



Coopetition between frenemies—interrelations and effects of seven collaboration problems in research clusters

Malte Hückstädt¹

Received: 6 January 2022 / Accepted: 8 July 2022 / Published online: 6 August 2022
© The Author(s) 2022

Abstract

Principal Investigators in research clusters find themselves in a Janus-faced situation: if they want to achieve their common research goals, fulfil their overarching function of integrative knowledge production and thus secure the continuity of their collaboration, they are required to cooperate closely. At the same time, they compete with each other for scientific recognition or third-party funding. Taking this as a background, the article explores the effects and interrelationships of seven collaboration problems that arise in the context of the tension between cooperation and competition. Based on the state of research, a club-theoretical heuristic is developed that captures the effects and interrelationships of seven collaboration problems. The specified hypothesis model is tested with the help of a structural equation model using data from a large-scale online survey of PIs and spokespersons involved in research collaborations. The data analysis confirms the assumption that especially conflictual personal relationships between the partners in a research collaboration (*relationship problems*) form a central node in the network of collaboration problems: A lack of reciprocity of costs and benefits (*fairness problems*) as well as the self-interested behaviour of the spokesperson of a research cluster (*management problems*) promote relationship problems between the partners in a research team. Likewise, relationship problems in turn promote an erosion of communication between collaboration partners (*communication problems*), of goal progress evaluation (*certainty problems*), of cross-disciplinary exchange (*difference problems*) and of partners' commitment to the common goals of the research collaboration (*goal commitment problems*). The structural equation model thus supports the widely held, but by no means trivial view in cooperation research that trusting and fair interaction between cooperating PIs in a research cluster is a necessary, if not sufficient, condition for their joint success.

Keywords Research collaboration · Collaboration effectiveness · Collaboration problems · Structural equation modelling · Club theory

✉ Malte Hückstädt
hueckstaedt@dzhw.eu

¹ German Centre for Higher Education Research and Science Studies, Governance in Higher Education and Science, Hanover, Germany

Introduction, research gap and research question

Research collaboration has become a widespread and diverse mode of scientific practice in recent decades (Chompalov & Shrum, 1999). In addition to numerous advantages that collaborative research potentially offers to different scientific actors (Olechnicka et al., 2019), there are also recurring obstacles to successful collaborative research (Blanckenburg et al., 2005; Cummings & Kiesler, 2005; Hackett, 2005). If, for example, a research cluster does not succeed in efficiently organising work processes, nor in reaching an interdisciplinary understanding and binding agreement on common goals, as well as generating social cohesion and trust given divergent interests and benefit calculations, and if contributions are not adequately rewarded or if individual collaborators feel unfairly treated, the collaboration threatens to falter and its success can subsequently be jeopardised (Hall et al., 2019).

Although research collaboration is not a novel mode of scientific practice (Vinck, 2010), its challenges and potential for conflict are well known (Bozeman & Youtie, 2017) and the demand for empirically robust knowledge regarding the preconditions for successful research collaboration is high (König et al., 2013), nevertheless, little evidence-based knowledge is available on how central research collaboration problems are interrelated and to what extent they influence the achievement of goals in research collaborations (John, 2019). Rather, the state of research is characterised by a wealth of anecdotal field reports (e.g. Laudel, 1999) and by theory-driven case studies (e.g. Sacco, 2020). Due to the use of statistically unrepresentative samples, the research results of the few quantitative studies are often not robust and cannot be generalised (Shrum et al., 2007). This article addresses this deficit: On the basis of data from the research project *Determinants and effects of cooperation in homogeneous and heterogeneous research clusters* (DEKiF), a club-theoretical heuristic (Buchanan, 1965) and structural equation modelling (Kline, 2016) are used to investigate the relationship between seven central research collaboration problems and their influence on achieving the goals of research collaborations. The empirical reference point of the paper is the collaboration between principal investigators (PIs) in ongoing and completed research collaborations funded by the German Research Foundation (DFG) programmes Cluster of Excellence (EXC), Research Units (FOR), Research Centres (FZT), Priority Programmes (SPP), Collaborative Research Centres (SFB) and Transregios (TRR).¹

The article starts with a basic definition of the term *research collaboration*, from which two collaboration types are derived. This is followed by a brief presentation of the organisational structures of DFG-funded research clusters and a description of research clusters from a club theory perspective. The club perspective focuses on the tension between cooperation and competition that accompanies collaboration between PIs and shapes the context in which seven problems arise. The characteristics and (inter)effects of these collaboration problems are outlined as part of the construction of the hypothesis model. The description of the data, methods and operationalisation is followed by the presentation of the results of the verification of the hypothesis model by means of structural equation modelling. The article concludes with a discussion of the central findings, theoretical contributions, practical implications and the identification of further research needs.

¹ In what follows, collaborations funded by any of these programmes will be referred to as *research clusters* or *RCs*.

What is a research collaboration?

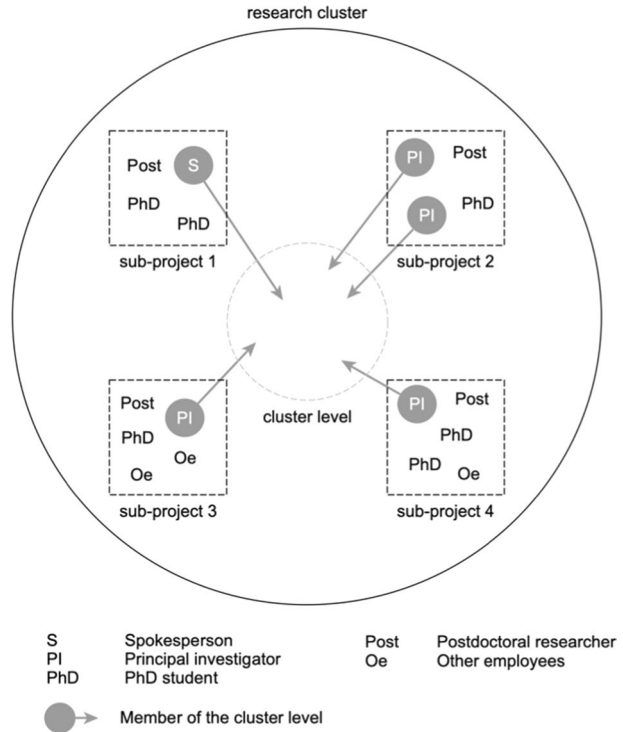
Following Laudel (1999), research collaborations can be defined as an association of $n > 1$ personally interacting collaboration partners who relate their research activities to each other in functional terms in order to achieve *common research* and/or *collaboration goals*. Only if the *individual research goals* of all partners involved in a collaboration are identical in essential parts, do *common research goals* exist. If the *individual research goals* of the collaborating researchers are not identical, the corresponding research activities of a collaboration are only linked by a *common collaboration goal*. A *common research goal* is therefore not a necessary prerequisite for research collaboration. Rather, researchers can also cooperate because they pursue individual interests with the collaboration, e.g., creating favourable conditions for the achievement of other research goals, allocating third-party funds, or observing social norms (Laudel, 2002). According to Laudel, a research collaboration can therefore also come about if one of the collaboration partners only satisfies their interests and acts as a kind of service provider or supplier (Hollaender, 2003).

Building on Laudel's definition of a research collaboration (Laudel, 1999, 2002), two different types of collaboration can be distinguished globally: *collaborations involving division of labour* are (1) characterised by a research goal shared by all partners, which the researchers achieve by making *creative contributions* within the framework of a joint research process. *Creative contributions* are understood to be those scientific achievements that arise from the tension between originality and scientific relevance, e.g. theoretical innovations, the application of new research instruments, methods, research techniques or special empirical discoveries (Heinze, 2012). Furthermore, *collaborations involving division of labour* are characterised by a close interlocking and integration of the collaborating PIs' contributions, which is maintained over long phases of the collaborative research process and is accompanied by corresponding coordination efforts (Laudel, 1999).

A *supporting collaboration* (Laudel, 2002), on the other hand, is characterised (2) by the orientation of the collaborative contributions towards the external research goals pursued by the collaboration partners. Collaboration partners can support each other's research goals by taking over part of the research work without making creative contributions. Usually, these are research services that have a routine character and can therefore be delegated (Laudel, 1999). In addition, services offered within a supporting collaboration usually include granting access to material or immaterial resources. Examples of supporting research collaborations include time-consuming measurements, developing instruments or testing new methods. Similarly, a supporting collaboration can also consist of providing access to research equipment or passing on already existing specialised knowledge on an ad-hoc basis (Laudel, 1999).

In the DFG-funded research clusters (RC), pure and mixed forms of both types of collaboration can in principle arise at different levels and between different status or project groups. Depending on whether the *research* and/or *collaborations goals* of an RC require monodisciplinary or cross-disciplinary collaboration, on the extent to which the sub-projects are interlinked in terms of content, on the social cohesion or on the subject-related and personnel heterogeneity of a research cluster, the occurrence of *division of labour* and *supporting* collaboration sequences within RCs can vary greatly (Laudel, 1999). In general, the DFG requires that collaboration between the principal investigators (PIs) at the cluster level (Fig. 1) must be oriented towards a *common research goal*, which the PIs usually approach with a *division of labour* and by contributing interlocking, *creative* research contributions (German Research Foundation, 2010, 2015, 2020, 2021). In this respect, it can

Fig. 1 Cooperation between status groups at the sub-project and cluster level of a research cluster according to Defila et al. (2006)



be assumed that the collaboration of PIs at the cluster level in particular is most strongly characterised by the type of *collaborations involving division of labour*.

DFG research clusters: a special type of research collaboration

In order to effectively achieve the complex, overarching goals of the RC, which is the (usually interdisciplinary) cooperative production and integration of knowledge, RCs are modularised and simultaneously structured in a decentralised manner (John, 2019). This modularisation and decentralisation manifests itself in a number of special, structural features of RCs' organisation:

1. RCs unite $n > 1$ sub-projects whose respective research activities are assigned to a common research goal (Fig. 1). In this respect, an RC with its sub-projects forms a *team of teams* (Defila et al., 2008).
2. At the sub-project level, the PIs pursue their individual interests and research goals in the sub-projects for which they are responsible. At the same time, the PIs cooperate on the basis of the work produced by their sub-projects at the cluster level in order to achieve the RC's *common research goal* (Defila et al., 2008).
3. The collaboration between the PIs and their staff in their sub-projects is organised hierarchically, whereas the collaboration between the PIs at the cluster level is not. Accordingly, the responsibility for personnel, resource and content-related decisions

- in the sub-projects usually lies solely with that sub-project's PI. Decisions concerning staffing, resources and content that affect the entire RC are either the joint responsibility of all PIs, elected committees and/or the spokesperson (Defila et al., 2008).
4. Depending on the extent of the integration, an RC's sub-projects are more or less strongly connected to each other and their research work is mutually (in)dependent. Either way, the PIs' sub-projects have their own standing: they each work on their own research questions according to their own specifications and produce their own products in relative independence of the RC in terms of content and resources (Defila et al., 2008). On the one hand, the decentralised organisational structure of the RC forms the basis for the PIs' highly specialised research to be bundled, coordinated and directed towards an overarching research goal (Bozeman & Lee, 2005). On the other hand, the RC's organisation, which is modularised, decentralised and based on a division of labour, results in significant information asymmetries between the PIs: firstly, the PIs can neither fully observe nor assess each other's sub-project-internal research work, and secondly, at the same time it remains uncertain "whether one's own efforts will not be opportunistically exploited by the other members of the network" (John, 2019, p. 33).² The organisational structures of RCs thus open up considerable scope for opportunistic behaviour, allowing PIs to withhold contributions from the RC while exploiting other PIs in the use of collaborative resources.

The potential risk of opportunistic behaviour is increased by the fact that the PIs' sub-projects compete with each other for scientific recognition or third-party funding (Defila et al., 2006). At the same time, the PIs are required to cooperate closely if they want to achieve their *common research goals*, fulfil their overarching function and thus secure the continued existence of their RC (Defila et al., 2006). Influenced by the resulting tension between cooperation and competition, collaboration between PIs becomes *cooptation* (Olechnicka et al., 2019), which makes PIs *frenemies*, i.e. *competitive peers* (Merton, 1949).

