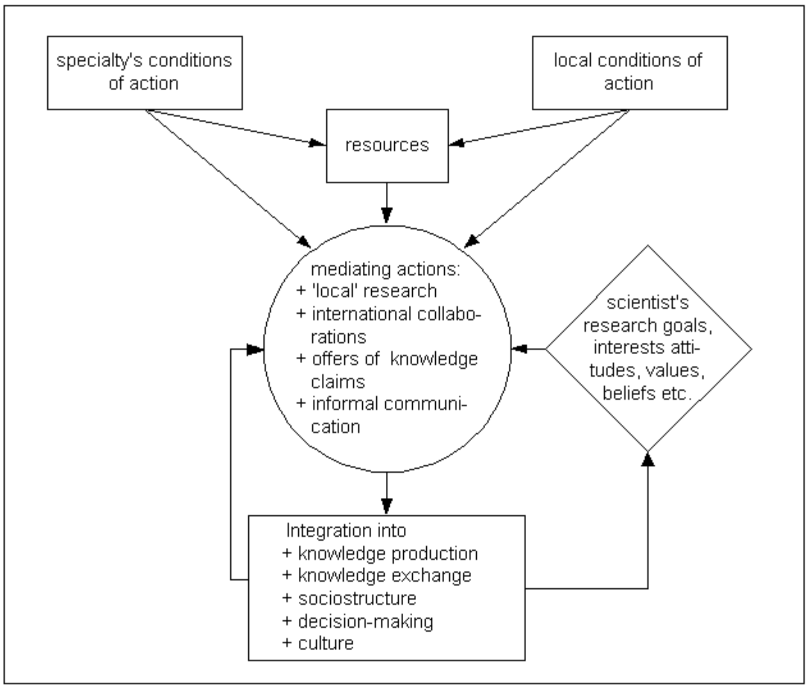

Figure 1. Variables and assumed causal relations regarding a scientist's integration into his or her specialty

The empirical investigation combines a secondary analysis of qualitative interviews with scientometric analyses. Interviews with East German scientists and West German colleagues working in East German research institutions have been conducted in several projects. A common topic of these projects has been the interviewees' integration into their specialties.

A computer-aided qualitative content analysis of selected interviews is currently being conducted. The variables described above are used to extract information about scientists' integration at different points in time, their actions in response to integration, and the conditions of action provided by the different social contexts. This secondary analysis of interviews is being supplemented by scientometric analyses of the interviewees' publication behaviour and received citations (see next section).

Integration of scientometric methods into the study of scientists' integration

General methodological framework

A crucial aim of our investigation was to determine the state of scientist integration. From our theoretical considerations it was clear that there is no 'typical' or 'average' integration but a variety of different 'integrations'. Moreover, in order to explore the impact of the different conditions on integration, their variation had to be taken into account, too. Therefore, it was necessary to treat each scientist as an individual case and look at his or her individual 'integration history'.

A scientist's integration into a specialty as discussed earlier, is only partially observable with the methods we were able to apply. Table 1 shows the aspects of integration we are trying to investigate and the indicators and methods we are applying. Generally, we are using three different kinds of information: complex self-assessments of their integration by the scientists, information about certain facts that are relevant to integration, and scientometric indicators. For reasons of space, we cannot fully outline the translation of our theoretical framework into an empirical approach. We must limit our detailed methodological discussion to the 'measurement' of one variable (integration) and concerning this variable, to the application of a partial set of our methods (scientometric methods).

Table 1
Table of indicators and methods

Aspect of Integration	*Indicators*	*Methods*
Integration into the collective production of knowledge	Self-assessment; evaluation by others	Analysis of evaluation protocols; interviews
	Number of publications Impact factors of publications Number of citations International co-authorships	SCI-based scientometric methods
	Conference attendance	Interviews
Integration into informal networks	Invited presentations	Interviews
	Research visits	Interviews
Integration into decision-making	Work as reviewer	Interviews
	Member of conference committees and editorial boards	Interviews

The central assumption that underlies this application of scientometric indicators is that journals represented in the SCI data base (in our case, in the CD-Rom version) represent the specialties' main communication channels, that is the arena in which knowledge claims are negotiated. It is assumed that it is impossible to be integrated in the sense we have defined in our analytical framework *without* publishing and being cited in SCI journals. To avoid distortions by the basic/applied character of the field, we excluded applied specialties from the scientometric analysis. A short test showed that there are indeed not many publications from these applied scientists. An early finding of one empirical study (*Meske* et al., 1997) was that scientist integration into applied science must be analysed by means of other indicators.

