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Integrating geometric data analysis and network analysis by iterative reciprocal mapping. The example of the German field of sociology

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ABSTRACT

This paper presents an iterative procedure for reconstructing a scientific field by relating two relational methods. The procedure involves using geometric data analysis and network analysis in several steps. Blocks from block model analysis are projected into a space constructed by MCA, considered as subspaces using CSA, and subsequently inspected with regard to their manifest interaction structures. The findings allow us to examine the overall structure of a scientific field vis-à-vis the relative autonomies and eigenstructures of its subspaces and the homology-heterology relations they show to each other and the main space, thus providing a more differentiated view of the interplay of social spaces and networks.

1. Introduction

The relational approach to the study of science has emerged as a prominent perspective in recent years, offering comprehensive frameworks for examining the intricate relations that underpin scientific knowledge production. This approach acknowledges the relationality of scientific ideas, practices, and actors, emphasizing that scientific knowledge is not generated by a monolithic entity but rather a dynamic system of interrelated elements. In this context, two schools of thought are among the most prominent in recent times: the construction of scientific fields (Bourdieu, 1988; Kropp, 2011, 2013; Renisio, 2015; Rossier & Benz, 2021; Rossier et al., 2023; Schmitz et al., 2019; Schmidt-Wellenburg & Schmitz, 2023; Schneickert et al., 2019; Schwemmer & Wieczorek, 2020; Warczok & Beyer, 2021) and the construction of scientific networks (Cugmas et al., 2016; Lietz et al., 2024; Moody, 2004, Newman, 2001; Uzzi & Spiro, 2005; Volle et al., 2024). Both belong to the modern movement of relational sociology (Crossley, 2011; Emirbayer, 1997; Witte et al., 2017) and provide us with elaborated tools to understand the relation between cultural and social structures (cp. Mohr, 1998: 361). The burgeoning availability of multimodal relational data, including linked network, prosopographical, and textual information, further reinforces the relevancy of the relational approach in the contemporary sociology of science. Against the background of the relationalism that characterises both traditions (cp. Basov, 2020), we will develop an integrative research strategy.

In theoretical terms, several contributions have been showing the family similarity between the two paradigms (De Nooy, 2003; Mohr, 2013). Some studies have been integrating methods, such as by projecting network positions into a space of actors (cp.

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D'Esposito et al., 2014, Serino et al., 2017). While this approach of investigating the network structure of fields can generate rich insights, such as by relating centrality in collaborative networks to the centrality of a scientific field, we see considerable potential in a more comprehensive and flexible *methodological* integration. In this paper, we develop an approach of switching *between the field and network perspectives, by subsequently investigating the network structure of fields and the field structures of networks*. Specifically, we propose an iterative reciprocal mapping approach that uses recent variants of geometric data analysis and network data analysis for a differentiated reconstruction of scientific fields as positional structures.

Using the case of current German sociology and an integrated data set of prosopograhic and publication data, we first construct a field of scientists using multiple correspondence analysis (MCA) to reveal the *latent* cultural and material relations that constitute this field and the different research cultures it comprises. We will, secondly, identify groups of co-authors using block model analysis to grasp and empirically classify the *manifest* relationships of coproduction of symbolic goods between German sociologists. Thirdly, we employ passive projection and concentration ellipses to identify the positions of co-author groups in the latent cultural and material structure of the overall field. Fourthly, we employ the rather recent development of class-specific multiple correspondence analysis (CSA) to reconstruct each co-author-group as latent subspace within the overall field. This allows us to assess the relative *homology and heterology*[1] (cp. Witte & Schmitz, 2020: 68) of each block from the overall field, i.e. subspace-specific capital structures, subspace-specific logics of antagonism and subspace-specific semantics. Fifthly, we relate the block-specific co-authorship networks to the respective subspaces in order to assess the different interplays of manifest cooperation presented by the manifest network graph and latent structures inherent in the geometric space.

We conclude with a discussion of our main findings, their implications, main directions for further research, and a reflexion on the interplay between publication data and the representation of research cultures.