Theory and hypotheses

Buchanan's (1965) club theory can be used to theorise the tension between cooperation and competition that arises in the collective production and consumption of exclusive, common goods: Club theory describes the voluntary association of people who jointly provide a good at the cost of individual contributions. Due to their association, the average costs incurred per person for the production of the good are lower than the costs that the club members would have incurred individually for the production of the same good. If this were not the case, there would be no reason for rational individuals to form a club, nor would there be effective incentives to join it (Buchanan, 1965). However, in order to maximise their utility, the members of a club may withhold services in the context of the collective production of the club's goods at the expense of others, or overreach them in the use of the collective resources. As a result, the notorious social dilemma looms: the self-interested behaviour of individual club members leads to a result that harms the common interests of the entire club (Buchanan, 1965).

² Translated by the author.

Table 1 Type of goods

		Rivalry	
		Low	High
Exclusion	Low	Public goods e.g. knowledge	Common goods e.g. libraries
	High	Club goods e.g. research cluster funding	Private goods e.g. sub-project funding

Club theory, which was originally shaped by economics, has been expanded in various ways: for example, in addition to the connection between club size and the optimal cost–benefit structure for the members, the effects that various inter- and intrapersonal factors associated with clubs exert on the internal production and allocation of the clubs' goods have been increasingly analysed. The areas where club theory is applied are accordingly diverse: for example, in addition to water supply systems (Rosen & Sexton, 1993), the safety of cities (Craig & Heikkila, 1989) and pricing in ski resorts (Barro & Romer, 1987), fashion influencer networks (Adams & McCormick, 1992), religious (Warner et al., 2015) and state communities (Schemm Gregory, 2010) as well as research teams (Baurmann & Vowe, 2014; Meißner et al., 2022) have been analysed in the past using club theory.

Research clubs: research collaboration from a club-theoretical perspective

From the perspective of club theory (Buchanan, 1965), an RC can be viewed as a *research club* that can only exist and be successful in the long term if the interests of all PIs as well as those of the funding agency are satisfied to a sufficient degree. In this context, the members of an RC must succeed in producing three different types of goods. These types of goods can be differentiated from the perspective of the theory of goods on the basis of the degree to which consumers can be excluded from their consumption and on the basis of the rivalry that occurs between consumers in the context of their consumption (Buchanan, 1965; Musgrave, 1959; Ostrom & Ostrom, 1977; Samuelson, 1954) (Table 1).³

Club goods can be understood as those goods for which there is little or no rivalry in consumption, but for which it is possible to exclude other people from using them (Ostrom & Ostrom, 1977) (Table 1). Accordingly, in the context of research collaboration, *club goods* can be classified as those resources that researchers jointly produce and provide on the basis of shared effort costs (Baurmann & Vowe, 2014), e.g. through the expenditure of temporal resources, scientific expertise, reputation or social network relationships (Preuß, 2017). These are (1) the exclusive funding for staff and materials that an RC receives with the successful acquisition of third-party funding, and which enables the employment of scientific staff as well as the acquisition and/or use of scientific equipment and/or laboratories. Furthermore, an RC (2) also provides its PIs with access to a unique pool of competencies and expertise, which results from the accumulated *scientific* and *technical human capital* of all participating researchers (Bozeman & Corley, 2004). The pooling of individual competencies and expertise enables the partners of an RC to use their professional competencies

³ In the author's view, *common goods* do not play a central role in the context of research collaboration and are accordingly excluded from further analysis.

and technical skills synergistically and thus to carry out highly complex research work that cannot be carried out on a stand-alone basis in a time- and resource-efficient manner (Olechnicka et al., 2019).

An RC's *club goods* form the constitutive basis for its overarching goal: the successful production of the *public good* of innovative knowledge (German Research Foundation, 2010, 2015, 2020, 2021). However, the *club goods* are only granted to a research team by the funding agency if the team can credibly demonstrate that it “wants to and is able to jointly solve a relevant research problem within the framework of an overarching research programme” (Baurmann & Vowe, 2014, p. 76).⁴ In this respect, a *research club* can only be founded and be successful if its members prove that they have a realistic research goal that addresses a relevant research gap and that research collaboration is constitutive to achieving the goal in terms of content (Baurmann & Vowe, 2014).

Public goods can be defined as those goods for which there is no rivalry in consumption (i.e. if one person uses the good, this use does not reduce the benefit for other people) and that individuals cannot be excluded from using (Ostrom & Ostrom, 1977) (Table 1). In the context of research collaboration, the knowledge jointly produced, published and transferred by the PIs of an RC can be classified as a *public good* (Baurmann & Vowe, 2014; German Research Foundation, 2022). The production of the *public good* of innovative knowledge does not happen on its own, but requires integration-oriented, long-term, continuous and close cooperative relationships (Defila et al., 2006). If the PIs remain fixed within the boundaries of their disciplines or sub-projects in the context of their collaborative knowledge production, an RC does not add any value, i.e. the research could just as well have been carried out by its individual projects (Defila et al., 2006). Since the German Research Foundation considers not only the production of innovative knowledge but also close and integration-oriented research collaboration in the context of collaborative knowledge production to be a constitutive prerequisite for the establishment and continuation of research collaborations (German Research Foundation, 2010, 2015, 2020, 2021), *collaboration involving division of labour* (Laudel, 1999) is an essential prerequisite for the survival of a *research club*: it ensures the collaborative and integration-oriented production of innovative knowledge and thus the long-term safeguarding of the RC's exclusive *club goods*, which were first realised in the initialisation phase.

Finally, *private goods* are those goods that other people can be excluded from consuming and for which rivalry for their consumption exists (i.e. if one person uses this good, other people can no longer use it) (Ostrom & Ostrom, 1977) (Table 1). PIs have the opportunity to produce *private goods* with the sub-project's own staff and materials—relatively independently from the research cluster (see above). These can be, for example, enhanced career opportunities or improved reputation values, which the PIs can realise through the research work of the sub-projects for which they are responsible, by means of successful publications and/or further acquisition of third-party funding (Baurmann & Vowe, 2014).

In order to ensure the collaborative production of innovative knowledge, an RC must provide significant incentives for the long-term commitment of the PIs at the cluster level. The time- and cost-intensive, collaborative knowledge production must therefore be linked to the credible prospect that it will result in individual benefits that significantly exceed those that the PIs can generate with their sub-projects alone (John, 2019). Especially for the production of *club goods* and *public goods* in jointly responsibility, the PIs are dependent

⁴ Translated by the author.

on close cooperative relationships. Accordingly, the PIs of an RC must be willing to invest significant amounts of time and energy in collaborative knowledge production. Only if an RC succeeds in balancing the competitive and collaborative dynamics between PIs resulting from disparate individual and common research goals, individual interests and common collaborative goals, can an RC generate optimal synergy effects and avoid friction and process losses (Cooke & Hilton, 2015).

Effects and interrelations of seven collaboration problems

In this context, RCs are confronted with seven central collaboration problems. The identification of the seven problems is based on an extensive review of the research literature as well as on the analysis of 18 semi-structured interviews with PIs and spokespersons involved in RCs that were heterogeneous in terms of subject matter and personnel and were either monodisciplinary or interdisciplinary (Meißner et al., 2022). These seven collaboration problems are of course not an exhaustive list of possible challenges and obstacles that RCs may face. However, the review of the relevant literature suggests that these seven research collaboration problems can have a great impact on the performance of a wide variety of cluster constellations (small and large, interdisciplinary and cross-disciplinary, virtual and co-present RCs in all disciplines). In what follows, the seven problem types are defined and their interrelationships and effects on RCs' goal achievement are described based on the state of research. In this way, a theoretical model of the interrelationships and effects of seven collaboration problems, supported by the club theory heuristic, is developed step by step, which can then be tested using structural equation modelling.

Fairness problems

Following Meißner et al. (2022), *fairness problems* (FP) can be defined as a lack of reciprocity of effort and returns on the PIs' collaboration (FP1) as well as an inadequate recognition of the contributions that the PIs make to collaboration at the cluster level (FP2). From a club theory perspective, the *fairness problem* is central to the functionality of an RC: PIs produce *club goods* and *public goods* cooperatively and at the expense of individually varying costs. When distributing access rights to the jointly realised *club goods* or allocating the *private goods* resulting from them, PIs are expected to strike a balance between the costs incurred and the returns received (Pritchard, 1969). In the context of collaboration between PIs, however, there are effective incentives for the participants to engage in free-rider behaviour given the principle of competition for knowledge, which is deeply rooted in science (van den Besselaar et al., 2012): PIs may withhold their contributions to the joint production of knowledge at the expense of their partners or take advantage of them when using joint resources. The risk of free-rider behaviour is exacerbated in the context of research for three reasons: (1) The disciplinary heterogeneity, modularisation and simultaneous decentralisation of an RC result in significant information asymmetries between the PIs (see above). As a consequence, the internal research work of a sub-project is difficult for the PIs to mutually observe and/or assess (John, 2019). (2) The quality of the contributions depends on the PIs' intrinsic desire to produce the best possible result by their own standards. (3) The PIs of an RC are used to great autonomy in the context of their research and resist hierarchical controls (Defila et al., 2008).

If, from the point of view of the PIs, unjustified imbalances occur between the efforts made and the benefits gained, if these are not appropriately corrected or (in the case of

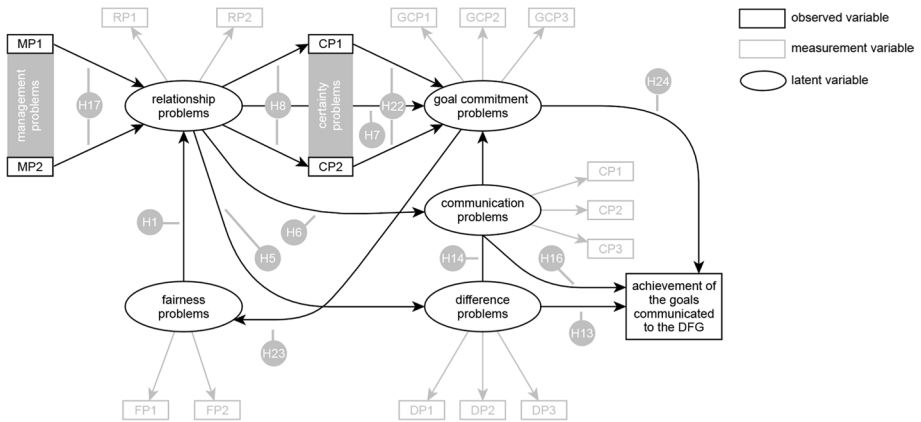


Fig. 2 Hypothesis model of the direct interrelations and effects of seven research collaboration problems

free-rider behaviour) not sanctioned, then trust between the partners in an RC is weakened (Antoni, 2000) and reactions of unfair follow-up behaviour are evoked (Fehr & Gächter, 2000). In extreme cases, *fairness problems* can lead to a downward spiral of social misbehaviour, resulting in a climate of destructive competition or personal conflicts (Baurmann & Vowe, 2014). In this respect, it is to be expected that *fairness problems* favour a climate of cooperation that is characterised by mistrust and unfair behaviour (*relationship problems*) (H1) (Fig. 2). From a club theory perspective, it can also be assumed that *fairness problems*, and the *relationship problems* they foster, promote a club-wide *sucker effect* (Cornes & Sandler, 1996): PIs who feel cheated also reduce their commitment and contributions to collaboration at the cluster level and withdraw into their sub-projects (Defila et al., 2008; Kerr, 1983). This has the consequence that an RC cannot fulfil its overall objective, namely the integrative production of knowledge. As a result, the funding agency does not approve extending the duration of the RC and the production of *private, club* and *public goods* cannot be secured for another funding period. In this respect, it can be assumed that *fairness problems* have an indirect, negative effect on the extent to which goals are achieved (O’Donnell & Derry, 2005): In the first order, mediated by conflicting social relationships (*relationship problems*), in the second order, mediated by a lack of commitment on the part of the PIs regarding their cooperation at the cluster level (*goal commitment problems*) (H2), in the context of cross-subproject communication (*communication problems*) (H3) and in the context of their monodisciplinary and interdisciplinary cooperation (*difference problems*) (H4) (Table 2).

