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Outsiders, Peers and Stars: Analysing Scientists' Integration into Scientific Communities with Scientometric Indicators

Paper presented at the Second Berlin Workshop on Scientometrics and Informetrics/ Collaboration in Science and in Technology, 1-4 September, 2000, Hohen Neuendorf, Germany.

1. Introduction

During the last decades, the distance between the sociology of science and scientometrics has grown. This is unfortunate because scientometric methods can be a useful tool and should therefore be applied more often and more systematically in the sociology of science. In order to promote dialogue between the two fields, we will describe how we included scientometric indicators in our empirical investigation and discuss some of the methodological problems that arose. The aim of our project was to answer the following question: How does a scientist's integration into his or her scientific community change under conditions of rapid institutional change? When we tried to integrate scientometric methods into our study we struck some problems regarding their applicability to individual scientists and their communities. Therefore, we will consider hereunder which conditions SCI-based methods are applicable on the micro- and meso-levels mainly addressed by the sociology of science. This discussion leads us to an even more fundamental question. The growing gap between scientometrics and the sociology of science is at least partially due to their seemingly incompatible methods: While scientometric methods are quantitative by their nature, the sociology of science – especially theory-driven sociology of science – favours a qualitative approach. Thus the question arises under what conditions scientometrics can contribute to sociological explanations.

2. The theoretical problem: Scientists' integration into their communities

Our question about how scientists integrate into their communities grew out of several projects that focused on the transformation of East German science. After German unification, several science policy mechanisms were set up to promote East German scientists' integration into their national and international scientific communities. An empirical investigation of the institutionally promoted integration process enables theoretical questions to be answered about the dynamics of a scientist's integration in his or her scientific community under conditions of rapid institutional change. As a starting point, a conceptual scheme is necessary that makes it possible to determine indicators for scientists' integration into scientific communities and to select empirical methods for the investigation.

It is important to regard a scientific community as an actor constellation of scientists who directly or indirectly interact in the development of a common body of knowledge by producing new knowledge and changing existing knowledge. From this follows that scientific communities are collective producers and scientists (or research groups) only contribute components to the common product. This idea is recurrent in the sociology of science (Polanyi 1962; Chubin 1976; Hagstrom 1976; Whitley 1974, 1982) but never gained enough attention. Instead, the market-like perspective has dominated in which scientists are regarded as local producers of knowledge, each competing for the recognition of their respective knowledge claims. However, this perspective can explain neither the growth of knowledge nor the social dynamics of scientific communities (Gläser 2000).

Scientific communities are internally structured by institutional boundaries (Laudel/ Gläser 1998). One important type is the system of national institutional boundaries. These are produced by the national institutions involved in funding and peer review and, last but not least, by languages. They delineate national subcommunities within an international scientific community. For similar reasons, a 'socialist subcommunity' was defined by existent political and financial institutional boundaries until the end of the 1980s (Diagram 1).

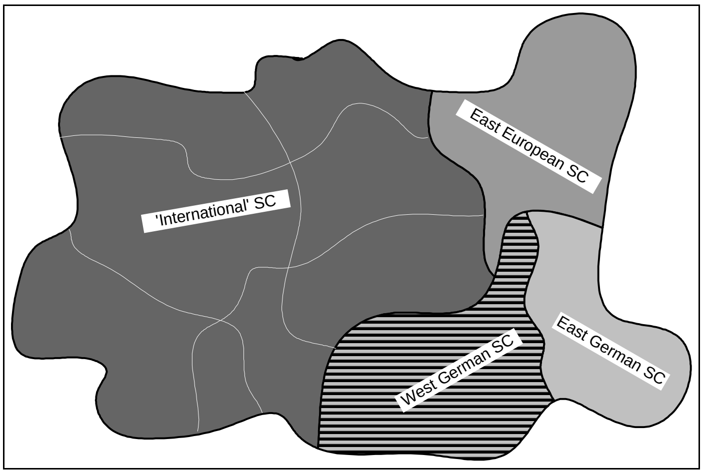

Diagram 1: Scientific communities' internal structuring by institutional boundaries

A scientist's integration into a scientific community can be understood as the extent to which he or she has built up cognitive and social relations that are typical for the community. The cognitive dimension describes integration into collective knowledge production, i.e.