The combination of scientometric methods with other sociological methods is a widespread practice. However, most combinations are eclectic in that different phenomena are investigated using the different methods, such as formal and informal communication (*Chu*, 1992a; 1992b), publication output and reasons for selecting journals for publications (*Rey-Rocha* and *Martín-Sempere*, 1999), or productivity and international contacts (*Kyvik* and *Larsen*, 1994). Moreover, in most cases, scientometric methods are combined with quantitative sociological methods (surveys), as has been the case in all three studies referred to above.

Theoretical and methodological foundation of the scientometric indicators applied

As Table 1 indicates, our application of scientometric indicators is based on the assumption that publication behaviour and citations tell us something about a scientist's integration into the collective production of knowledge. This assumption needs to be theoretically and methodologically justified by determining (a) which aspects of knowledge production can be measured by the indicators that are to be applied and (b) how the measured aspects relate to the investigation's theoretical framework. Therefore, we looked for a conceptual foundation that explained the relations between knowledge production, publication and citation. Unfortunately, neither the sociology of science nor scientometrics offers much in this direction, the former because of its current microsociological focus and the latter because of its focus on quantitative aspects of science. Since we felt it necessary to apply scientometric indicators, we had to bridge the gap between sociological concepts (in our case, the concepts of knowledge production, common body of knowledge, exchange of knowledge etc.) and scientometric indicators by means of our own methodological considerations. Below we present these methodological considerations for each scientometric indicator and illustrate them using selected empirical data.

In a system of collective knowledge production, publications and presentations at conferences offer knowledge claims that are components, that is they are offered to be integrated into the common body of knowledge. This idea has been suggested by Price's 'jigsaw puzzle' of scientific papers (*Price*, 1981: p. 12–13). However, adding new knowledge does not mean simply writing a paper that fits into the jigsaw puzzle. The authors' knowledge claims include the description of the gap that is to be closed by the new knowledge. They offer a description of how the new knowledge has been produced and suggestions about any new gaps that may follow from the closure. These contributions always rest on an interpretation of existing empirical, methodological and theoretical knowledge. Thus, a publication offers both an interpretation of the existing knowledge and (at least) one new knowledge claim. This has been empirically confirmed by citation context analysis, which has studied whether and how knowledge claims of cited papers are used (e.g. *Chubin* and *Moitra*, 1975; *Moravcsik* and *Murugesan*, 1978; *Oppenheim* and *Renn*, 1978, *Small*, 1978; *Amsterdamska* and *Leydesdorff*, 1989). Both the provided interpretation of existing knowledge and the new knowledge claims proposed are subject to continuous negotiation, and one important way these negotiations proceed is through mutual reference by means of citation. The social character of negotiation about knowledge claims opens up the broad area of micromotives for single citations, but the fact that knowledge claims are negotiated simultaneously limits the actual citation behaviour.

To be integrated into this system of collective knowledge production means that scientists publish, cite other papers and are themselves cited. Since in many specialties collaborative work is a common phenomenon, a scientist's integration should be indicated by international co-authorships as well.

For reasons we have explained earlier, it is impossible to establish a specialty's 'average integration value' in the form of an average publication or citation rate. Thus, the attempt to measure a national subspecialty's international integration by comparing the number of national and international citing authors (*Jiménez-Contreras* and *Ferreiro-Aláez,* 1996) is questionable. There is no theoretical justification for the authors' assumption that a national subspecialty is integrated if it receives citations from as many foreign authors as from domestic ones. Many authors have observed that national science systems may be highly fragmented and scientists cite the members of the international core rather than colleagues from their own country (*Macías-Chapula,* 1992; *Godin* and *Ippersiel,* 1996). In those cases, it was possible to observe an equally low proportion of foreign and domestic citing authors, whose relation would, in the view of Jiménez-Contreras and Ferreiro-Aláez, indicate integration. Similar considerations could be applied to individual scientists: a scientist who receives citations from two foreign and two domestic authors would be regarded as integrated, while a scientist who is cited by 20 domestic and 15 foreign authors would not.