Relationship problems

Following Meißner et al. (2022), the *relationship problem* (RP) can be defined as unjust behaviour (RP1) and lack of trust (RP2) between PIs in the context of their cooperation at the cluster level. Relationship problems are of little importance for many forms of clubs: for a tennis club, for example, it is irrelevant whether the five hundred members of the club mutually like and trust each other. For the provision and consumption of the *club good*—the opportunity to play tennis—it suffices if the members regularly pay their club fees and find a playing partner for whom they can muster some sympathy for an hour once a week.

Table 2 Hypotheses on the indirect interrelations and effects of seven research collaboration problems

	Predictor	Mediator 1	Mediator 2	Mediator 3	Outcome
H2	<i>Fairness problems</i>	<i>Relationship problem</i>	<i>Goal commitment problem</i>		Achievement of goals
H3	<i>Fairness problems</i>	<i>Relationship problems</i>	<i>Communication problems</i>		Achievement of goals
H4	<i>Fairness problems</i>	<i>Relationship problems</i>	<i>Difference problems</i>		Achievement of goals
H9	<i>Relationship problems</i>	<i>Goal commitment problems</i>			Achievement of goals
H10	<i>Relationship problems</i>	<i>Communication problems</i>			Achievement of goals
H11	<i>Relationship problems</i>	<i>Difference problems</i>			Achievement of goals
H12	<i>Relationship problems</i>	<i>Certainty problems (CP1)</i>	<i>Goal commitment problems</i>		Achievement of goals
		<i>Certainty problems (CP2)</i>	<i>Goal commitment problems</i>		Achievement of goals
H15	<i>Difference problems</i>	<i>Goal commitment problems</i>			Achievement of goals
H18	<i>Management problems (MP1)</i>	<i>Relationship problems</i>	<i>Goal commitment problems</i>		Achievement of goals
		<i>Relationship problems</i>	<i>Goal commitment problems</i>		Achievement of goals
H19	<i>Management problems (MP1)</i>	<i>Relationship problems</i>	<i>Difference problems</i>		Achievement of goals
		<i>Relationship problems</i>	<i>Difference problems</i>		Achievement of goals
H20	<i>Management problems (MP1)</i>	<i>Relationship problems</i>	<i>Communication problems</i>		Achievement of goals
		<i>Relationship problems</i>	<i>Communication problems</i>		Achievement of goals
H21	<i>Management problems (MP1)</i>	<i>Relationship problems</i>	<i>Certainty problems (CP1)</i>	<i>Goal commitment problems</i>	Achievement of goals
		<i>Relationship problems</i>	<i>Certainty problems (CP2)</i>	<i>Goal commitment problems</i>	Achievement of goals
		<i>Relationship problems</i>	<i>Certainty problems (CP1)</i>	<i>Goal commitment problems</i>	Achievement of goals
		<i>Relationship problems</i>	<i>Certainty problems (CP2)</i>	<i>Goal commitment problems</i>	Achievement of goals

In contrast, the members of an RC must maintain close working relationships over many years, especially in the context of *collaborations involving division of labour* (Laudel, 2002). Successful collaboration in an RC is fundamentally dependent on the ability of its members to informally coordinate among themselves, to communicate with each other professionally and to agree on differences, rights and obligations in a trusting and fair manner (Kerasidou, 2019). If this does not succeed, the *functional openness* (Blanckenburg et al., 2005, p. 146) of an RC's communication is compromised: PIs do not share relevant information with their partners, or only partially, out of mistrust (Hollaender, 2003). This makes goal progress evaluations, which are particularly important in the context of the dynamics and openness of science, as well as the flexible handling of unpredictable situations, considerably more difficult (Kozlowski & Bell, 2001). Likewise, *relationship problems* also lead to an erosion of commitment to the common goals of an RC: the interconnectedness of the PIs' research work is partially or completely dissolved under the influence of a negative climate of cooperation: PIs increasingly withdraw into their sub-projects, reduce cross-sub-project collaboration and their commitment in the context of disciplinary exchange (Shrum et al., 2001). As a result, there are considerable process and synergy losses at the cluster level due to coordination losses, motivation deficits, a lack of willingness to exert effort and a diffusion of responsibility (Blanckenburg et al., 2005). The knowledge produced by the PIs can ultimately only be compiled rather than integrated due to a lack of interconnection between the sub-projects and could just as well have been produced by the PIs alone (Defila et al., 2008). Accordingly, it is assumed that *relationship problems* increase problems occurring in the context of professional and disciplinary understanding (*difference problems*) (H5), cluster-wide communication (*communication problems*) (H6), commitment to common goals (*goal commitment problems*) (H7) as well as problems in the context of preparing for unforeseen situations (*certainty problems*) (H8) (Fig. 2). It is also to be expected that *relationship problems*, mediated by the aforementioned four problems, indirectly reduce the extent of goal achievement (H9–H12) (Table 2).

Difference problems

Following Meißner et al. (2022), *difference problems* (DP) can be defined as PIs' unwillingness to engage with unknown perspectives (DP1), to clarify their own perspectives with collaboration partners (DP2) and to anticipate the ways of thinking and methodological approaches of different disciplines (DP3). The *difference problem* is a symptom of the functionally highly differentiated disciplinary structure of contemporary science (Stichweh, 2013) and thus a problem specific to research clubs (Baurmann & Vowe, 2014): On the one hand, the heterogeneity of the competencies, scientific knowledge and perspectives contributed by PIs enables the solution of broad and/or cross-disciplinary scientific problems (Pacheco et al., 2017), and thus serves the overarching goal of a *research club*: the collaborative production of the *public good* of innovative knowledge. However, on the other hand, due to heterogeneous disciplinary cultures, the disciplinary heterogeneity of an RC also makes mutual understanding between the PIs considerably more difficult (O'Donnell & Derry, 2005). For collaborative knowledge production, it is therefore indispensable that the PIs of an RC are willing to devote sufficient time and energy to understanding different methods, ways of thinking and perspectives (Blanckenburg et al., 2005). It is also important for the success of content-related communication processes that the PIs are able to make their own discipline-specific boundaries, axioms, methods, ways of thinking and perspectives understandable to their partners (O'Donnell & Derry, 2005). Only if the PIs

succeed in communicating with each other on a content-related level can the early inter-connection and integration of the sub-project-internal research work and thus the collaborative and integration-oriented production of knowledge succeed (Defila et al., 2006). If, on the other hand, the content-related understanding of the PIs does not succeed, research work conducted in the sub-projects cannot be coordinated and their research results cannot be integrated. As a result, it is not possible to overcome the perspectives specific to the sub-projects and answer the common research questions of the RC in a discipline-independent manner, which is why the achievement of the common goals becomes unrealistic (Defila et al., 2006). As a consequence of low prospects of returns, PIs reduce their investments in collaborative knowledge production in favour of their sub-projects, resulting in an erosion of goal commitment at the cluster level. Accordingly, *difference problems* are expected to negatively influence the extent of *goal achievement* (H13). Likewise, *difference problems* are expected to reduce PIs' commitment to cooperation at the cluster level (*goal commitment problems*) (H14) (Fig. 2). Finally, it is expected that *difference problems* indirectly reduce the extent of goal achievement, mediated by a lack of PIs' commitment to the common goals of the RC (*goal commitment problems*) (H15) (Table 2).

Communication problems

Following Meißner et al. (2022), *communication problems* (CP) can be defined as a lack of active, transparent and exhaustive communication by the spokespeople (CP1) or PIs (CP2, CP3) at the cluster level. *Communication problems* arise from the fact that an RC places not only content-related demands on its members but also expects a specific work organisation, resulting from the members' dual role as producers and consumers of the research club's goods (Baurmann & Vowe, 2014): In a *prosumer club*, the contributions to the production of the *club good* must be made by the club members themselves (Cornes & Sandler, 1996). In this context, to fulfil the overarching purpose of a *research club*—the collaborative production of knowledge—it is essential that PIs act as a team to the highest degree: The development and updating of common goals and questions, the association-wide organisation of work, the interconnection of the research work of the sub-projects, the formation of syntheses and the development of common, scientific products do not take place on their own, but require continuous coordination and organisation by the PIs (Beer et al., 2020). If the PIs of an RC do not actively participate in organisational communication or if their communication at the cluster level is not comprehensive and transparent, there is a risk of misunderstanding, and communication barriers and implementation problems may arise (Defila et al., 2006). As a result, cooperation between PIs across sub-projects is made considerably more difficult, leaving synergies, innovation and strength potentials unused (Blanckenburg et al., 2005). Accordingly, it is assumed that *communication problems* have a negative impact on the extent to which goals are achieved (H16) (Fig. 2).

Management problems

Following Meißner et al. (2022), the *management problem* (MP) can be defined as the self-promotion of an RC's spokesperson at the expense of their PIs (MP1) and the lack of alignment between a spokesperson's management behaviour and the concerns of the cluster (MP2). RCs cannot organise their collaboration efficiently when a *management problem* occurs (Salazar et al., 2019). This applies to coordination tasks in the context of work planning and sharing, but also to solving challenges typical of the production and use

of *club goods* (Cornes & Sandler, 1996). In the interest of achieving common goals, an RC's spokesperson must show motivational capacity for cross-subproject cooperation and interdisciplinary exchange (Defila et al., 2006). In addition, they must support the cluster members in resolving conflicts (Blanckenburg et al., 2005), create an open and participatory environment for collaboration between PIs at the cluster level (Zaccaro et al., 2001), address the varying information needs of the PIs and project groups and anticipate the need for strategic steering processes in a timely manner, stimulate them, moderate their implementation and accompany them (Defila et al., 2006). However, if the spokesperson acts out of self-interest and without sufficient reference to the needs of the PIs, there is a risk that the collaboration problems and obstacles that arise will not be addressed appropriately, will expand and thus lead to significant process losses.

In a research collaboration, management competence is especially important in the case of conflict management, as the club members are hierarchically on the same level (Defila et al., 2008), place great value on their autonomy and can only be controlled to a limited extent (John, 2019). This requires that the leadership is able to mediate in an appreciative, discreet and inclusive manner when content-related and personal conflicts arise between PIs (Salazar et al., 2019). Accordingly, it is assumed that, as a result of *management problems*, serious personal and content-related conflicts remain unresolved, thus directly promoting unfair behaviour and a lack of trust between PIs (*relationship problems*) (H17) (Fig. 2). It can also be assumed that *management problems* have an indirect, negative effect on the extent to which goals are achieved: In the first order, this is mediated by a negative climate for cooperation (*relationship problem*), in the second order by a lack of commitment by the PIs to cooperation at the cluster level (*goal commitment problems*) (H18), their content-related and disciplinary understanding (*difference problems*) (H19), their cross-subproject communication (*communication problems*) (H20) and in the third order by PIs' preparation for unforeseen situations (*certainty problems*) (H21) (Table 2).

Certainty problems

Following Meißner et al. (2022), the *certainty problem* (CP) can be defined as a lack of regular progress evaluations (CP1), as well as insufficient preparation for delays or unforeseen situations in the context of collaboration between PIs at the cluster level (CP2). The *certainty problem* is rooted in the fact that the non-routine research processes of *collaborations involving division of labour* (Laudel, 2002) in particular are in principle open-ended and thus can only be formally planned and controlled to a limited extent (John, 2019). Because the medium-term survival of an RC can only be ensured if the goals communicated to the funding agency are achieved (see above), a pragmatic approach to obstacles, unforeseen situations and the resulting situational challenges is of existential importance for a *research club* (Knorr-Cetina, 1984): Delays or unforeseen situations—e.g. due to the impracticability of individual research activities, staff turnover or defective research equipment—must be anticipated in a timely, flexible and pragmatic manner (Choi & Pak, 2007; Klein, 2005). On the one hand, this requires regular monitoring of the progress towards goals during which feedback is obtained from the PIs on whether the set (sub-)goals of their sub-projects can be achieved. On the other hand, regular evaluation of work progress allows PIs to react to unforeseen situations and problems in an agile manner, i.e. to update their project plans and work processes coherently according to changing circumstances (Blanckenburg et al., 2005). If PIs fail to regularly review the progress of their sub-projects and if impending delays and challenges to individual research projects are not anticipated

and addressed at the cluster level, subsequent research risks being delayed or even blocked as a result. This, in turn, contributes to the fact that joint knowledge production at the cluster level is so far behind schedule that the joint achievement of goals seems increasingly impossible. As a result, PIs' commitment to the common goals threatens to erode successively (John, 2019). In this sense, *certainty problems* are expected to promote a lack of commitment among PIs regarding their collaboration at the cluster level (*goal commitment problems*) (H22) (Fig. 2).

