

4.10 NETWORK ANALYSES

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In the area of research, technology and innovation policy, the promotion of "innovation networks", "competence centres" "competence networks" etc. is increasingly being discussed (see Boekholt et al. 1998). These initiatives have in common that not (only) a narrowly defined research or technological goal should be achieved, but also that an impetus towards a *structural and behavioural change* in the participating institutions should be provided. The following contribution shows which instruments evaluation research has at its disposal to cope with this complex policy measure and, based on one concrete example, discusses the strengths and weaknesses of the applied method.

4.10.1 General Description

In the social sciences a special research focus – social network research – has emerged, which serves to analyse the structure of (cooperation) relationships and the consequences for actors' decisions on actions. The premise of this approach is to be able to formulate explanations for the actions/activities of individuals by describing and analysing their social embeddedness, i.e. individual actions are neither attributed to the normative convictions of the actor nor to the mere membership of a certain category, such as e.g. age groups, but to the individually structured relationships between the actors (cf. Laumann 1979, Milardo 1988, Marsden 1992). Another approach is the „Actor-Network-Theory“, a concept to explain scientific and technological innovations developed by Callon and Latour (Callon/Latour 1992, Callon 1986, 1987). The central thesis is that science and technology development is the result of the connection of heterogeneous components into networks. This process is as more successful as more the components involved are able to act in a way taking the perspectives of the other components into account.

Social networks can be regarded from various perspectives. A central difference is the question whether the relationships among several units is being considered (*total network*) or a network is being examined from the *perspective of a single actor*: in this case, we are dealing with ego-centred or personal networks (cf. Fisher 1977, Craven/Wellman 1973, Kaufmann et al. 1989). A further differentiation can be made as to whether partial networks are being studied, i.e. those which are restricted to a certain type of relationship (e.g. relationships with friends), or total networks, which comprise all possible relationships within the total network (Pappi 1987)⁵³.

In social network research it is customary to differentiate between the structural or morphological criteria (of the total network) and content characteristics (the dyadic relationships). Although almost every author who has written an overview of the characteristics of social networks has utilised different systematics, the most significant network features can however be resumed as follows (cf. Hall/Wellman 1985, 28):

- *Characteristics of relationships*:⁵⁴ (1) strength of the bond, (2) frequency of interaction⁵⁵; (3) multiplexity (number of resources which are exchanged by two network members in the relationship)⁵⁶; (4) duration of the relationship⁵⁷; (5) symmetry and reciprocity of the exchange; (6) intimacy (emotional attachment).
- *Characteristics of networks*: (1) size or scope of the network; (2) density; (3) extent to which a network member is directly connected with others; (4) demarcation (share of all bonds of network members which are contained within the network); (5) availability (average number of attachments which are necessary to connect the network members as a couple); (6)

⁵³ Network studies do not only record the existing relationships, more interesting are often the potentially possible, factually non-existent relationships ('structural holes') (Knoke/Kulinski 1982: 12). Relational analyses must also be differentiated, in which the kind of transaction as well as density, cliques and clusters of the total network are investigated, and positional analyses, in which the relationship of the actors to each other is examined, for example, questions about the structural equivalence and alterations in stable relationships in formal organisations (Kaufmann et al. 1989: 15ff.; Pappi 1987: 18ff.).

⁵⁴ Larson/Bradney (1988, 109) differentiate in addition interactions (specific exchange at a certain point in time) and relationships (relationships existing beyond the moment).

⁵⁵ The measurement of the frequency of contact was repeatedly criticised, as it says nothing about the content or type of relationship (Allan 1979, 10; cf. Allan 1989, 93, Jackson/Fischer/McCalliser-Jones 1977, 47; Grieco 1987, 42; Mitchell 1969, 28).

⁵⁶ In the literature on the subject the assumption is to be found that the degree of dependency increases with the *multiplexity*, i.e. a multiplicity of relational contents. Moreover, it is presumed that multiplex relationships are particularly intensive, trusting ties. Uniplex relationships on the other hand are used more for instrumental and material aid (Jackson/Fisher/McCalliser-Jones 1977, 41; cf. Boissevain 1978, 32).

⁵⁷ The duration serves often as a measurement for joint experience and is significant above all in the area of emotional support (Jackson/Fischer/McCalliser-Jones 1977, 46). According to Boissevain (1978, 34) it is also better suited to determine the investment of an actor in the relationship than the frequency of contact.

homogeneity (extent to which the network members possess similar personal characteristics); (7) cliques (network areas in which all members are directly connected); (8) clusters (network areas with high density, but less stringently defined connection criteria than for cliques); (9) components (network areas with which all members are directly or indirectly connected).