While there are no absolute scientometric measures of integration, the individual scientist's publication and citation history has been expected to indicate how integration develops over time. To study these integration histories we tried to apply the indicators listed in Table 1.

Publications. As a first step, scientist integration into knowledge production was measured by numbers of publications per year. Any publication in a SCI journal implies the existence of several social relations. Firstly, the scientist who publishes offers an interpretation of a specialty's body of knowledge and one or more knowledge claims he or she believes to be new. This means the scientist perceives himself or herself as belonging to the respective specialty and, therefore, actually *is* a member of this specialty. Secondly, the publication will have been accepted by the editors and (in most cases) by one or more reviewers. Thus, at least two or three peers with gatekeeper functions also perceive the scientist as belonging to their specialty.

We counted published original research results found in the SCI data base (articles) and excluded notes, reviews, and letters. Data were collected for each scientist from 1985 to 1999. This was possible because most scientists in our sample were older than 30 in 1985. At this age, the GDR's scientists had usually embarked on their PhD and, by international standards, should have been starting to publish. It was necessary, however, to control for age because publication dynamics vary with career stages. Homonyms could be controlled for because scientists' fields and addresses were known. Variations in address due to research stays abroad could be validated by using both biographical data from the Internet and reports in interviews. It was possible to distinguish three groups of scientists according to the integration dynamics. A first group consisted of scientists that had already published in SCI journals before unification and increased their output thereafter. A second group began publishing in SCI journals after German unification, the first hint of a significant change in their integration history. A third, comparatively small, group consisted of scientists that have not published regularly either before or after German unification. For the purposes of illustration we selected scientists who represent the three groups (Table 2).

Table 2
Number of publications per year for six scientists of the sample (S1…S13)

	85	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**
S1	**3**	**6**	**3**	**1**	**2**	**5**	**2**	**3**	**4**		**1**	**5**	**5**	**7**
S2		**3**		**2**	**4**	**4**	**1**	**1**	**6**	**3**	**9**	**11**	**14**	**8**
S6							**2**		**1**	**1**	**1**	**1**	**4**	**2**
S7			**2**					**2**	**1**	**3**		**3**	**1**	**4**
S12	**1**	**3**												
S13	**1**			**1**						**1**				

Impact factors. Although publication in a SCI journal undoubtedly implies a provision of knowledge claims it does not say much about the contribution that is actually made. Therefore, we tried to determine the dynamics of knowledge claim placement by tracing the *average journal impact factor of a scientist's publications*. However, a scientist's journal impact factors cannot be accumulated this way because the impact factor neglects the variation in the cited half-lifes of journals. Since the measurement error for a journal's impact factor depends on the relation between cited half-life and the two-year period that is used to calculate the impact factors, we have an unknown and varying error at the individual level. Therefore it is impossible to use aggregate impact factors as indicators for changes in the placement of an individual scientist's contributions. The difficulties of aggregating or even comparing the impact factors of journals from different fields seriously diminish this indicator's applicability for sociological investigations.

Citations. If other scientists perceive that a knowledge claim has been presented that is relevant to their own work, they indicate this perception by citing the knowledge claim's source. This statement seems to be the weakest possible interpretation of what is measured by citations: Citations indicate perceptions of relevant knowledge claims. Citation content analysis confirms this interpretation in that all categories applied (including perfunctory or historical citations) indicate at least that citations signal perceptions of relevance.