Goal commitment problems

Following Meißner et al. (2022), the *goal commitment problem* (GCP) can be defined as a lack of engagement among the PIs to their cooperation at the cluster level (GCP1), a lack of cooperation across sub-projects (GCP2) and low commitment among PIs to the common goals of the RC (GCP3). The *goal commitment problem* can in principle occur in all clubs in which the production of the *club good* is provided by the club members themselves (Cornes & Sandler, 1996). However, the *goal commitment problem* is particularly pronounced in the science-specific context of *research clubs*: In an RC, continuous teamwork with regular contributions must be ensured for joint success (Olechnicka et al., 2019). This requires considerable upfront efforts on the part of the PIs, while at the same time the prospects of success are difficult to calculate. Especially at the beginning of the implementation phase of a collaborative research project, it is difficult to foresee how much time and energy the PIs will have to devote in order to achieve the goals communicated to the funder (Blanckenburg et al., 2005). Likewise, it is unclear how great the return will be that can be gained from the achievement of goals by the individual PIs. It may therefore seem wiser for PIs to withhold investments until there is a sufficient likelihood of success. This may result in not investing early and intensively enough in collaborative knowledge production (Meißner et al., 2022). Similarly, it is conceivable that the PIs of top-down initiated RCs, in particular, develop little or no commitment to the overarching goals of their RC because they can exert little influence on the design and definition of the common research questions compared to the PIs of bottom-up initiated RCs (Twyman & Contractor, 2019). Finally, due to unforeseen problems and obstacles, the goals of an RC may only turn out to be unrealistic during the lifetime of an RC. As a result, PIs are at risk of the notorious loss of motivation and thus a comprehensive erosion of commitment to the common goals of the cluster (John, 2019).

Under the influence of *goal commitment problems*, the sub-projects of an RC gradually drift apart (Defila et al., 2006): The PIs increasingly withdraw into their sub-projects, focus on their own interests and benefit calculations, while the common goals of the RC are only pursued with low priority. As a result, the cross-sub-project collaboration necessary to achieve the goals comes to a standstill and it becomes increasingly difficult to control the research activities of the sub-projects (Defila et al., 2006). In extreme cases, the PIs' withdrawal into their sub-projects develops into *free-rider* behaviour (Bikard et al., 2015): PIs focus exclusively on the interests of their sub-projects at the expense of the RC and withhold all further investment of contributions and resources for collaboration at the cluster level. *Free-rider* behaviour subsequently undermines the reciprocity of effort and return, which all those PIs who remain committed to the cluster's common research goals presuppose. In this sense, *goal commitment problems* are expected to influence *fairness problems* positively (H23) and the extent of goal achievement negatively (H24) (Fig. 2).

Data

The hypothesis model (Fig. 2, Table 2) framed by the club-theoretical heuristic and derived from the state of research is tested with cross-sectional data obtained from a large-scale web survey conducted in 2020 as part of the collaborative project Determinants and effects of cooperation in homogeneous and heterogeneous research clusters (DEKiF). The survey focused on the internal collaboration processes of RCs, collaboration problems that arise in the course of collaborative work, and possible solutions to internal collaboration problems. The population targeted by the survey was $n = 15,595$ PIs and spokespeople who since 2015 are or have been involved in RCs funded by the German Research Foundation in the programmes *Cluster of Excellence* (EXC), *Research Units* (FOR), *Research Centres* (FZT), *Priority Programmes* (SPP), *Collaborative Research Centres* (SFB) and *Transregios* (TRR) (German Research Foundation, 2010, 2015, 2020, 2021). The targeted population included disciplinary and interdisciplinary, large and small (in terms of staff), disciplinary homo- and heterogeneous and multilocal RCs (Figs. 6, 7, 8, 9, 10 in Appendix).

The determination of the population size as well as the collection of contact information was based on the database GEPRIIS (German Research Foundation, 2019), which contains information about projects (and project members) funded by the German Research Foundation, was used to determine the population size as well as to collect contact information. The target population was invited to take part in the survey by email. Due to out-of-date email addresses, contact could not be initiated to 4% of the population. The collected sample consisted of $n = 5312$ participants from $n = 948$ RC, of which $n = 4972$ were PIs, and $n = 340$ were spokespersons. This translates to a response rate of 34 per cent. The sample consisted of 26% female and 74% male participants. As only .001% of respondents were of diverse gender, these were excluded from the analyses due to the small group size. The average age of respondents was $\bar{x} = 52.67$ years with a standard deviation of $SD = 9.52$.

Total survey error analyses (Weisberg, 2009) showed that the quality of the obtained sample is comparatively good: using GEPRIIS (German Research Foundation, 2019), the author was able to create a complete list with the address data of all target persons in the population, which formed the basis for generating a statistically robust sample. The availability of data on the whole target population eliminated the difference between the inferential population and the target population (Weisberg, 2009). Therefore, significant bias in the representation of the sample could have only occurred through the failed contact attempts and unit non-response. Finally, non-response analyses (Groves et al., 2001) of the obtained sample revealed that the non-response error was low with regard to (1) the PIs' disciplinary affiliation, (2) their gender, (3) their affiliation to ongoing or terminated collaborations, and (4) different funding lines (Figs. 4, 5, Appendix). The relative frequencies of the characteristics of the aforementioned variables in the sample deviated by no more than 5% from those of the population. It can therefore be assumed that the following analyses are based on a statistically robust sample.

Methods

In what follows, the specified hypothesis model is tested with structural equation modelling (SEM).⁵ In addition to the simultaneous, inferential statistical testing of all direct effects postulated by the hypothesis model, SEM also reveals indirect effects between collaboration problems on the one hand, and between collaboration problems and goal achievement on the other. In contrast to classical regression methods, SEM thus allows a comprehensive mediation analysis which reveals the complex correlation structures of the specified model variables (Hayes, 2009).

Since the structural model of the SEM contains dichotomous and ordered endogenous variables in addition to latent ones, the WLSMV model estimator (“weighted least squares estimator with standard errors and mean and variance adjusted chi-square test statistic” (Urban & Mayerl, 2014, p. 71)) is specified. The WLSMV estimator has the advantage that the estimates produced by multivariate probit regression procedures are robust to non-normally distributed, endogenous model variables (Kline, 2016). In contrast, the disadvantage is that the standardised probit coefficients produced by WLSMV estimators are difficult to interpret (Urban & Mayerl, 2014, p. 74) and can only be transformed into more intuitively interpretable conditional probabilities through laborious, manual conversion (Muthén & Muthén, 2017, p. 552). Moreover, since the model estimation is based on cross-sectional data, only the direction and significance of an effect can be interpreted. Statements about effect sizes and causal relationships between exogenous and endogenous variables cannot be made on the basis of cross-sectional data and the WLSMV estimator (Urban & Mayerl, 2014, pp. 14, 74).

Item non-response failures are addressed in the context of SEM by the *Full Information Maximum Likelihood* (FIML) (Cham et al., 2017) procedure. In contrast to listwise case exclusion, where a case is already excluded from the analysis if it has a missing value on only one model variable, the FIML procedure uses all available information from all cases in the sample for the model estimation. The FIML procedure has the advantage that in combination with the WLSMV estimator it produces particularly robust and consistent estimated values (Asparouhov & Muthén, 2010). Finally, due to the hierarchical data structure,⁶ a correction for the standard errors and the chi-square test is applied within the SEM (Muthén & Muthén, 2017, p. 659). In order to avoid biased parameter estimates due to unit non-response, appropriate post-stratification weights are considered in the model estimation (Lumley, 2010).

Operationalisation

Five of the seven collaboration problems enter the model analysis as latent constructs. The internal consistency of the latent constructs can be classified as acceptable with Cronbach’s alpha values between $\alpha = .79$ and $\alpha = .86$ (Cronbach, 1951) (Table 6, Appendix). The indicators for the latent constructs *fairness*, *communication*, *relationship*, *goal commitment* and *difference problems* were recorded using a five-point scale (1 = *not at all*, 5 = *fully*) with

⁵ Data preparation and analysis was conducted with Mplus (Muthén and Muthén, 2017), R (R Core Team, 2020) and the R-Packages Tidyverse (Wickham et al., 2019), Psych (Revelle, 2020) and MplusAutomation (Hallquist and Wiley, 2018).

⁶ The $n = 5312$ PIs and Spokespeople are clustered into $n = 948$ RCs and are thus not statistically independent.

which the respondents scaled their assessments of the extent to which the respective statements applied to cooperation at the cluster level (Table 6, Appendix). All numerical values of the indicators are inverted before analysis. Thus, increases in the inverted scale represent greater rejection of the specified indicators. As a result of the inversion, an increase in the values of the latent constructs can be interpreted as an increase in the strength of the respective problem dimension.

In addition to the five latent constructs, two further dummy variables for the remaining *management problems* and *certainty problems* are included in the model estimation for lack of internal consistency. The scale value 1 indicates the presence of a problem indicator (Likert scale point 3, 4 and 5), whereas the scale value 0 indicates its absence (Likert scale point 1, 2) (Table 6, Appendix). Finally, the central endogenous variable is the extent to which the research collaboration has achieved the goals it communicated to the DFG before the start of the project. This is also measured using the above-mentioned five-level scale and is included in the model analysis without further transformation (Table 6, Appendix).

Results

Fairness problems

Consistent with hypothesis H1, the structural model of the SEM (Fig. 3) shows that an increase in *fairness problems* is significantly associated with an increase in *relationship problems* ($\beta = .57, p < 0.001$). Moreover, the mediation analysis of structural equation modelling shows that *fairness problems* indirectly negatively affect the extent of goal attainment: In the first order mediated by conflicting social relationships (*relationship problems*), in the second order mediated by a lack of commitment among PIs to cluster-level collaboration (*goal commitment problems*) (H2) ($\beta = -1.40, p < 0.001$), and by a lack of content-related and disciplinary understanding among PIs (*difference problems*) (H4) ($\beta = -1.80, p < 0.001$). Finally, in contrast to hypothesis H3, *communication problems* do not prove to be a significant mediator of a negative effect of *fairness problems* on the extent of goal achievement ($\beta = -.01, p < 0.05$) (Table 3).

Relationship problems

According to hypotheses H5, H6, H7, and H8, *relationship problems* are significantly positively associated with *difference problems* ($\beta = .68, p < 0.001$), *communication problems* ($\beta = .92, p < 0.001$), *goal commitment problems* ($\beta = .77, p < 0.001$) and the two dummy-coded indicators of *certainty problems* ($\beta = .38, p < 0.001, \beta = .37, p < 0.001$). Furthermore, according to hypotheses H9 and H11, *relationship problems* significantly reduce the extent of goal achievement, mediated by *goal commitment problems* ($\beta = -1.60, p > 0.05$) on the one hand and *difference problems* ($\beta = -.18, p > 0.05$) on the other hand. However, contrary to hypotheses H10 and H12, neither *communication problems* ($\beta = -0.01, p > 0.05$) nor the dummy-coded indicators of *certainty problems* ($\beta = -0.17, p > 0.05, \beta = -0.8, p > 0.05$) proved to be significant mediators of a negative, indirect effect of *relationship problems* on the extent of goal achievement.