4.10.2 Policy Instruments / Interventions to be Evaluated with the Method

In research and technology policy programmes, *cooperation and communication processes* are gaining ever increasing importance. The reason is that classical programme promotion is being abandoned in favour of comprehensive attempts to influence whole innovation systems by means of policy measures. An outstanding example in this context is the promotion of competence networks, respectively competence centres, which often emerge alongside certain technologies (biotechnology, medical technology, nanotechnology). The promotion of innovation networks to encourage business start-ups should also be mentioned in this context.

Why d

o policy measures target network dynamics? For several years, scientists have been emphasizing the increasing importance of networks as a mechanism to improve knowledge and technology transfer (see Freeman 1991, Lundvall 1992, Metcalfe 1996). Due to the increased complexity and dynamics of the innovation processes in a globalised economy, the capability of institutions to absorb and transfer knowledge and their overall learning capacities are seen as crucial success factors (Foray/Lundvall 1996). Especially inter-organisational cooperations are becoming more and more important in order to cope with the challenges of modern innovation systems.

The following section describes an example of a network analysis in the context of clinical research centres in German university hospitals. This example is less typical in the sense of stimulating innovation processes, but delivers some useful insights into the advantages of such an approach to improve policy measures.

4.10.3 Good Practice Examples:

Communication and Cooperation in the Interdisciplinary Centres for Clinical Research

Since 1996 the Federal Ministry for Education and Research (BMBF) has been supporting eight model centres for interdisciplinary clinical research at university hospitals (called IZKF in the following text). This promotional measure was monitored evaluatively from the beginning by the Fraunhofer Institute for Systems and Innovation Research, Karlsruhe. The decision to examine the communication and cooperation structures within the eight centres in the programme in-depth, stems from the catalogue of objectives of the promotional measure itself, where the *encouragement of junior staff* and the establishment of efficient structures for clinical research on an *inter-disciplinary* plane, respectively the *intensification of interdisciplinarity* and scientific quality assume a prominent role⁵⁸. As the encouragement of junior staff and the extent of interdisciplinary cooperation are reflected in daily work, an analysis of the cooperation and communication forms and mechanisms can contribute to answering the question, to what extent the programme participants already meet these objectives.

The communication and cooperation structures in the IZKF were determined and interpreted via a *survey of total networks*. Based on the possibility of a comparison among the eight centres, such an approach was promising, as taking into account the differing framework conditions of each centre, it was possible to identify influential factors for successful communication and cooperation. The following topics were examined in detail:

- How successful is the integration and socialisation of the junior scientists? Are the up-and-coming scientists sufficiently integrated in the centre structures?
- How are the measures implemented to encourage communication and cooperation judged? How are the premises, the existence of central labs etc. assessed?
- Which formal and informal communication mechanisms could be ascertained? Do the researchers from all levels of the hierarchy participate? Are there differences regarding social integration between the hierarchy levels?
- How does the interdisciplinary discourse take place in practice? How often does a cooperation with external persons (including industry) take place?

⁵⁸ A further goal refers to the increase of transparency and performance orientation in the financing of research projects (cf. Bühner et al. 2001).

The cooperation and communication analysis was based on a *written survey* of all persons identified as members of the clinical centres (total survey). The questionnaire consisted of three groups of questions:

Group A was designed to ascertain from the questionees an assessment of the efficacy of different measures to promote communication and cooperation (colloquiums, seminars) and structures (central lab space, spatial proximity).

Group C inquired after personal data (highest scientific degree, professional position, age, research orientation, scientific discipline, self-definition as the up-and-coming scientific generation, length of activity in the IZKF, membership in committees) as well as the question of general job satisfaction in the IZKF.

Group B formed the core of the questionnaire. It consisted of the following parts:

- A list of all employees of the IZKF was supplied; this list could be added to by the questionees if required; the names of the employees were provided with a code for anonymity, which – with the corresponding "choice" of person - should be entered into the questionnaire.
- All in all, four *network generators* were used⁵⁹, in order to survey four different kinds of networks: the cooperation network, the network to pass on information, the network to receive information and the "sympathetic" network.
- A number of *name interpretators* were added, i.e. questions which were designed to elicit information about the characteristics of the persons named in the first question. The questionnaire took on the form of a matrix. In detail, the question was posed how long the questionee had known the person named, which highest academic degree and professional status this person has, which research orientation, scientific discipline and faculty he/she belongs to and whether the person is regarded as influential in certain pre-determined areas.
- In addition, the questionee was asked to describe the type of relationship to the named partners in more detail; this should encompass the criteria origin of the contact, duration of the relationship, frequency of contact, subjects of discussion and perceived quality of the relationship.