As citation context analysis has also taught us, citations do not necessarily indicate that knowledge claims are actually used and this way become integrated into the common body of knowledge. Such an integration of knowledge claims could be assumed if several citations have been given by more than one colleague. But even in this case the possibility remains that perfunctory citations have been given for work that duplicates important mainstream research. The only reliable indicators for the use of a scientist's contributions by his or her colleagues are very high numbers of citations (highly cited papers), eponymy or a confirmation of use by citation context analysis. For reasons of time and resources, only the number of citations can be applied in our investigation. Unfortunately, the correlation between numbers of citations and actual use of knowledge claims has not yet been investigated. This would require a combination of citation context analysis and citation counts.

Thus, the perception of a knowledge claim is a necessary but not a sufficient condition for its use. Therefore, it is not justified to conclude from citation counts a common body of knowledge. That is why we applied the indicator 'citation' exclusively as a measure of how East German scientists' knowledge claims are perceived by their wider specialty.[*] This use of citations as indicators of scientists' integration is different from the usual application of citations as measures of influence or impact that ultimately rests on the assumption that citations indicate an integration of knowledge claims. Our 'weakest possible interpretation' justifies the application of citations on the micro-level.

Citation data were obtained by identifying all publications of a scientist between 1985 and 1998 and tracing their citations via the first author, beginning in 1987. Self-citations were excluded. Since we expected that the breakdown of the socialist world system would impact on citation behaviour, we investigated not only whether the

[*] Because of this parsimonious interpretation of citations it is justified to disregard the variation in the content of citations: affirmative, rejective and even perfunctory citations indicate at least a perception of knowledge claims, possibly negotiation about knowledge claims and therefore integration of the *producers* of the knowledge claims.

Table 3
Citations received by the six scientists of the sample (grey fields indicate that at least one citation has been given by an author outside the former socialist system)

	87	88	89	90	91	92	93	94	95	96	97	98
S1		6	5	1	1	1	1	4	4	5		3
S2		3	3	2	6	9	5	5		13	6	22
S6							1		2	1		
S7									1	7	5	2
S12				1								
S13	2										1	

scientists are cited but also by whom they are cited, thus trying to detect a changed perception in the Western core of the specialty. At first glance, the citation pattern confirms the grouping that originated from the publication counts (Table 3).
Two scientists were continually cited by Western colleagues from abroad, and today these scientists receive the most citations. Other scientists who have regularly published in SCI journals received citations only after German unification. This might be due to a change in the language of publication* or a change in the place of publication, or caused by international contacts that support perception in formal communication channels (*Chu*, 1992b). Naturally, the scientists who do not publish are not cited. Finally, the scientists who began to publish in SCI journals mainly after German unification began to receive citations, too. However, in this group we also find scientists who do publish but receive no citations. This is not surprising because such a state of (low) integration is quite common: many scientists will publish but not be cited.

Co-authorships. The integration into collaborative research was analysed by *co-authorships*. There is certainly no isomorphic relation between collaboration and co-authorship: not all co-authors are necessarily scientists who have contributed on a collaborative basis to the scientific findings published, nor are all collaborative contributions acknowledged by granting a co-authorship. However, it has been confirmed that certain contributions (especially creative contributions) are usually rewarded with a co-authorship (*Laudel*, 2001). Moreover, it is very unlikely that

* A general trend to English as the language of publication has been observed for the remaining East German SCI journals (*Czerwon*, 1997).

international co-authorships with formerly unknown East German scientists are constructed for social reasons without any basis in collaborative research. Thus, if international co-authorships are identified, there is a high probability that it refers to collaborative research.

International co-authorships indicate a high level of international integration for several reasons. Firstly, they indicate that the contributions of East German colleagues meet the expectations of his or her international collaborators with regard to both content and quality. Secondly, they indicate repeated personal contacts and continuous informal communication between the collaborators. Thirdly, frequent and continuous co-authorships indicate a repeated choice of the East German scientist as collaborator. This fact, in turn, hints to the East German scientist's acculturation and integration into informal networks.