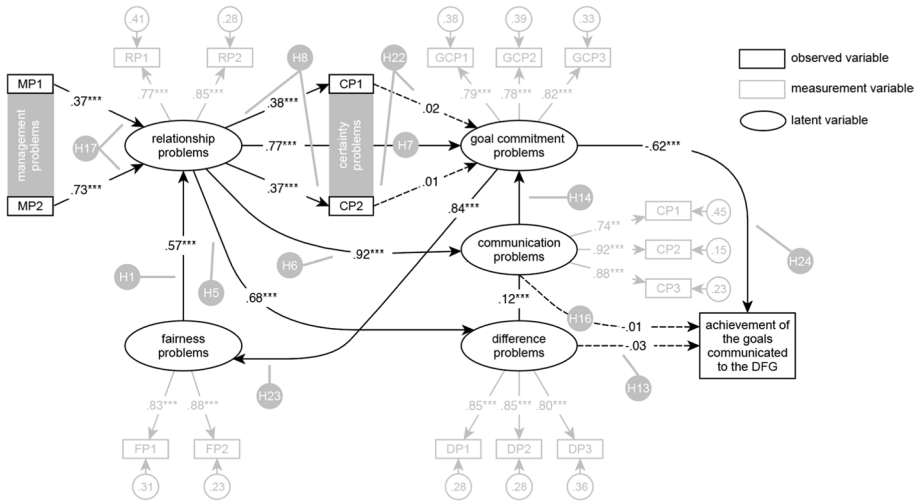


Fig. 3 Structural model of the direct interrelations and effects of seven research collaboration problems. Estimator: WLSMV, CFI = .97, TLI = .96, RMSEA = .05, SRMR = .04, $p < .05$ *, $p < .01$ **, $p < .001$ ***, standardised coefficients

Difference problems

The hypothesis H14, which was established in the context of *difference problems*, can also be confirmed: thus, on the one hand, the specified structural equation model shows, with a beta coefficient of $\beta = .12$ and a probability of error of $p < 0.001$, that *difference problems* increase *goal commitment problems* significantly. In comparison, the specified structural equation model does not support the assumptions of hypothesis H13 that *difference problems* ($\beta = -.03$, $p > 0.05$) directly negatively affect the extent of goal attainment. However, hypothesis H15 can be accepted: *difference problems* exert an indirect negative influence on the extent of goal achievement ($\beta = -2.20$, $p < 0.001$), mediated by *goal commitment problems*.

Communication problems

The analysis does not support the assumption that *communication problems* have a negative impact on the extent of goal achievement ($\beta = -.01$, $p > 0.05$). Accordingly, hypothesis H16 must be rejected.

Management problems

According to H17, both dummy-coded *management problem* indicators are significantly positively associated with *relationship problems* ($\beta = .37$, $p < 0.001$; $\beta = .73$, $p < 0.001$) and negatively affect the extent of goal achievement (H18, H19), mediated by *relationship problems*, *goal commitment problems* ($\beta = -.93$, $p < 0.001$; $\beta = -1.85$, $p < 0.001$), and *difference problems* ($\beta = -1.11$, $p < 0.001$; $\beta = -.30$, $p < 0.001$). In contrast to

Table 3 Indirect effects of the structural model

Predictor	Mediator 1	Mediator 2	Mediator 3	Outcome	β	σ
H2	Fairness problems	Relationship problem	Goal commitment problem	Achievement of goals	-1.40***	0.03
H3	Fairness problems	Relationship problems	Communication problems	Achievement of goals	-0.01	0.06
H4	Fairness problems	Relationship problems	Difference problems	Achievement of goals	-1.80***	0.40
H9	Relationship problems	Goal commitment problems		Achievement of goals	-1.60***	0.13
H10	Relationship problems	Communication problems		Achievement of goals	-0.01	0.07
H11	Relationship problems	Difference problems		Achievement of goals	-0.18***	0.04
H12	Relationship problems	Certainty problems (CP1)	Goal commitment problems	Achievement of goals	-0.17	0.01
	Relationship problems	Certainty problems (CP2)	Goal commitment problems	Achievement of goals	-0.08	0.01
H15	Difference problems	Goal commitment problems		Achievement of goals	-2.20***	0.04
H18	Management problems (MP1)	Relationship problems	Goal commitment problems	Achievement of goals	-0.93***	0.01
	Management problems (MP2)	Relationship problems	Goal commitment problems	Achievement of goals	-1.85***	0.16
H19	Management problems (MP1)	Relationship problems		Achievement of goals	-1.11***	0.20
	Management problems (MP2)	Relationship problems	Difference problems	Achievement of goals	-0.30***	0.04
H20	Management problems (MP1)	Relationship problems	Communication problems	Achievement of goals	-0.01	0.04
	Management problems (MP2)	Relationship problems	communication problems	Achievement of goals	-0.02	0.08
H21	Management problems (MP1)	Relationship problems	Goal commitment problems	Achievement of goals	-0.02	0.01
	Management problems (MP1)	Relationship problems	Goal commitment problems	Achievement of goals	-0.01	0.02
	Management problems (MP2)	Relationship problems	Goal commitment problems	Achievement of goals	-0.01	0.01
	Management problems (MP2)	Relationship problems	Goal commitment problems	Achievement of goals	-0.01	0.01

Bold paths indicate significant, indirect effects on the extent of goal achievement

*p<0.05; **p<0.01; ***p<0.001

Table 4 Configural invariance of the structural model by mode, disciplinary affiliation, status and size

	CFI	TLI	RMSEA	SRMR
Mode of cooperation of the RC				
Monodisciplinary*	.98	.98	.05	.04
Multidisciplinary	.98	.97	.06	.05
Cross-disciplinary	.95	.94	.06	.05
Interdisciplinary	.97	.97	.05	.04
Transdisciplinary	.99	.99	.03	.04
Disciplinary affiliation of the PIs				
Humanities*	.97	.96	.05	.05
Engineering	.98	.98	.04	.05
Life sciences	.97	.96	.05	.04
Natural sciences	.97	.97	.05	.04
Status of the RC				
Ongoing	.97	.97	.05	.04
Terminated*	.97	.96	.05	.04
Size of the RC				
1–15 Sub-projects	.97	.97	.05	.04
16–30 Sub-projects	.97	.96	.05	.04
> 30 Sub-projects	.98	.97	.04	.04

*Model without effect of CP1 on GCP (*goal commitment problems*)

hypotheses H20 and H21, neither *communication problems* ($\beta = -0.01$, $p > 0.05$; $\beta = -0.02$, $p > 0.05$) nor *certainty problems* ($\beta = -0.01$, $p > 0.05$; $\beta = -0.01$, $p > 0.05$; $\beta = -0.01$, $p > 0.05$; $\beta = -0.02$, $p > 0.05$) proved to be significant mediators of a negative effect of *management problems* on the extent of goal achievement.

Certainty problems

The specified structural model of SEM also does not support hypothesis H22: *Certainty problems* exert a partially negative effect on *goal commitment problems*, but this effect cannot be generalised beyond the sample ($\beta = .01$, $p > 0.05$; $\beta = .02$, $p > 0.05$).

Goal commitment problems

Finally, the SEM structural model confirms both hypothesis H23 and hypothesis H24: *goal commitment problems*, on the one hand, have a significant positive effect on *fairness problems* with a beta coefficient of $\beta = .84$ and a probability of error of $p < 0.001$. Simultaneously, *goal commitment problems* reduce the extent of goal achievement significantly with a beta coefficient of $\beta = -.62$ and a probability of error of $p < 0.001$.

The key fit indices (West et al., 2012) show that the specified hypothesis model has a good fit to the input data ($CFI = .97$, $TLI = .96$, $RMSEA = .05$, $SRMR = .04$).⁷ Overall, the

⁷ The 2-test as well as the 2/df ratio are largely unusable for SEM models based on larger samples ($n > 300$) (Bentler & Bonett, 1980; West et al., 2012). They are therefore not considered in evaluating the model fit.

structural model of the SEM thus supports the hypothesis model to a sufficient degree. The examination of configural invariance also shows that the specified model fits the survey data on research collaborations with different modes of cooperation just as well as it fits ongoing and completed research collaborations, research collaborations of different sizes and research collaborations from all scientific disciplines (Table 4).

Discussion

Summary of the findings

The testing of the hypothesis model based on the club-theoretical heuristic showed the interrelations and effects of seven central collaboration problems. Overall, seven of the twelve hypotheses relating to indirect effects were confirmed. Likewise, nine of the twelve hypotheses relating to direct effects were confirmed. Thus, the hypothesis model of the seven collaboration problems can be grosso modo confirmed by the SEM. Despite its comparatively low complexity, the structural equation model showed a good fit with the survey data of $n = 4972$ PIs cooperating in interdisciplinary and cross-disciplinary RCs of various sizes as well as in ongoing and completed RCs in all disciplines. The paper's stated aim—the theoretically guided and empirically grounded examination of the interrelationships and effects of seven central collaboration problems—was thus met.

The specified structural model of SEM confirmed the assumption of the hypothesis model that *relationship problems* in particular form a central node in the network of collaboration problems: They are exacerbated by *fairness* and *management problems* (H1, H17), in turn they foster *certainty*, *difference*, *communication* and *goal commitment problems* (H5–H8) and (indirectly) negatively affect the extent of goal achievement (H9, H11). The structural model thus supported the widespread (John, 2019, p. 36)—but by no means trivial (De Jong & Dirks, 2012; Shrum et al., 2001)—assessment of science collaboration research that trusting and fair interaction between collaborating PIs is a necessary, if not sufficient, condition for achieving the goals of research collaborations. Furthermore, the structural model of SEM confirmed the central importance of successful goal commitment (Hollaender, 2003; Loibl, 2005): on the one hand, the structural model showed that RCs achieve their goals less completely when they are affected by *goal commitment problems* (H24), on the other hand, it showed that failed goal commitment is associated with an increase in *fairness problems* (H23). In addition, both *relationship problems* (H2, H4, H9, H11, H18, H19) and *goal commitment problems* (H2, H9, H15, H18) emerged as significant mediators of negative effects that various collaboration problems exert on the extent to which an RC achieves its goals.

Contrary to the assumption of the hypothesis model, *certainty problems* had no significant effect on *goal commitment problems* (H22), nor did they prove to be a significant mediator of negative effects on the extent of goal achievement of other problems (H12, H21). This lack of effects can be attributed to the strong trust that the PIs (have to) place in each other's internal sub-project research work, because the "*highly specific task bundles of scientific work* [of all other PIs] *are often not very comprehensible and therefore hardly controllable*" (John, 2019, p. 2). In particular, *certainty problems* that occur within the sub-projects can only be recognised with difficulty by PIs external to the sub-project and consequently cannot be synchronised with personal expectations for success of the RC. As a result, PIs' goal commitment remains largely unaffected by *certainty problems*. The

structural model also showed that *difference problems* (H14) had no (direct) effect on the extent of goal achievement. However, the effect of *difference problems* on the extent of goal attainment was completely mediated by *goal commitment problems* (H15), and therefore lost its significance in the direct relationship to the extent of goal attainment. Finally, the fact that communication problems neither appeared as a significant mediator (H3, H10, H20) nor had a significant impact on the extent of goal achievement (H16) suggests that RCs are successful even when communication at the cluster level is not simultaneously exhaustive, transparent and active. This shows that communication at the cluster level can certainly also be selective and take place according to situational requirements. In this way, a paralysis of communication can be avoided (Misra et al., 2011) and efficient cooperation between the PIs can be fostered (Anderson et al., 2000).

Theoretical and practical contributions

Even though the seven collaboration problems have already been addressed implicitly or explicitly by other researchers, to the author's knowledge no study has yet presented a similar systematisation of central collaboration problems and examined their interrelations and effects on the success of RCs on the basis of representative survey data. With the help of the systematisation of the seven collaboration problems and on the basis of the statistical modelling of their interrelations and effects, the paper was able to differentiate the understanding of how collaboration problems are interrelated and which direct and indirect effects they exert on the performance of RCs. As a theoretical framework, the club perspective proved to be a useful micro-sociological heuristic: with club theory, it was possible to clarify the role that *private goods*, *club goods* and *public goods* play in the context of collaboration between researchers in RCs and to disentangle the strands of action, challenges and conflicts associated with their production (Baurmann & Vowe, 2014). The club perspective also enabled a differentiated view on the tension between collaboration and competition, which the members of an RC must continually balance over the years for long-term, solitary and collaborative success. From the perspective of club theory, collaboration and competition did not appear as antagonistic forms of scientific interaction, but rather as indissolubly intertwined, especially in the context of collaborative knowledge production: The PIs of an RC thus appeared as frenemies who must cooperate closely in the sense of the overarching purpose of collaborative knowledge production, but at the same time compete to maximise individual scientific distinction opportunities (Defila et al., 2008; Nickelsen & Krämer, 2016). In this context, club theory underlined the notorious social dilemma that can potentially affect all RCs: The self-interested behaviour of individual collaboration partners threatens to lead to an outcome that harms the common interests of all participants in an RC.