2. Relating field structures and network structures

2.1. Spatial structures and network structures

The relational approach has proven successful in the analysis and reconstruction of symbolic fields such as art, literature, and science, thereby consequently relating cultural, social, and material aspects. The relational idea is taken up methodologically in different ways, arguably, most prominently as fields or networks. While the former understands social, material, and symbolic relations as *latent structures* and primarily aims to reconstruct dimensions such as field structures and capital forms, the latter is primarily concerned with *manifest relationships* and examines, for example patterns of cooperation or the emergence of cliques. Both approaches are associated with specific relational methods. On the one hand, techniques from geometric data analysis (e.g., MCA and PCA) allow us to represent a sphere such as a scientific field as a spatially and dimensionally structured entity. In this context, individuals such as scientists and groups, that can be conceptualized as research cultures or thought collectives (Fleck, 1981), are situated within a common field that grasps the latent, dimensional structure of their differences and commonalities, which are important conditions of scientific practice, career outlooks, conflicts, alliances, etc. (cp. Warczok & Beyer, 2021; Kropp, 2011, 2013; Münch & Baier, 2012; Schmitz et al., 2019; Schmidt-Wellenburg & Schmitz, 2023). On the other hand, techniques from social network analysis allow us to reconstruct scientific fields as relationally structured graphs in which specific positions are defined by manifest relationships such as networks scientists span in their collaborations or referencing practices. As network theory also informs us, these manifest relationship networks can form groups with dense internal ties that are otherwise separated from each other such as groups of scientists emerging from collaboration or citation patterns (Akbaritabar et al., 2020; Volle et al., 2024). Such groups can fundamentally impact on scientist's practice and career outlooks (Heffernan, 2021) and they serve as practical and strategic orientation references. Thus, apart from constructing mere networks, this branch of relational methods provides us with techniques for analysing various aspects of networks such as network structures (Newman, 2001), individual positions and their embeddedness (Cugmas et al., 2016; De Stefano et al., 2011) and group structures, for example through block model analysis, a tool that detects groups of structural similarity within networks (cp. Peixoto, 2019).

2.2. Network structure of fields and field structure of networks

Based on their theoretical family similarity, research has been relating these relational methods and their underlying questions, which yields considerable analytical potential, not least since manifest and latent structure can be understood as co-constitutive (cp. de

[1] The concept of heterology (Witte & Schmitz 2020: 68), introduced in and embraced by an international network on Homology, was developed to differentiate and complement Bourdieu's concept of homology, which tends to overemphasise structural similarities between two or more fields or spaces. This conceptual advancement, which emphasises structural dissimilarities, enables a systematic assessment of the varying degrees of homologous (or heterologous) relations between structures, such as fields and spaces. It also allows for differentiating the ways in which structures can be more or less homo- or heterological (e.g., latent, dimensional homology between fields with manifest heterologies regarding the categories). In terms of theory, this conceptual extension aims to integrate two of Bourdieu's (1993) key ideas in the context of societal differentiation: the search for universal principles of fields and for the specificities of fields. The quest for 'general social laws' of fields is thus understood as a search for both, recurring and divergent field structures and mechanisms. Regarding empirical research, the homology-heterology couplet is currently being employed in a range of research contexts and has been applied recently to examine the interplay between different national fields (e.g. Schmitz & Schmidt-Wellenburg 2024).

Nooy, 2003). Indeed, there is an increasing amount of work that combines both approaches (cp. Basov, 2020). On a practical level, the structure of a field and the structure of a network can each be reconstructed and then related to one another (Bühlmann et al., 2012). Such approaches can be used to plot into a geometric space, the manifest network structure (cp. Denord, 2015), and the parameters of network analysis (cp. Benz & Rossier, 2022) or, as we shall illustrate later, the spatial positions of blocks derived from block modelling. Yet, we shall argue that this *perspective of network structure of fields* is merely a first step in relating relational methods. If we employ a methodologically complementary view-point, we can think and assess the *field structure of networks (or blocks)*: Based on a given network or block, the perspective of field theory, i.e. asking for the latent structure of this entity can be mobilized, to ask, for example, for network-(or block-)specific latent capital structures. Although the 'two-step' methodical combination is a good practice in the sociology of science, culture and beyond, we argue that scientists can adopt a more general approach to combining both method families, which can inform and guide their research endeavours.