A total of 713 persons were addressed, of which 270 responded. This corresponds to a response rate of 36% (cf. in the following Bühner/ Peter 1999). Information was given on a total of 2,390 network members, whereby the average number was nine persons. The largest share fell - not least because of the formulation in the questionnaire – to the cooperation network with 1,508 citations in all.

One of the results of the study was that the *satisfaction or identification* with the job in the centres is *high*: 83% of those questioned stated that they would recommend a job in the IZKF further. In-depth analyses have made clear that the *quality of social integration* (measured according to the indicators duration of the relationship, frequency of interaction, quality of the relationship, number of subjects of discussions) exercised hardly any influence on the identification. An important factor however consists in the promotion of *independence of the junior scientists*, i.e. their possibility to head independent projects. Moreover, the junior scientists asked (both post-docs and post-grads) displayed a higher degree of satisfaction than those with a habilitation thesis.

A core question of the survey was, to which extent the promotional measure led to *cooperation not only on an inter-disciplinary but also cross-hierarchy level*. Regarding this last point, it could be demonstrated that habilitated scientists tend to name "their own kind" as cooperation partners. Scientists with doctorates and graduates also cited habilitated scientists more frequently as members of their network than members of their own group, although the networks of these two groups were more widely diversified. The higher the level in the hierarchy, the greater the tendency to demarcate, i.e. the higher those questioned are on the hierarchy ladder, the more inclined they are to confine their "social circle" to the own group or to perceive them as possible cooperation partners.

The analysis of the cross-disciplinary cooperation produced results which must give cause for concern in the sense of the promotional programme. For example, *over two thirds* of the networks of the clinicians questioned were comprised of members of clinical research orientations. This applies for all centres, i.e. the two-thirds share represents the *minimum*. The networks of the natural scientists as well as the pre-clinicians were clearly inter-disciplinarily structured, even if here too the majority cooperated with members of the same research field.

⁵⁹ The wording of the question was: (1) "With whom do you cooperate in your project work in the Clinical Centre?"; (2) "Are there other persons to whom you pass on important professional information – also outside the Centre?"; (3) "Are there persons – besides the above named - from whom you receive important work-related information – also outside the Centre?"; (4) "Are there colleagues to whom your relations are primarily of a "social nature" (spending time together in the breaks from work or in leisure time) and who have not yet been named?"

The communication and cooperation analysis has two structural types – identified "old" and "new" networks, which are significant for the further evaluation. "Old" networks are characterised by actors who are older and have a higher professional status. This group of persons is characterised by less frequent interactions, spatial proximity is regarded as less important for initiating and cultivating communication and cooperation relationships. In contrast, "new" networks are characterised by a multiplicity of younger staff, who as a rule have graduated, received doctorates or have just recently habilitated. For the first two groups in particular frequent interactions and spatial proximity play an important role.

What does this mean for the success of the promotional measure, i.e. the creation of new, interdisciplinary research structures which are able to integrate the younger generation of scientists appropriately? Old networks, for which spatial proximity⁶⁰ is less important and which are often characterised by less frequent interactions, have far less need of measures to intensify cooperation and communication than new networks. The explanation is obvious: often, people in new networks do not yet have relevant own contacts and have to build these up first. The spatial proximity is the most obvious possibility for these persons to make contacts. Additionally, measures to intensify communication – also a first step towards possible cooperations - encounter a clearly higher need in these persons and respectively a greater willingness to use them. If there is no spatial proximity, then the measures promoting communication are of far greater importance. A centre with new networks must therefore attach considerable importance to the communication aspects.

Central results have also emerged regarding *interdisciplinarity*. That interdisciplinarity is a result of the quality of communications, respectively of the size and duration of exchange relationships, can be clearly confirmed by the results obtained. In centres with old networks it was seen that longstanding communicative relations can even, under certain circumstances, compensate for unfavourable research frame conditions, i.e. for example the lack of central "meeting places", in the form of central labs. For the new networks, spatial proximity is the outstanding criterion for establishing new networks and – where given – is encouraging. As the lack of sufficiently large, established and diversified networks, which are characteristic for younger people, also reflects on the interdisciplinarity, special efforts are necessary in order to anchor the targets of the promotional measure sufficiently: one way to do this is to integrate the younger generation of scientists better in the "established" networks of experienced colleagues.

4.10.4 Conditions for Methodology Application to Evaluation

As mentioned above, the conduct of a network analysis entails great effort on both sides – the evaluators and those to be evaluated. Before starting the survey, it is necessary to know precisely the universe, i.e. the members of the networks – not only the formal ones, but especially those who are involved in the daily network activities. In a second step, different pre-tests are necessary – not only to test the appropriateness of the questions, but also to enhance the acceptance for this kind of investigation. Finally, the results of the quantitative survey should be complemented by qualitative interviews with some selected network members. It is also possible to organise workshops with the members in order to validate the results and discuss ways to optimise the network structure.