This raises issues for science policy, which can set specific incentives to prevent or solve research collaboration problems through funding and evaluation measures. Despite the unprecedented increase in scientific collaboration, the governance of collaborations is often not yet sufficiently developed to support the success of collaborative research to an adequate degree (Kleimann et al., 2019). One certainly important reason for this is that the development of functional governance requires multiple areas of expertise and is often given too little space in the process of initiating an RC by both applicants and research funding organisations (Defila et al., 2006). Moreover, for capacity reasons, it is difficult for the PIs concerned to develop and effectively implement preventive measures and solutions for collaboration problems that arise in

parallel with their research activities. Rather, it must be the responsibility of science policy to sustainably promote the systematisation of suitable governance mechanisms. In this respect, it is essential that existing knowledge about already tested approaches to cooperation governance be made accessible (Kleimann et al., 2019).

What contribution can this paper make to the development of effective collaborative governance? It has been shown *grosso modo* that RCs can only be successful if the PIs have an intrinsic interest in joint success: On the one hand, all PIs must therefore be better off (e.g. in the form of reputational gains, access to third-party funding or to exclusive resources) as a result of collaborative knowledge production. On the other hand, even if success is uncertain, PIs must be willing to invest significant time and energy in collaborative knowledge production in order to fulfil the overarching purpose of the RC. It is central to the success of an RC that the PIs can communicate with each other in the context of collaborative knowledge production, create social cohesion at the cluster level, balance personal and content-related tensions between the participants, and organise collaborative knowledge production efficiently through functional communication and goal-oriented research network management (Hall et al., 2019). It goes without saying that there can be no one-size-fits-all governance for RCs. Instead, the research management of an RC should pursue tentative governance (Kuhlmann et al., 2019), i.e. governance that adapts agilely to the needs of an RC and its institutional or disciplinary environment.

Limitations and gaps for future research

What are the limitations of the results? A first limitation is the fact that the extent of goal achievement was measured by subjective assessments based on the perceptions of the PIs responsible for the sub-projects. The extent to which the central, endogenous variable of the degree of goal achievement was influenced by desirability effects must remain an open question. In particular, bibliometric measures of success or productivity would more validly reflect the performance of an RC—even if not fully. Since the modelled SEM is based on survey data collected from PIs and deals exclusively with their collaboration at the cluster level, it was only possible to derive statements from the SEM on the interrelationship and effect structure of collaboration problems for the collaboration of PIs at the cluster level. Survey data on the experiences and assessments of staff in RCs that cooperate within the sub-projects and are hierarchically located *below* the PIs and the spokespeople would provide further insights into the interrelations and effects of research collaboration problems.

The characteristics of the different RCs (cooperation mode, duration status, size and disciplinary composition) were only taken into account with regard to configural invariance within the framework of the SEM. It remains an open question whether the specified structural models of the respective subgroups are completely invariant and, if not, which substantively significant differences exist between the subgroups with regard to the interrelations and effects of research collaboration problems.

Finally, the analysed data were collected in a survey of researchers who are or were associated with at least one DFG-funded research collaboration as PIs. The extent to which the findings derived from the specified structural model can also be transferred to research collaborations of other nations and funding systems must remain open.

Appendix

See Figs. 4, 5, 6, 7, 8, 9, 10, Tables 5, 6.

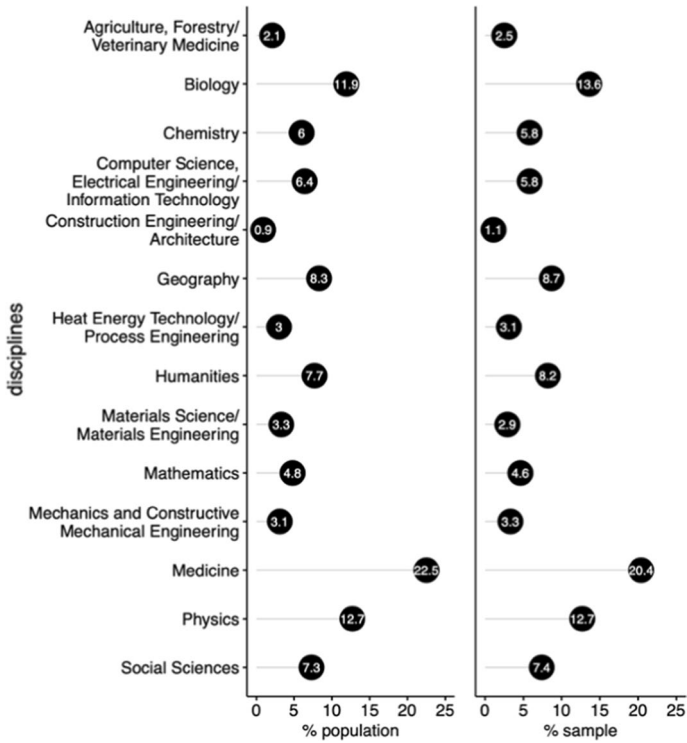


Fig. 4 Relative frequencies of the disciplinary affiliation of the PIs and spokespeople in the population and the sample. *Source: DEKiF-Survey*

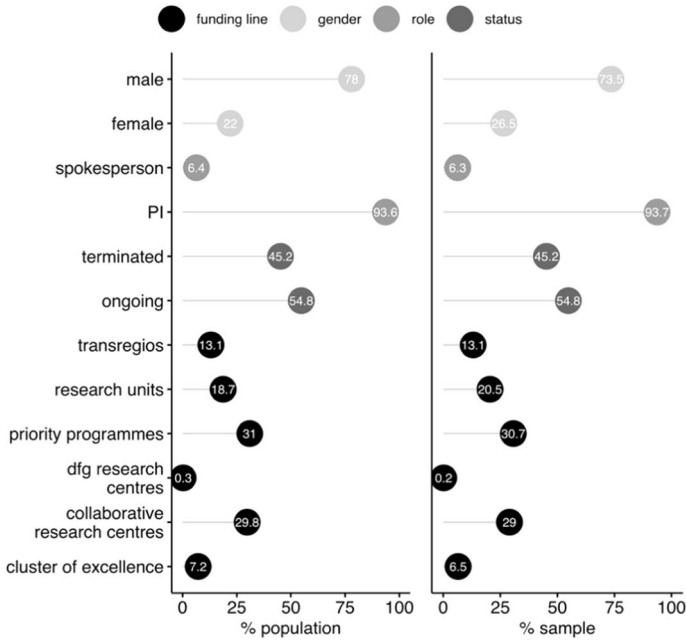


Fig. 5 Relative frequency of researcher's gender and roles, RC status and their funding line in the population and in the sample. *Source: DEKiF-Survey*

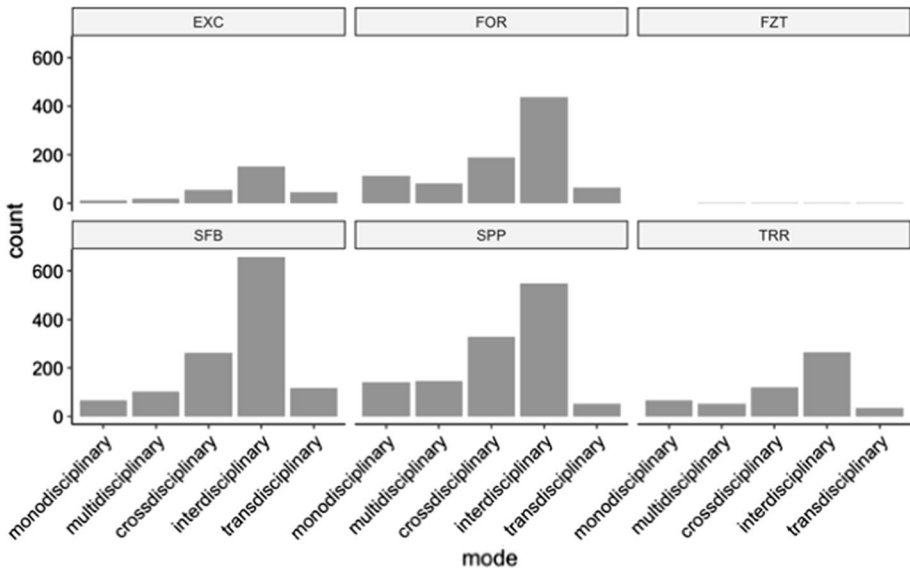


Fig. 6 Mode of collaboration of the research cluster sorted according to German Research Foundation funding lines: *Research Units (FOR), Research Centres (FZT), Clusters of Excellence (EXC), Collaborative Research Centres (SFB), Transregios (TRR) and Priority Programmes (SPP)*. *Source: DEKiF-Survey*

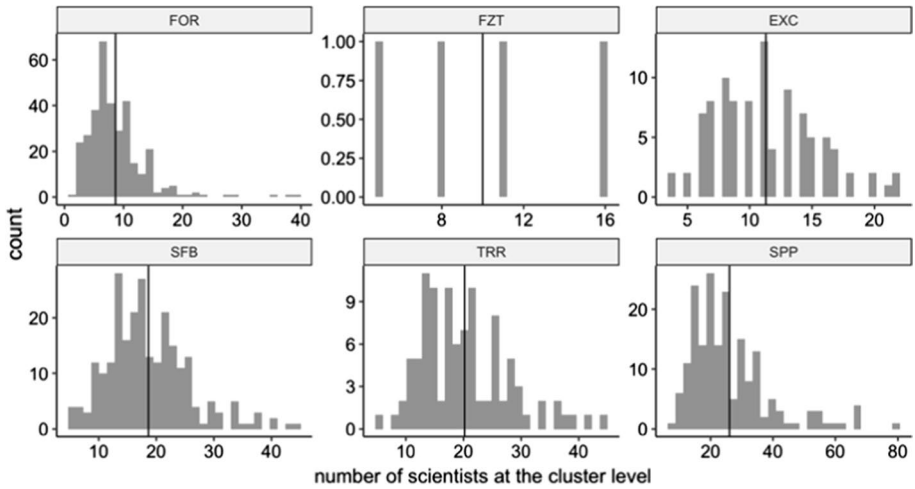


Fig. 7 Number of scientists at the cluster level according to funding lines of the German Research Foundation: *Research Units (FOR), Research Centres (FZT), Clusters of Excellence (EXC), Collaborative Research Centres (SFB), Transregios (TRR) and Priority Programmes (SPP)*. Source: DEKiF-Survey

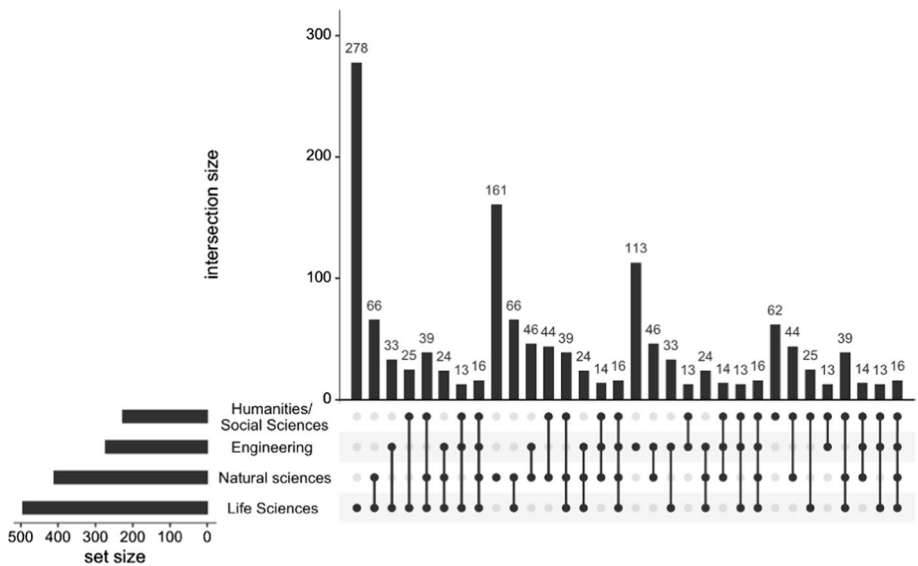


Fig. 8 The four most frequent disciplinary heterogeneities at the cluster level between scientific disciplines. Source: DEKiF-Survey