As we saw, the structure of a field and the structure of a network can each be reconstructed and then related to one another in order to understand how the latent structure of this field and the manifest structures of interaction are interrelated. Yet, it is of equal importance, for example in order to better understand the functioning of a scientific field, to inquire the presence of possibly semi-autonomous field structures that may be operating within specific co-authorship networks (or blocks thereof) (i.e. the spatial structure of a block) and, in doing so, the extent of their homo- and heterology vis-à-vis both the main space and with respect to other subspaces. Likewise, then, our interest also concerns the manifest relationships between scientists that characterize a given block-specific spatial structure (i.e. the network structure of subspaces). In doing so, each step is a switch in perspective: switching from the field structure to the network view of the field or from a network structure to the field view of this network. Yet, in methodological terms, switching in perspectives and relating relational methods can, theoretically, be conducted as a three-step, four-step, etc. process, which is only limited by the actual research interests (and pragmatics). Regarding the methodical implementation, each step can be any specific variant from the families of geometric data analysis (GDA, PCA, MFA, CSA) and network analysis (centrality measures, block modelling, link prediction, etc.). In this light, we propose to see the practical combination of the respective relational method families as an *iterative switching between the perspective of the network structure of fields and the perspective of the field structure of networks*. Consequently, we propose to move back and forth between the construction and analysis of latent relations and the construction of manifest relationships. Since it is not least the theoretical underpinnings or rather their often-hasty interpretation that prevents such methodological and practical integration (cp. Mohr, 2013), we shall first discuss some of the most pertinent theoretical issues and restrictions that motivate our conceptual approach.

Sometimes, there is the erroneous assumption that Bourdieu's approach would focus only on the latent relations of actors while ignoring the manifest relationships between them, would restrict any manifest relationship to instances of close proximity within a field, would assume that proximity in the field determines subjective closeness, and would only depict opposition and conflict, while ignoring cooperation. Yet, as Schmitz (2017) reconstructs, field theory is genuinely interested in manifest relationships such as interactions (see, e.g., the concept of social capital), in relationships between actors from different positions in the social space (see, e.g., the issue of non-homophilous interactions), in proximity as a mechanism of fostering subjective social distance and distance in interaction, and in the issue of cooperation between (spatially close or distant) positions (cp. Basov, 2020).

2.3. Spatial position of nodes and network blocks

In order to use these field-theoretical considerations methodologically, network analyses can be particularly convenient. However, while the network perspective is open for embedding (Granovetter, 1985), it is usually not devoted to a systematic concept of how manifest interactions could be embedded in latent structures and spaces (beyond those that are based on manifest ties themselves, cp. Sosa & Buitrago, 2021). At this point, research can contextualize the information gained from network models to a previously constructed space or field. For example, Anheier et al. (1995) employ correspondence analysis on individuals' memberships in blocks and addition variables depicting individuals' social structural characteristics. In contrast, our approach refrains from actively using block models or other results from the network analysis to construct geometric spaces, thereby allowing us to raise questions on the form and nature of the relation between network blocks and latent field structures. For example, centrality values or blocks of a block model analysis can be passively located in a field and their dispersion can be illustrated in the space, using concentration ellipses. In this way, it can be assessed in how far actors from different areas of the field form group cultures across positions (cp. Basov, 2020; Basov et al., 2021) such as cooperating with each other in the form of co-authorship. From a field-theoretical point of view, this can be understood as the strategic formation of alliances and the merging of complementary capital endowments and, with White (2008), as getting action, i.e. as the creation of room for manoeuvre, for example, through the inclusion of alternative questions and methods, adding to shared stories. Passive projection of network parameters or positions can be mobilized to map where the boundaries of such dispersion lie. Such boundaries can be understood as delineating legitimate or strategically given areas of degrees of freedom for interaction or delineating areas of restriction of switching between different styles of thinking i.e. as blocking action. In the context of science, one may think of the boundaries between research cultures or thought collectives, that is, groups of scientists emerging from their practices of interaction and thereby fundamentally structuring their discipline (Moody, 2004). At the same time, projecting network vectors or block-membership into a field can be used to investigate whether actors do not cooperate with each other despite spatial proximity in the field. For example, there are plenty of instances of non-cooperating scientists despite their proximity in terms of scientific capital and resources. Indeed, there might be good strategic reasons for that such as nourishing on differences in order to sharpen one's profile vis-à-vis similar colleagues.