- the extent to which the scientist selects problems that are regarded as important by the community,

- contributes knowledge that is regarded as important and meets the community's standards, and
- collaborates with other members of the community.

The social dimension describes the extent to which a scientist is integrated into the informal networks that maintain collaborations, attempt to direct the specialty's research by promoting or hindering certain research trails and determine resource allocation. An important mediating variable between the cognitive and social dimensions of integration is the scientist's status, which is based upon recognition as well as prior integration into informal networks.

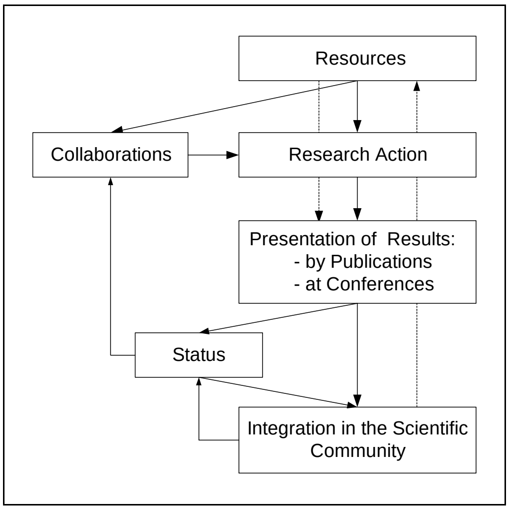

Diagram 2: Hypothetical causal model

Based on experience gained from the sociology of science, a hypothetical causal model can be proposed that describes influences on a scientist's integration into his or her community (Diagram 2). Integration depends primarily on the scientist's research activity and those results offered as publications, conference papers, etc. The research activity depends on funding, available collaborations and, ultimately, on the level of integration that has been achieved so far. In empirical investigation, the integration and its changes must be measured and the institutional influences' impact on integration uncovered.

3. Empirical investigation

Since integration concerns a scientist's relation to his or her community, its measurement must be conducted at the micro-level. To encompass the complexity of this variable, we used a combination of qualitative interviews and scientometric methods. Table 1 provides an overview of the indicators and methods that were used.

Aspect of Integration	Indicators	Methods
Integration into the collective production of knowledge	Self-assessment; Evaluation by others	Analysis of evaluation protocols; Interviews
	Publications in important journals Citations 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

Table 1: Indicators and methods used in the empirical investigation

Qualitative data about scientists' integration into the collective production of knowledge were the scientists' self-assessment as given in interviews and an assessment by other scientists, in particular by referees (obtained from evaluation protocols). The scientometric indicators applied were publications in SCI-journals, co-authorships, citations and the journals' impact factors. As additional information we used conference attendance, invited presentations and visits to other research groups. This information was obtained in the interviews and validated using the institutions' reports. Activities such as reviewing research proposals and journal papers, and membership in conference committees and editorial boards were used as indicators for integration into a community's decision-making processes. The institutional mechanisms and their effects were explored in the qualitative interviews.

4. Results

Our first and most simple scientometric indicator for integration, the number of publications in SCI-journals, already enabled us to identify three possible groups of scientists:

- Scientists who were already integrated prior to unification and who have improved their integration by using the supportive institutional arrangements after unification.
- Scientists who were not integrated before unification and whose integration has substantially increased under conditions of specific institutional support.
- Scientists who were not integrated and remained so despite institutional support.

For purposes of illustration, we selected six scientists from our sample. Their integration can be expressed by scientometric indicators (Table 2).