Table 4 reveals the co-authorships of the six scientists from our sample. Since unification, the scientists who have always been integrated have started to collaborate with West German scientists and colleagues from the international scientific community. Scientist S2 is an especially interesting case because a comparison between his publication and co-authorship records reveals a change in research practice and publication behaviour. S2 obviously published mainly as a sole author until 1989 and in 1991. From 1992 on all his publications in SCI journals have been multi-authored articles. The newly integrated scientists have collaborated with Western scientists once special institutional arrangements supporting such collaborations had been set up in the middle of the 90s. The non-integrated scientists have not any authorships and therefore no co-authorships at all. Again, the correspondence is not perfect in all cases because some scientists publish and are cited, but have no international co-authorships.

Table 4
Co-authorships of the six scientists of the sample
(grey fields indicate that at least one co-author is located outside the former socialist system)

	85	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**
S1	3	6	3	1	2	5	2	3	4			5	5	7
S2		3				4		1	6	3	9	11	14	8
S6							2							2
S7								2		3			1	4
S12														
S13				1										

Relations between scientometric and qualitative data

Qualitative data on scientist integration in the collective production of knowledge were obtained from the scientists' self-assessment of their integration given in interviews. In some cases, this self-assessment could be supplemented by statements from other scientists, especially referees, whose judgements were obtained from evaluation protocols. For additional information we used statements about conference attendance, invited presentations, and visits of other research groups. This information was obtained by the interviews and validated by information from official annual reports of the institutions. Activities such as reviewing research proposals and journal articles, as well as memberships of conference committees and editorial boards were used as indicators for the integration into a community's decision-making.

Table 5
Corroboration of scientometric data by qualitative data

Indicators	**Scientist S7**	**Scientist S12**
Publications in SCI journals	Several SCI publications, almost continuous production	None
Co-authorships	With West German and foreign (Western) authors	None
Citations	Yes	None
Frontline research	Yes	"Invisible so far", funding cancelled after 3 years
Conference attendance	Regularly	Only national conferences, one international conference held in Germany
Research stays abroad	Yes	No
Invited presentations	Yes	No
Work as reviewer of SCI journals	Regularly	One article
Work as reviewer of grant proposals	Regularly	No
Membership of editorial Boards	No	No

By combining qualitative and quantitative (scientometric) methods it was possible to obtain a more complex picture of scientist integration dynamics. Furthermore, since the integration into knowledge production was investigated by both scientometric and qualitative methods, it was possible to corroborate results. The qualitative data on cognitive and social integration of our sample scientists confirm the scientometric indicators. The general picture of the corroboration of scientometric data by qualitative data is shown in Table 5. Scientist S7 became integrated after the special institutional measures for supporting integration were set up. Scientist S12 is characterised by a constant level of non-integration.

Referees described S7 as conducting frontline research. S12 was described as "invisible so far". The further funding of his project was cancelled after 3 years. S7 regularly attends conferences in Germany and abroad. S12 attended only 1 international conference and this was held in Germany. The same pattern is revealed with regard to the other indicators: stays abroad, invited presentations, work as reviewer for publications and for grant proposals. The only thing scientist S7 has not as yet achieved is membership of an editorial board.

It goes without saying that the clear-cut picture provided by our data on sample scientists and especially by Table 5 is not representative for the whole range of data and combinations of data. There are grey areas between the types presented here, and there are contradictions between some qualitative findings and scientometric data, too. For example, there is often a significant time lag between integration into knowledge production, on the one hand, and integration into informal networks and decision-making, on the other.

Integration of scientometrics and the sociology of science

Our attempt to integrate scientometric indicators into a sociological investigation has raised methodological questions on two different levels. The first level is essentially technical and relates to how the indicators should be applied, what counts as a publication, etc. These technical decisions have been described in the previous section. They affect both the validity and the reliability of our ‘measurement’ of integration. The ongoing methodological discussion in the field of scientometrics offers a strong background here.