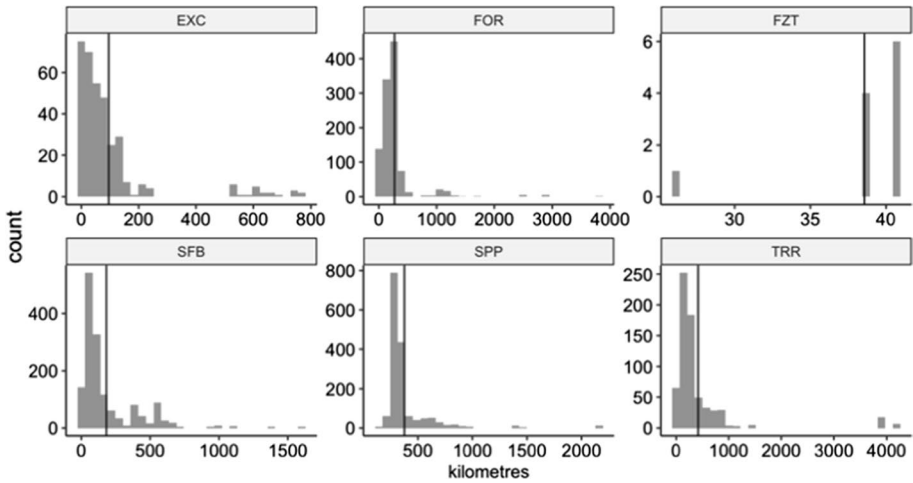


Fig. 9 Average spatial distribution of scientists per research cluster in kilometres, according to funding line: *Research Units (FOR), Research Centres (FZT), Clusters of Excellence (EXC), Collaborative Research Centres (SFB), Transregions (TRR) and Priority Programmes (SPP)*. Source: DEKiF-Survey

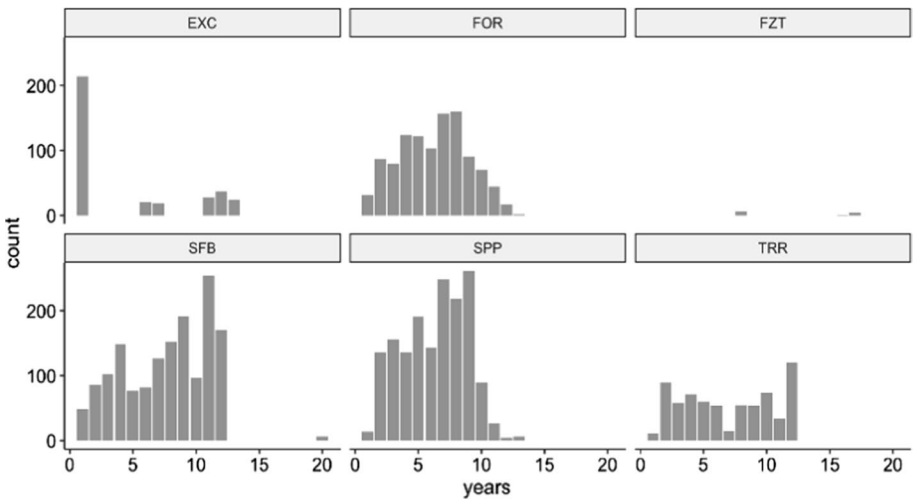


Fig. 10 Duration of the research cluster in years according to funding line: *Research Units (FOR), Research Centres (FZT), Clusters of Excellence (EXC), Collaborative Research Centres (SFB), Transregions (TRR) and Priority Programmes (SPP)*. Source: DEKiF-Survey

Table 5 Correlation matrix of the seven collaboration problems

	<i>Communi- cation problem</i>	<i>Goal com- mitment problem</i>	<i>Differ- ence problem</i>	<i>Rela- tionship problem</i>	<i>Fairness problem</i>	<i>Certainty problem</i>	
						<i>CP1</i>	<i>CP2</i>
<i>Communication problem</i>	1						
<i>Goal commitment problem</i>	.56	1					
<i>Difference problem</i>	.66	.64	1				
<i>Relationship problem</i>	.62	.64	.72	1			
<i>Fairness problem</i>	.63	.64	.70	.61	1		
<i>Certainty problem</i>	<i>CP1</i> .36	.38	.28	.38	.36	1	
	<i>CP2</i> .33	.33	.26	.36	.33	.51	1

Information: since correlations between exogenous observed variables and latent factors are not calculated by Mplus (Muthén & Muthén, 2017), the correlations between the two indicators of the *management problem* and the remaining model variables cannot be listed

Table 6 Description of the sample characteristics of the measurement variables used for model analysis

Variable	Yes (%)	No (%)	Mean (SD)	Name	Cronbach's Alpha
Relationship problems					
There is [no] fair interaction between the cluster members at Cluster level	–	–	4.3 (0.8)	RP1	.79
The collaboration at cluster level is [not] characterised by mutual trust	–	–	4.2 (0.8)	RP2	
Difference problems					
The cluster members are [not] willing to see different points of view	–	–	4.1 (0.8)	DP1	.84
The cluster members can [not] make their own viewpoint understandable to the other cluster members	–	–	4.1 (0.7)	DP2	
The cluster members [do not] strive to understand the mindset and methodological approaches of other disciplines	–	–	4.1 (0.8)	DP3	
Communication problems					
[No] comprehensive and transparent communication [by the spokesperson]	–	–	4 (1)	CP1	.82
Communication at the cluster level is [not] comprehensive	–	–	4 (0.9)	CP2	
The cluster members [do not] actively contribute to communication within the association	–	–	3.8 (0.9)	CP3	
Goal commitment problems					
The cluster members do [not do] everything in their power to reliably deliver their contributions to the achievement of the [...] cluster objectives	–	–	4 (0.8)	GCP1	.86
Cluster members do [not] collaborate across sub-project borders to achieve common research goals	–	–	4.2 (0.9)	GCP2	
The cluster members are [not] committed to the common goals of the cluster	–	–	4.1 (0.8)	GCP3	
Fairness problems					
The costs and benefits of cluster work are [not] shared fairly between the members	–	–	–	FP1	.79
The contributions made by the cluster members [...] are [not] appropriately recognised at the cluster level	–	–	–	FP2	
Certainty problems					
[No] regular feedback is obtained from the sub-projects as to whether the set (sub-)goals of the cluster are being achieved	27	73	–	CP1	–
The cluster is [not] adequately prepared for the fact that delays or unforeseen situations may occur during the research process	14	86	–	CP2	–

Table 6 (continued)

Variable	Yes (%)	No (%)	Mean (SD)	Name	Cronbach's Alpha
Management problems					
[...] Self-promotion [by the spokesperson] at the expense of the cluster	17	83	–	MP1	–
The spokesperson is [not] primarily oriented towards the interests of the cluster as a whole	13	87	–	MP2	–
Central endogenous variable					
The cluster achieves the objectives communicated to the DFG	–	–	4.3(0.7)	GOA	–

Funding Open Access funding enabled and organized by Projekt DEAL. This research was supported by the German Federal Ministry of Education and Research (Grant Number: M527600).

Declarations

Conflict of interest The authors have no conflict of interest to declare that are relevant to the content of this article.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Adams, R. D., & McCormick, K. (1992). Fashion dynamics and the economic theory of clubs. *Review of Social Economy*, 50(1), 24–39. <https://doi.org/10.1080/759368947>
- Anderson, N., Brodeck, F. C., & West, M. A. (2000). *The team climate inventory: Manual and validation of the German version*. Hogrefe.
- Antoni, C. H. (2000). *Teamarbeit gestalten: Grundlagen, Analysen, Lösungen*. Beltz.
- Asparouhov, T., & Muthen, B. (2010). *Weighted least squares estimation with missing data*. Retrieved June 24, 2022, from <https://www.statmodel.com/download/GstrucMissingRevision.pdf>
- Barro, R. J., & Romer, P. M. (1987). Ski lift pricing, with applications to labor and other markets. *American Economic Review*, 77(5), 875–890.
- Baurmann, M., & Vowe, G. (2014). Governing the research club: Wie lassen sich Kooperationsprobleme in Forschungsverbänden lösen? *Forschung. Politik Strategie Management*, 2, 73–84.
- Beer, A., Henke, J., & Pasternack, P. (2020). *Integrieren und kommunizieren. Leitfaden und Toolboxen zur koordinativen Begleitung von Forschungsverbänden und Förderprogrammen (HoF-Handreichung 13)*. Institut für Hochschulforschung.
- Bentler, P. M., & Bonett, D. G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin*, 3(88), 588–606.
- Bikard, M., Murray, F., & Gans, J. S. (2015). Exploring trade-offs in the organization of scientific work: Collaboration and scientific reward. *Management Science*, 61(7), 1473–1495. <https://doi.org/10.1287/mnsc.2014.2052>
- Blanckenburg, C., Böhme, B., Diemel, H.-L., & Legewie, H. (2005). *Leitfaden für interdisziplinäre Forschergruppen: Projekte initiieren—Zusammenarbeit gestalten*. Steiner.
- Bozeman, B., & Corley, E. (2004). Scientists' collaboration strategies: Implications for scientific and technical human capital. *Research Policy*, 33(4), 599–616. <https://doi.org/10.1016/j.respol.2004.01.008>
- Bozeman, B., & Lee, S. (2005). The impact of research collaboration on scientific productivity. *Social Studies of Science*, 35(5), 673–702. <https://doi.org/10.1177/0306312705052359>
- Bozeman, B., & Youtie, J. L. (2017). *The strength in numbers: The new science of team science*. Princeton University Press.
- Buchanan, J. M. (1965). An economic theory of clubs. *Economica*, 32(125), 1. <https://doi.org/10.2307/2552442>
- Cham, H., Reshetnyak, E., Rosenfeld, B., & Breitbart, W. (2017). Full information maximum likelihood estimation for latent variable interactions with incomplete indicators. *Multivariate Behavioral Research*, 52(1), 12–30. <https://doi.org/10.1080/00273171.2016.1245600>
- Choi, B. C. K., & Pak, A. W. P. (2007). Multidisciplinarity, interdisciplinarity, and transdisciplinarity in health research, services, education and policy: 2. Promotors, barriers, and strategies of enhancement. *Clinical & Investigative Medicine*, 30(6), 224.
- Chompalov, I., & Shrum, W. (1999). Institutional collaboration in science: A typology of technological practice. *Science, Technology, & Human Values*. <https://doi.org/10.1177/016224399902400302>