	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**
S3							**2**		**1**	**1**	**1**	**1**	**4**	**2**
S4			**2**					**2**	**1**	**3**		**3**	**1**	**4**
S5	**1**	**3**												
S6	**1**			**1**						**1**				

Table 1 Number of publications per year for six East German scientists

Publication dynamics were measured using SCI analyses over a period of 14 years. On top we find those scientists who have always been integrated, in the middle those whose integration has significantly increased, and below the scientists who remained at a level of non-integration.

The scientists' individual integration patterns were confirmed by the other scientometric indicators. Since a publication's reception depends on the journal's importance, we attempted to use the Journal Impact Factor. However, we had to exclude this indicator for methodological reasons that will be explained below (see Section 5.)

The community's perception of a given scientist was measured using citation analysis (Table 3). This should reveal whether a scientist is cited at all and, if so, by whom. We used citing authors' addresses in order to locate them in one of the international community's segments (see Section 2.). The grouping of scientists by publication activities is confirmed:

- Scientists who have always published have always been cited by colleagues from all over the world. These scientists receive the most citations today. Their citation by West German colleagues has increased.
- Scientists who had not been cited often before 1990 but whose publication activity has significantly increased since 1990 are today cited significantly more frequently.
- Quite naturally, the scientists who have rarely published have received almost no citations over the whole period.

	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
S3							1		2	1		
S4									1	7	5	2
S5				1								
S6	2										1	

Table 2 Citations received by the six East German scientists (grey fields indicate that at least one citation is granted by an author outside the former socialist system)

Integration into collaborations was analysed on the basis of co-authorships (Table 4). After unification, those scientists who had always been well integrated began to collaborate with West German scientists (i.e. colleagues from their new national scientific community) and colleagues from their international scientific community. The newly integrated scientists have collaborated with Western scientists since the mid 1990s, when special institutional arrangements were set up. The non-integrated scientists have no co-authorships with new partners at all.

	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
S3							2							2
S4								2		3			1	4
S5														
S6				1										

Table 3 Co-authorships of the six East German scientists (grey fields indicate that at least one co-author is located outside the former socialist system)

The qualitative data obtained about cognitive and social integration confirm the scientometric indicators. In order to give an overall picture of these qualitative data, the integration of two scientists at the time of the interview is compared in Table 5 below: Scientist S4 became integrated after special institutional measures for supporting integration were set up. Scientist S5 is characterised by a constant level of non-integration.

Indicators	Scientist S4	Scientist S5
Publications in SCI journals	Several SCI-publications, impact factor ca 1	None
Co-authorships	With West German and foreign (Western) authors	None
Citations	Yes	None
Research at the frontier	Yes	"invisible to date", funding was cancelled after 3 years
Conference attendance	Regularly	Only national conferences, apart from one international conference held in Germany
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

Table 5: Comparison of two scientists' integration as described by quantitative and qualitative indicators

Referees described S4 as conducting research at the frontier. S5 was described as "invisible to date". The further funding of his project was cancelled after three years. S4 regularly attends conferences both within Germany and abroad. S5 has attended only one international conference, which was held in Germany. The same pattern can be observed with regard to the other indicators: stays abroad, invited presentations, work as a reviewer for publications and for grant proposals. The only thing scientist S4 has not achieved at this point in time is membership in an editorial board.

Causal analysis had to answer the question whether we can assume that the changes in integration were fully or partly caused by the science policy measures. The answer to this question must also provide an explanation as to why the institutional support was not sufficient in cases like scientist S5.