What's more is that the observation of a tie between two actors, or of their co-membership in a common block may lead one to assume a corresponding positive intention to interact or even a positive assessment of the interaction. This is why the circumstance of a

manifest relationship, such as a joint publication between scientists, runs the risk of being reduced to consensual aspects of cooperation. Yet, the subjective dimension of network relationships may imply very different orientations, including 'negative ties' (cp. Labianca & Brass, 2006), one may only think about stress-inducing dependence relationships between advisor and Ph.D. student.

2.4. Network blocks as subspaces

Each manifest relationship of those interacting directly or within a common block may well be subject to differences between the interacting parties, regarding the meaning they give to the network, the traits they bring into the network, or the symbolic goods they co-produce within the network. If we take this consideration one step further, we can formulate the more general question of the latent structure that might underlie a given social network or a specific block of actors. Conveniently, this is the perspective field-theory can provide us with.

In the simplest case, one could assume a general homology, namely that the structure of a field, such as the field of German sociology, also constitutes the internal structure of any subgroup (say, of co-authors of a block that all engage and collaborate in the context of a specific quantitative method). Yet, from the point of view of generalized field theory (Schmitz et al., 2017), which assumes partially *heterologous* subfields, this is by no means necessarily the case. What is evident from a network perspective also applies to field theory, which would not assume that a given subgroup of cooperating scientists must have the same structure and practices as the overall field. Rather, a subgroup of scientists may exhibit specific internal structuration and the structure they form might thus be more or less heterologous, i.e. may more or less diverge from the overall structure of a field. Such *refraction* (cp. Basov, 2020) may comprise group-specific resource relations, cooperation strategies, competitive relations, capital accumulation, capital pooling, capital conversion, oppositional relations, domination relations, division of labour, logics of integration, etc., in short: the entire spectrum of the field analytical gaze.

Further, neither field nor network theory would claim distinct independence between a group's internal structure and its position in the overall field. Rather, both make us aware of the interplay between external (here: a scientific field) and internal (here: a subspace of scientists within this field) structure. The field-theoretical idea of relative autonomy, can also be found in network theory: Blocking action and getting action and thus the extent to which actors are enabled or denied productivity or innovation can be investigated more comprehensively if we achieve to reconstruct the structure of *nested social shells* (White, 1993: 84).

When examining the internal network structure of a given network block, the manifest relationships within this block would be revealed and one could well use further information to describe the nodes of this network, e.g. according to issues of substantive interest (such as resources, cultural specificities, of the different actors, etc.). However, one would not grasp, at the same time, everything that transcends manifest relationships, i.e. the myriads of similarities and dissimilarities that might be structured by other relations than the ones made manifest. Geometric data analysis, employed onto a given block, can help to identify the latent structures such as power differentials and, consequently, contribute to our understanding as to why certain nodes show strong, weak, or no ties. The recent development of CSA can play an instructive role here. CSA allows us to employ relational reasoning in the form of subspace analyses of previously defined categories such as membership in a block and to reveal latent differences and differences within this subgroup of a field. Employing this view on co-authorship blocks, we shall speak of *network blocks as subspaces*. This means to investigate the latent structure within a given block, i.e. the structures of unity and opposition spanned thereby, and thus the differences that are transcended by the actors involved. Thanks to the properties of CSA, the metric of the overall space is preserved (Le Roux and Rouanet, 2004, 2010), so that we can formalize the relative autonomy and heteronomy of a subspace, or more specifically, of the spatial structure of a network block.

2.5. Subspace-specific relationship structures

Finally, while the spatial approach and its appurtenant geometric methodology is open for what we call the *Eigenlogik* and *Eigenstructures* of subspaces, the spatial Eigenlogik and Eigenstructure of manifest relationship constellations are rarely assessed. Yet, by inspecting the distribution of a network over a given subspace (i.e. for a given block), one can explicitly focus on *subspace-specific manifest relationship structures*. Again, the simplest case, would be a subspace where every actor is linked to every other actor. Yet, the relationship structure within a given subspace may well follow a specific internal logic and can take particular forms. Thus, conceptually, not only are networks embedded in an overall field, but also in their own subspaces. The subspace's dimensionality can provide informative context for both existing and absent ties (or structural holes). For example, a subspace's network overall structure may form a hierarchical structure spanning across scientists' power positions, a community structure characterized by weakly connected groups of co-authors, a star structure where one central node influences the flow of information, or a ring structure representing scientific exchange circles, to name but the most prominent. Thus, different subspaces might well be characterized by specific research cultures and styles of association (such as co-authorships) (cp. Kim et al., 2022).