- Cooke, N. J., & Hilton, M. L. (2015). *Enhancing the effectiveness of team science*. The National Academies Press.
- Cornes, R., & Sandler, T. (1996). *The theory of externalities, public goods, and club goods*. Cambridge University Press.
- Craig, S. G., & Heikkilä, E. J. (1989). Urban safety in Vancouver: Allocation and production of a congestible public good. *Canadian Journal of Economics*, 17(4), 867–884.
- Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, 16(3), 297–334. <https://doi.org/10.1007/BF02310555>
- Cummings, J. N., & Kiesler, S. (2005). Collaborative research across disciplinary and organizational boundaries. *Social Studies of Science*, 35(5), 703–722.
- De Jong, B. A., & Dirks, K. T. (2012). Beyond shared perceptions of trust and monitoring in teams: Implications of asymmetry and dissensus. *Journal of Applied Psychology*, 97(2), 391–406. <https://doi.org/10.1037/a0026483>
- Defila, R., Di Giulio, A., & Scheuermann, M. (2006). *Forschungsverbundmanagement: Handbuch für die Gestaltung inter- und transdisziplinärer Projekte*. VDF Hochschulverlag.
- Defila, R., Di Giulio, A., & Scheuermann, M. (2008). *Management von Forschungsverbänden: Möglichkeiten der Professionalisierung und Unterstützung*. Wiley-VCH.
- Duysburgh, P., Naessens, K., Konings, W., & Jacobs, A. (2012). Collaboration in a multidisciplinary, distributed research organization: A case study. *Higher Education Policy*, 25, 267–288.
- Fehr, E., & Gächter, S. (2000). Fairness and retaliation: The economics of reciprocity. *Journal of Economic Perspectives*, 3(14), 159–181.
- German Research Foundation. (2010). *Guideline research centres*. Retrieved June 24, 2022, from https://www.dfg.de/formulare/67_10e/67_10e.pdf
- German Research Foundation. (2015). *Open access*. Retrieved June 24, 2022, from https://www.dfg.de/en/research_funding/programmes/infrastructure/lis/open_access/index.html
- German Research Foundation. (2019). *GEPRIS*. Retrieved June 24, 2022, from <https://gepris.dfg.de/gepris/OCTOPUS>
- German Research Foundation. (2020). *Guideline collaborative research centres*. Retrieved June 24, 2022, from https://www.dfg.de/formulare/50_06/50_06_en.pdf
- German Research Foundation. (2021). *Guideline research units*. Retrieved June 24, 2022, from https://www.dfg.de/formulare/50_04/50_04_en.pdf
- German Research Foundation. (2022). *Open access*. Retrieved June 24, 2022, from https://www.dfg.de/en/research_funding/programmes/infrastructure/lis/open_access/index.html
- Groves, R. M., Dillman, D. A., Eltinge, J. L., & Little, R. J. A. (2001). *Survey nonresponse*. Wiley.
- Hackett, E. J. (2005). Essential tensions: Identity, control, and risk in research. *Social Studies of Science*, 35(5), 787–826. <https://doi.org/10.1177/0306312705056045>
- Hall, K. L., Vogel, A. L., & Croyle, R. T. (2019). *Strategies for team science success: handbook of evidence-based principles for cross-disciplinary science and practical lessons learned from health researchers*. Springer.
- Hallquist, M. N., & Wiley, J. F. (2018). MplusAutomation: An R package for facilitating large-scale latent variable analyses in Mplus. *Structural Equation Modeling: A Multidisciplinary Journal*, 25(4), 621–638. <https://doi.org/10.1080/10705511.2017.1402334>
- Hayes, A. F. (2009). Beyond Baron and Kenny: Statistical mediation analysis in the new Millennium. *Communication Monographs*, 76(4), 408–420. <https://doi.org/10.1080/03637750903310360>
- Heinze, T. (2012). Was sind kreative Forschungsleistungen?: Konzeptuelle Überlegungen sowie Beispiele aus der Wissenschaftsgeschichte und bibliometrische Befunde. *KZfSS Kölner Zeitschrift Für Soziologie Und Sozialpsychologie*, 64(3), 583–599. <https://doi.org/10.1007/s11577-012-0173-6>
- Hollaender, K. (2003). *Interdisziplinäre Forschung: Merkmale, Einflußfaktoren und Effekte* [Dissertation]. University of Cologne.
- John, M. (2019). *Management interdisziplinärer Forschungsverbände: Institutionelle Bedingungen nachhaltiger Kooperation in der Medizin*. Springer.
- Kerasidou, A. (2019). The role of trust in global health research collaborations. *Bioethics*, 33(4), 495–501. <https://doi.org/10.1111/bioe.12536>
- Kerr, N. L. (1983). Motivation losses in small groups: A social dilemma analysis. *Journal of Personality and Social Psychology*, 45(4), 819–828. <https://doi.org/10.1037/0022-3514.45.4.819>
- Kleimann, B., Winde, M., Wagner, N., Nieveler, S., & Dauchert, A. (2019). *Kooperationsgovernance. Herausforderungen bei der Organisation und Gestaltung kooperativer Wissenschaft*. Workingpaper Stifterverband.

- Klein, J. T. (2005). Interdisciplinary teamwork: The dynamics of collaboration and integration. In S. J. Derry, C. D. Schunn, & M. A. Gernsbacher (Eds.), *Interdisciplinary collaboration: An emerging cognitive science* (pp. 23–50). Lawrence Erlbaum.
- Kline, R. B. (2016). *Principles and practice of structural equation modelling* (4th ed.). The Guilford Press.
- Knorr-Cetina, K. (1984). *Die Fabrikation von Erkenntnis: Zur Anthropologie der Naturwissenschaft*. Suhrkamp.
- König, B., Diehl, K., Tscherning, K., & Helming, K. (2013). A framework for structuring interdisciplinary research management. *Research Policy*, 42(1), 261–272. <https://doi.org/10.1016/j.respol.2012.05.006>
- Kozlowski, S. W. J., & Bell, B. S. (2001). Work groups and teams in organizations. In W. C. Borman, D. R. Ilgen, & R. J. Klimoski (Eds.), *Handbook of psychology. Industrial and organizational psychology*. (Vol. 12). Wiley.
- Kuhlmann, S., Stegmaier, P., & Konrad, K. (2019). The tentative governance of emerging science and technology—A conceptual introduction. *Research Policy*, 48(5), 1091–1097. <https://doi.org/10.1016/j.respol.2019.01.006>
- Laudel, G. (1999). *Interdisziplinäre Forschungs Kooperation: Erfolgsbedingungen der Institution "Sonderforschungsbereich."* Edition Sigma.
- Laudel, G. (2002). What do we measure by co-authorships? *Research Evaluation*, 11(1), 3–15. <https://doi.org/10.3152/147154402781776961>
- Loibl, M. C. (2005). *Spannungen in Forschungsteams: Hintergründe und Methoden zum konstruktiven Abbau von Konflikten in inter- und transdisziplinären Projekten*. Carl-Auer-Systeme.
- Lumley, T. (2010). *Complex surveys: A guide to analysis using R*. Wiley.
- Meißner, F., Weinmann, C., & Vowe, G. (2022). Understanding and addressing problems in research collaboration: A qualitative interview study from a self-governance perspective. *Frontiers in Research Metrics and Analytics*, 6. <https://doi.org/10.3389/frma.2021.778176>
- Merton, R. K. (1949). Social theory and social structure: Toward the codification of theory and research. *Social Forces*, 28(4), 443–444. <https://doi.org/10.2307/2572257>
- Misra, S., Hall, K., Feng, A., Stipelman, B., & Stokols, D. (2011). Collaborative processes in transdisciplinary research. In M. Kirst, N. Schaefer-McDaniel, S. Hwang, & P. O'Campo (Eds.), *Converging disciplines* (pp. 97–110). Springer.
- Musgrave, R. A. (1959). *The Theory of Public Finance*. McGraw-Hill.
- Muthén, L. K., & Muthén, B. (2017). *Mplus statistical analysis with latent variables: User's guide—Version 8*. Retrieved June 24, 2022, from https://www.statmodel.com/download/usersguide/MplusUserGuideVer_8.pdf
- Nickelsen, K., & Krämer, F. (2016). Introduction: Cooperation and competition in the sciences. *NTM Zeitschrift Für Geschichte Der Wissenschaften, Technik Und Medizin*, 24(2), 119–123. <https://doi.org/10.1007/s00048-016-0145-4>
- O'Donnell, A. M., & Derry, S. J. (2005). Cognitive processes in interdisciplinary groups: Problems and possibilities. In S. J. Derry, C. D. Schunn, & M. A. Gernsbacher (Eds.), *Interdisciplinary collaboration—An emerging cognitive science* (pp. 51–82). Psychology Press.
- Olechnicka, A., Ploszaj, A., & Celinska-Janowicz, D. (2019). *The geography of scientific collaboration*. Routledge.
- Ostrom, E., & Ostrom, V. (1977). Public goods and public choices. In E. S. Savas (Ed.), *Alternatives for delivering public services: Toward improved performance* (pp. 7–49). Westview Press.
- Pacheco, R. C. S., Manhães, M., & Maldonado, M. U. (2017). *Innovation, interdisciplinarity, and creative destruction*. Oxford University Press.
- Preuß, S. (2017). *Drittmittel für die Forschung*. Springer. <https://doi.org/10.1007/978-3-658-16452-2>
- Pritchard, R. D. (1969). Equity theory: A review and critique. *Organizational Behavior and Human Performance*, 4(2), 176–211. [https://doi.org/10.1016/0030-5073\(69\)90005-1](https://doi.org/10.1016/0030-5073(69)90005-1)
- R Core Team. (2020). *R: A language and environment for statistical computing [manual]*. Retrieved June 24, 2022, from <http://www.r-project.org>
- Revelle, W. (2020). *psych: Procedures for psychological, psychometric, and personality research [manual]*. Retrieved June 24, 2022, from <https://CRAN.R-project.org/package=psych>
- Rosen, M. D., & Sexton, R. J. (1993). Irrigation districts and water markets: An application of cooperative decision-making theory. *Land Economics*, 69(1), 39–53.
- Sacco, T. (2020). The good, the bad, and the ugly: Dimensions of success and failure in research collaboration. *Sociological Forum*, 35(2), 488–510. <https://doi.org/10.1111/soef.12591>
- Salazar, M. R., Widmer, K., Doiron, K., & Lant, T. K. (2019). Leader integrative capabilities: A catalyst for effective interdisciplinary teams. In K. L. Hall, A. L. Vogel, & R. T. Croyle (Eds.), *Strategies for team*

- science success: Handbook of evidence-based principles for cross-disciplinary science and practical lessons learned from health researchers* (pp. 313–328). Springer.
- Samuelson, P. A. (1954). The pure theory of public expenditure. *The Review of Economics and Statistics*, 36(4), 387–389. <https://doi.org/10.2307/1925895>
- Schemm Gregory, R. (2010). Europa als ein Club voller Clubs. *Peter Language*. <https://doi.org/10.3726/978-3-653-00349-9>
- Shrum, W., Chompalov, I., & Genuth, J. (2001). Trust, conflict and performance in scientific collaborations. *Social Studies of Science*, 31(5), 681–730.
- Shrum, W., Genuth, J., & Chompalov, I. (2007). *Structures of scientific collaboration*. MIT Press.
- Stichweh, R. (2013). *Wissenschaft, Universität, Professionen: Soziologische Analysen (Neuaufst)*. Transcript.
- Twyman, M., & Contractor, N. (2019). Team assembly. In K. L. Hall, A. L. Vogel, & R. T. Croyle (Eds.), *Strategies for team science success: Handbook of evidence-based principles for cross-disciplinary science and practical lessons learned from health researchers* (pp. 217–240). Springer.
- Urban, D., & Mayerl, J. (2014). *Strukturgleichungsmodellierung*. Springer.
- van den Besselaar, P., Hemlin, S., & van der Weijden, I. (2012). Collaboration and competition in research. *Higher Education Policy*, 25(3), 263–266. <https://doi.org/10.1057/hep.2012.16>
- Vinck, D. (2010). *The sociology of scientific work: The fundamental relationship between science and society*. Edward Elgar.
- Warner, C. M., Kılınc, R., Hale, C. W., Cohen, A. B., & Johnson, K. A. (2015). Religion and public goods provision: Experimental and interview evidence from catholicism and islam in Europe. *Comparative Politics*, 47(2), 189–209.
- Weisberg, H. F. (2009). *The total survey error approach: A guide to the new science of survey research*. University of Chicago Press.
- West, S. G., Taylor, A. B., & Wu, W. (2012). Model fit and model selection in structural equation modeling. In R. H. Hoyle (Ed.), *Handbook of structural equation modeling* (pp. 209–231). The Guilford Press.
- Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L., François, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T., Miller, E., Bache, S., Müller, K., Ooms, J., Robinson, D., Seidel, D., Spinu, V., ... Yutani, H. (2019). Welcome to the Tidyverse. *Journal of Open Source Software*, 4(43), 1–6. <https://doi.org/10.21105/joss.01686>
- Zaccaro, S. J., Rittman, A. L., & Marks, M. A. (2001). Team leadership. *The Leadership Quarterly*, 12(4), 451–483. [https://doi.org/10.1016/S1048-9843\(01\)00093-5](https://doi.org/10.1016/S1048-9843(01)00093-5)