On a second level a connection must be made between the theoretical question and the scientometric indicators that are used to produce the necessary data. This more strategic methodological level should be addressed by both the sociology of science and scientometrics. However, we found them almost void of answers. Not only has the sociology of science no idea about how to investigate science using scientometric indicators, scientometrics too is at a loss as to how its indicators could be rooted in sociological theory. The latter holds true despite the sometimes heated methodological discussions witnessed in scientometrics - by and large these discussions have completely different focuses. To illustrate this problem, we take the example of a 'theory of citations' that has recently gained much attention (*Luukkonen,* 1990; 1997; *Leydesdorff,* 1998 and comments; *Leydesdorff* and *Wouters,* 1999). The application of citation measures in sociological investigations presupposes that two questions can be resolved:

– Firstly, it must be established *what* can be measured by citations, i.e., which sociologically relevant features of scientific work and interactions between scientists are reflected by citations. Scientometrics has narrowed down this discussion to the question of whether citations measure impact and whether impact can be related to quality or performance. This focus has been facilitated by an increasing orientation of scientometrics towards science policy. We will not go further into this debate but simply mention that *Nederhof* and *van Raan* (1987) have provided a convincing answer to this question, namely that it is highly implausible to assume that citations are granted arbitrarily, i.e. independent of an article's actual impact. Our main concern is the different focus of the sociology of science: While 'impact' and 'quality' are politically important features of scientific work, they are seldom of interest to the sociology of science. As we have tried to demonstrate with our example, the sociology of science is much more interested in the intellectual and sociological embeddedness of scientists, for example their provision and perception of knowledge claims, the relations between knowledge production and rewards, etc. Citation measures can contribute much to sociological investigations in this area. However, the citation debate must shift attention from the justification of evaluations to the question of what aspects of scientists' actions are reflected by citations and how citations relate to other features of scientific work, say, to features that are observed qualitatively. In our example, we assumed that a citation at least reflects the citing scientist's perception of the cited colleague as being engaged in the same collective enterprise. That is why citations could be used as empirical indicators for our theoretical concept 'integration'. Moreover, the definition of integration linked scientometric indicators to qualitative data collected from peer evaluations and scientists' descriptions of their scientific activities.

– The second question is *how* citations measure what they are supposed to measure. Whatever the indicator 'citation' is intended to measure, the question arises as to what kinds of errors have to be taken into account. This aspect of scientometrics' 'microfoundation' has been addressed by *van Raan* (1998: p. 136) who compares the relation of scientometrics to a microtheory of citation with the relation of phenomenological thermodynamics to statistical physics. We agree with him when he argues that scientometrics cannot and must not develop a microtheory that explains every single citation. However, we think that van Raan is overly optimistic with regard to our knowledge about the distribution functions of the characteristics of citations. Research into establishing a typology of citations has ceased, and today we simply do not know how affirmative, rejective, perfunctory citations and the like are distributed, let alone how distributions vary between fields.[*]

Consequently, the knowledge accumulated by citation context analysis is not applied in 'normal' citation count-based studies (as has been observed by *Luukkonen,* 1990). The lack of knowledge about the distribution of different types of citations might be unproblematic for evaluations, though we doubt even this. In most sociological investigations, knowledge about variation as it affects citations is necessary. In our own study, we worked around this problem by interpreting all citations in their weakest sense – as 'perception'. However, this solution may severely limit other sociological investigations.

Scientometric 'theories of citation' answer none of these questions. This suggests a danger of separate scientometric theorising. This theorising naturally starts with a phenomenon that is of central concern to scientometrics - in this case, citation. However, this phenomenon is not necessarily a suitable starting point for the construction of a theory. In the case of a scientometric 'theory of citation' the wrong starting point leads to a neglect of the knowledge production in which citations are embedded and consequently to a lack of methodological support for the application of citation measures in investigations of knowledge production. As Small has stated, "a theory of citation makes sense only as part of a larger theory of how science and scholarship work" (*Small,* 1998: p. 143).