To sum up: network analysis is not only a measure to find out certain parameters of the network characteristics like density, centrality etc., but it is also a tool to promote the communication within the networks. This is why network analysis should be used in the context of intermediate evaluations. Our experience in different contexts shows that using network analysis as a learning medium to improve network communication is highly appreciated even by those to be evaluated.

4.10.5 Operational Steps for Method Implementation

Generally, in a network analysis we differentiate between three forms of social networks: (1) exchange networks, (2) information networks, (3) sympathy networks⁶¹. Under exchange networks is understood a multiplicity of interactions, which range from networks of friends over neighbourly aid up to recording professional relationships. For the field of science and technology policy evaluation, exchange and information networks are especially important.

In order to survey such networks, certain sector-oriented *network generators* are utilised (cf. Schenk/Pfenning 1993). Network generators are a listing of persons/ institutions according to a selection criterion, for example the question about the persons/ institutions with whom information is most frequently

⁶⁰ "Spatial proximity" refers in the context of the IZKF primarily to the question whether the individual institutes and departments of a university hospital are mainly centrally located, or whether they are spread over large grounds or even over the whole town.

⁶¹ Knoke/Kulinski (1982, 14ff) differentiate between following networks: (1) exchange of control over goods or means, (2) communication relationships, (3) 'boundary penetration relations' (overlapping memberships), (4) instrumental relationships, (5) emotional relationships, (6) authority and power relationships, (7) relationships with relatives and descendants.

exchanged. The second step comprises gathering information about the characteristics of the persons/institutions named in the first question (*name interpreters*). Possible characteristics are age, profession, type of institution (basic research, applied research, development etc.). In a third step the type of relationship between the questionee and the persons/institutions named by him is determined (*form and content of the dyad*). Examples of the questions to be put in this context are duration of the relationship and frequency of contact. The last step consists in analysing the *network structure*. For this, details of the size, the density or unity, the microstructure (existence of cliques etc.) as well as the homogeneity or heterogeneity of the networks is studied.

What does this mean for the evaluation of modern research and technology policy initiatives? First of all, a decision must be taken whether to examine total networks or ego-centred networks and what type of network is the object of the study (partial network or totality of the relationships). Also, it must be decided whether the approach should rather be formalistic (e.g. position analyses or examination of "structural holes", cliques etc.), or whether the primary question is which consequences the network characteristics have for the network members' options to act.

To conclude: network analysis requires detailed data about the actors belonging to the network (e.g. their institutional background, resources) and the kind of relationships between these actors. Usually, the "measurement" of the network takes place once, but it is also possible to repeat the survey in order to investigate changes within the network structure. Network analysis is a quantitative approach using highly formalised questions; the data gathered, however, should be complemented by some qualitative insights through personal interviews.

4.10.6 Data Requirements / Indicators

Data gained by network analysis are process data which deliver insights in "objective" characteristics of the network like density, central actors, accessibility etc. They are able to measure „impacts“ if the stimulation of innovation networks is the aim of the policy measure. It should be noted, however, that the stimulation of innovation networks is usually (only) a way to improve science and technology transfer and not the final aim. Yet it can be assumed that networks which function well are more likely to end up with the desired results (more innovative products, services etc.) than networks which function less well.

4.10.7 General Assessment of the Scope and Limits of Methodology

The study of total networks by means of written surveys produces comprehensive empirical material, which can be utilised in various ways for purposes of evaluation as well as for policy improvement:

- it can point to weak spots in the communication and cooperation of network members;
- the analysis of total networks provides a multiplicity of surprising results, even for the members, which can spark off intensive debates;
- because of the high standardisation of the procedure (open questions are the exception, most questions have (given) multiple choice answers), results of the separate participant clusters can be easily compared;
- by comparing different network types it is possible to derive specific success factors;
- especially in those cases in which several networks or centres are being promoted which have been explicitly granted a free hand in organisational matters, a comparison against the background of different context conditions offers the potential to identify "best practices" and so trigger learning and optimisation processes.

These positive results are also confronted with difficulties: the main problem consists in the time involved in such a written survey, especially for the questionees: in order to engender acceptance for such a survey and to attain a response rate necessary for empirically sound analyses, it is unavoidable to conduct not only pre-tests, but also to convince the main actors (as a rule the coordination or business office of the promoted institutions) in advance of this form of investigation.

4.10.8 Commented Bibliography for Further Insights

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