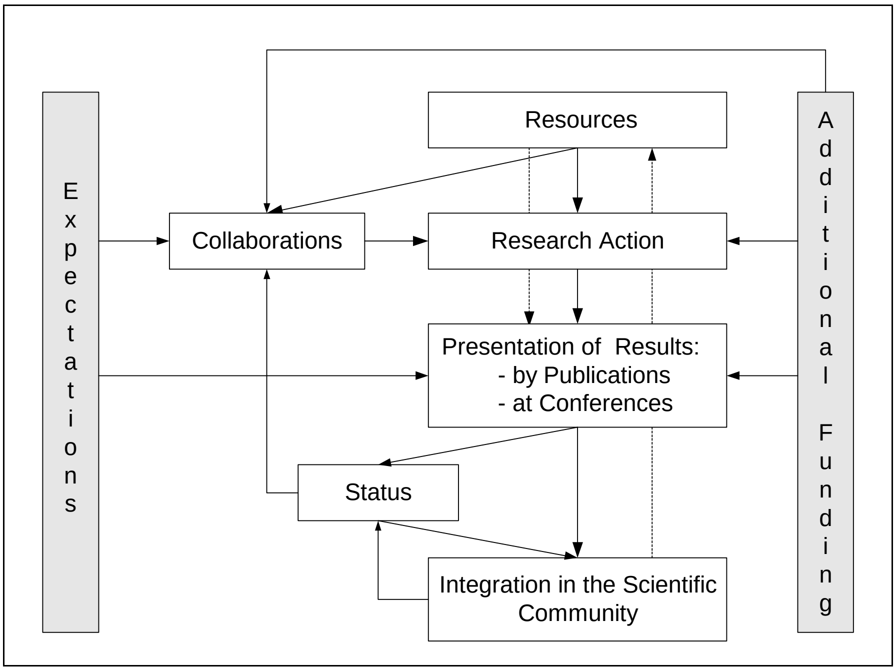

Diagram 3: How institutional measures affect integration

To judge the impact of new institutional measures, we tried to identify the causal factors in our general model that were influenced by them. Our example shows the impact of a special institutional setting that provided additional funding. One necessary condition for the funding was that the scientists plan and realise collaborations among themselves, a step that almost necessarily included collaborations between East and West German scientists at the universities. Additional money was provided to promote international integration: The scientists could easily finance conference attendance, visits by collaborators and extended stays abroad. Last but not least, the additional funding enabled research activities to be significantly enhanced and thus improved scientists' opportunities to present competitive results. This was also the core of the institutionalised expectations: Scientists were to use the money to implement active integration strategies.

The effects of these institutional measures can be assessed by analysing the necessary conditions for a successful integration. This analysis shows that scientists' individual situation at the turning point in 1990 was a crucial initial condition for the following integration process. For example, a Matthew effect could be observed: Those who were integrated before could benefit from additional institutional measures. In cases of successful integration after German unification, it is likely that a kind of passive integration existed before the fall of the Berlin Wall: Scientists who followed international developments in their choice of problems and methods but had few opportunities to participate actively. In some other cases, scientists who were young enough in 1990 could start a career that fitted West German institutional career patterns and thus led them into integration. Finally, some scientists were shielded from international science, thematically misdirected by the GDR's science system and not permitted to become independent researchers. These scientists never had a chance to integrate themselves into their new communities. As an overall conclusion, we would like to state that a minimal level of integration at the point of departure (the fall of the Berlin Wall) is a necessary condition for successful integration afterwards. An interesting observation that merits further research can be added here: There is a principal barrier to the integration of East German scientists. Many activities of networking and formal decision-making that take place in elite networks are not exclusively based on scientific excellence but also on shared professional biographies. East Germans who belong to the elite in the cognitive dimension often remain outsiders in the social dimension because they had not been able to build relationships via continuous personal interactions, exchange of fellowships, collaborative work and the like before 1990. In other words, they cannot become 'old boys'.

5. Scientometric methods in qualitative studies –micro-level problems

The sociology of science is primarily concerned with scientists, networks, communities and scientific organisations. The extent to which scientometric methods can produce data about these social entities determines their range of applicability. This is mainly a problem of validity: The scientometric indicators must measure what is theoretically intended. Validity has become a crucial methodological point for at least two reasons. Firstly, the sociology of science discovered that publications provide a poor picture of what is actually going on in scientific research. Secondly, scientometrics discovered that the SCI provides a picture of publication activity that is at least distorted.