Thus, scientometrics' neglect of methodological links to sociological theories seems partly due to the emergence of a separate scientometric theorising. This becomes clear if one applies the good old sociology of science to scientometrics. As could be seen in the discussion on a 'crisis' in scientometrics (*Glänzel* and *Schöpflin,* 1994 and comments), at least two completely different self-conceptions are applied by scientometricians. Scientometrics is sometimes regarded as a 'substantive' specialty that studies quantitative aspects of science and uses these data to construct theories of science. From this perspective, either scientometrics can be criticised for a lack of basic research, insufficient theoretical integration etc. (*Glänzel* and *Schöpflin,* 1994; *Peritz,* 1994; *Russel,* 1994) or scientometrics can be perceived as being in a healthy state (e.g., *van Raan,* 1994; *Griffith,* 1994). Another self-conception is that of a specialty that has

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[*] We agree with *van Raan* (1998) that it is important to establish distributions for the cited paper. However, this means answering the question of how often a paper can be assumed to be cited for the different reasons revealed by citation context analysis.

been cognitively institutionalised around a set of methods (see for example *Le Pair*, 1994: p. 519; *Barre*, 1994: p. 423). The latter perspective seems to be much more apposite because it is neither realistic nor appropriate to expect scientometrics to produce theories of science (*Kretschmer*, 1994: p. 535). Scientometric methods produce very specific data on science, and it would take a very lucky coincidence to build theories from these data alone. The expectations regarding theory-building arose only because the sociology of science left a vacuum in scientometrics' most important research object, namely specialties (*Gläser*, 2001). However, as we tried to show with the example of citations, theories built by scientometrics alone cannot meet the complexity of social activities in science.

To identify scientometrics as a method-centred specialty does not solve the problems that are discussed as a 'crisis', but it does change their location. They are no longer internal problems of scientometrics but problems of the relation of scientometrics to the sociology of science as the most important 'substantive' specialty related to scientometrics. As we have tried to show in explaining our empirical study, two important links between both fields have become weakened:

Theoretical foundations of scientometrics

In method-centred specialties, theories are borrowed from 'substantive' specialties and developed only to the extent that is necessary as a foundation for applying the methods. Nothing more, but also nothing less, should be expected from scientometrics. However, the sociological meanings of concepts like 'specialty', 'network' etc. have seemingly disappeared and been replaced by either a 'common-sense' or an operational understanding that identifies the concept with what is measured by certain indicators. As Griffith has observed: "Much of scientometrics appears defective methodologically, but is actually defective theoretically" (*Griffith*, 1994: p. 491). These reductionist approaches are facilitated, if not enforced, by the current microsociological theorising in the sociology of science that neglects the links between micro and macroprocesses. We completely agree with van Raan, who has complained that the current sociology of science is "offering too little and asking too much" (*van Raan*, 1998). Thus, the lack of methodological foundation is by no means a fault of scientometrics alone. A sociological theory of science that can frame the scientometric indicators and guide their application is currently lacking. We have tried to show that certain of the ideas of the older sociology of science offer more promising material for the theoretical foundation of scientometrics than current theorising does.

Application of scientometric methods in sociological investigations

Although method-centred specialties contain pure methodological and even technical research, they develop in close association with the 'substantive' specialties in which the methods are applied. The demands of these 'substantive' specialties act as a driving force that is as important as the internal dynamics of method-centred specialties. This *scientific* 'demand-pull' seems to be missing in the case of scientometrics. Important as it is, the application of scientometric methods for science policy provides only a highly specific demand-pull that seems insufficient to guide the field. Moreover, the internal dynamics of scientometrics leads primarily to new descriptions. The classic search for causal explanations that is realised by quantitative sociological methods plays only a minor role in scientometrics: hypotheses are not tested, nor are statistically significant associations that contribute to sociological explanations pursued. However, descriptions that are accumulated cannot be the basis for the development of a specialty in the long run.

Thus, from the perspective of scientometrics there are good reasons for a re-marriage of scientometrics and the sociology of science - even if this means for scientometrics marrying the current sociology of science's grandmother. If scientometrics wants to remain a scientific field (and not merely a technological community of people applying standardised methods), it must contribute to explanations in science studies. Such contributions are possible only if scientometrics is theoretically and methodologically rooted in the sociology of science. From the perspective of the sociology of science we would like to add another reason that is purely egotistical: we think that scientometric methods can produce unique data that help furnish answers to sociological questions. Therefore we want the field to stay near.

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