In our project, we had to find indicators for scientists' integration into their communities. By using scientometric indicators we did something that is almost forbidden in scientometrics: We applied these indicators to individual scientists. This 'sacrilege' is justified by the specific function of scientometric indicators in our study. We did not try to measure scientists' performance or impact. Measuring integration reduces the interpretation of scientometric indicators to the question whether scientists behave and are treated similarly to their colleagues, i.e. whether they publish, collaborate and are cited. This question can be answered with an SCI-based analysis if only the SCI depicts a community's core research activity. However, scientometric indicators alone cannot encompass the complexity of integration. Therefore, we must include a broad variety of qualitative data in our analysis.

But even with the support by qualitative data, we ran into difficulties when we tried to evaluate East German scientists' integration into their communities. In order to evaluate the dynamics of a scientist's integration, we must compare it with what is normal and exceptional in his or her specialty. However, both scientometrics and the sociology of science prove that a group of journals cannot depict a specialty. Therefore, it is impossible to establish average publication and citation rates as a basis for comparison. A closer look at the impact factor is even more depressing: To evaluate integration it is necessary to compare a scientist's cumulated impact factors per year with those of his or her peers and of outstanding scientists. However, the impact factor neglects the variation of journals' cited half-lives and thus prevents aggregations on lower levels such as individual scientists or specialties. For this reason we must revert to very simple solutions that, nevertheless, apparently worked well. We chose three frames of reference for our comparisons:

- The integration of other East German scientists working in the same field;
- The scientist's own integration at different points in time;
- The integration of some of the scientist's referees.

As a general conclusion, we would see two problems associated with scientometric methods that restrict their application in the sociology of science. The first limitation involves scientometric indicators that depict social phenomena in a reduced form. These must therefore be combined with qualitative data. The second limitation is the disparity between scientometric indicators that are journal-oriented and the social structures the sociology of science deals with. In the publication space created by journals, the social structures of scientific communities overlap and merge. Therefore, some problems cannot be addressed by the SCI's standard indicators.

6. Scientometrics and the sociology of science – general methodology

An even more interesting aspect of the relations between scientometrics and the sociology of science is that most applications of scientometric methods are incompatible with the qualitative-quantitative distinction in social science. Today, the distinction between a quantitative paradigm and a qualitative paradigm is passionately defended by both sides. It is, however, a fiction. If one accepts Max Weber's statement that the aim of sociology is the causal explanation of human action (Weber 1976), then what really matters is with what research strategies causal explanations can be achieved. So far, two different explanatory strategies have been developed. The first starts by looking for statistical associations. From these statistical associations, conclusions are drawn regarding causal associations, which should ultimately lead to causal explanation. The latter's scope is predetermined by the sampling. This strategy uses mainly quantitative methods and is based on inferential statistics, but qualitative methods can be included to explore the causal relationships. We will call it the statistics-based strategy.

The second strategy begins by looking for causal mechanisms. These are discovered by the in-depth analyses of one or a few cases. Thereafter, the causal explanation's scope is determined by a generalisation based upon comparisons of cases and theoretical considerations. This strategy relies on qualitative data but quantitative data about cases are often included. We will call this strategy the case-based strategy.

As we have already mentioned, the case-based strategy currently predominates in the sociology of science. Since scientometrics is quantitative by its nature, it is met with misgiving by the sociology of science. In our view, however, scientometrics does not fit the statistics-based strategy because it does not rely on statistical inference. Thus, the question arises how scientometrics contributes to causal explanations. There is no doubt that scientometric methods are excellent tools for finding regularities and patterns that are very often surprising. However, it seems impossible to explain these patterns with scientometric methods alone. We believe that this is the reason why scientometrics appears to give up all attempts to explain what is being observed.

To contribute to causal explanations, scientometric methods must be integrated into projects that follow one of the strategies described above. Since scientometric methods are used for descriptive rather then inferential statistics, it seems difficult to expect contributions to the statistics-based strategy. In our view, however, important contributions to the cased-based strategy are possible because scientometrics contributes data that cannot be obtained using other methods. Scientometrics must, however, meet the theoretical challenge and define its concept in the theoretical frameworks provided by the sociology of science.

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