3. Methodology: a five-step approach to reciprocally relating space and network information

As motivated in the previous section, we will now employ the iterative reciprocal strategy by proceeding in the following five-step

sequence.

Step 1: reconstruction of field structure (MCA)

For the construction of the field of German scientists, i.e. for the operationalization of the latent relational structure, we employ an original data set on German-speaking sociologists (N = 1124) actively engaged in sections or working groups of the German Sociological Association (DGS) or the Academy of Sociology (AS) .[2] The actors were identified through membership lists of sections, if publicly available, through the signatory list of the call to found the AS (2017), and by means of a web-based search for self- and third-party reported participation in events organised by the DGS, its sections, or the AS. The prosopographic dataset comprises basic academic career information, research topics sociologists engage with, theories employed, and methods used,[3] academic achievements, academic and public visibility, and academic and institutional resources (online appendix table A1). We use MCA (Benzécri, 1973; Le Roux & Rouanet, 2004) to reconstruct the cultural and material structure of the field (Fig. 1).

Step 2: reconstruction of co-author-groups (block model analysis)

In order to take the manifest relationships between scientists into account, we construct collaborative communities. For that purpose, we use cooperation data comprising publications from sociologists in the prosopographic dataset that are indexed in the Scopus database. A total of 1478 publications from 880 German-speaking sociologists between 1996 and 2022 were extracted from the Scopus database for analysis,[4] which allows us to trace the degree of establishment of manifest social relationships. We have constructed author-co-author networks, leveraging the well-established disambiguation quality of the Scopus Author ID (Aman, 2018). The nodes in this network represent the authors, connected with an edge if they have published jointly. The edges are weighted using the sum of joint publications normalized by the number of authors per publication, indicating the strength of social connection among the corresponding authors. The overall network consists of 571 nodes und 847 edges and has a density of 0.0052 and an average local cluster coefficient of 0.46, which indicates a loose and clustered network structure (the graph of the full network is provided in online appendix figure A1). We employ block model techniques to cluster nodes into groups using a Bayesian stochastic block model (SBM). In particular, we used the planted partition model to find assortative community structures (Zhang & Peixoto, 2020). For every group of authors, we computed network size and density metrics, along with the segregation from other blocks within the network using Freeman's segregation index.

Step 3: spatial position of network blocks in the field (passive projection/concentration ellipses)

In this step, we switch from the field perspective to the network perspective and identify the block-structure of scientific collaboration that characterizes the German field of sociology. Membership in a block is projected as a passive variable in the space, whereby we consider the mean position of each block (Fig. 2). Concentration ellipses will be employed to show the blocks' dispersion patterns in the space of individuals. We will also keep all actors who are not present in the Scopus-data and all who are members of peripheral blocks without connection to the largest component, for the very reason of assessing their position within the overall field. This allows us to interpret differences between those present in the co-authorship sample and those who are not, taking the specific selection processes of the database (Volle et al., 2024) into account.

Step 4: reconstruction of network blocks as subspaces (CSA)

Switching again, now from the network-perspective to the field perspective, we reconstruct the previously described network blocks as subfields. Each block will be analysed using CSA (Le Roux & Rouanet, 2010). The internal dimensional structure of subspaces will be assessed and its (more or less) homo- or heterologous orientation vis-à-vis the general field will be interpreted. For this, we consider the angles between axes of the subspaces and the main space. In addition, we interpret each subspace by using contributions of active and location of passive variables, by drawing on contributions of specific variables to different subspaces (online appendix tables A4–A8), and by contrasting interpretations between the subspaces and the subspaces vis-à-vis the main space. CSA analysis takes into account the relations of the main space when constructing the subspaces. Thus, a common reference and yardstick – the structure of the main space – is extant, allowing for comparisons between the blocks' subspaces and their homology-heterology relations. In addition, the blocks are described by their semantic specificities, i.e. words typically used in abstracts compared to other blocks (tf-idf scores; online appendix A3).

Step 5: mapping of subspace-specific relationships (passive projection network)

Switching back to a network perspective, we construct how the manifest relationships within the block-specific subspaces differ. Plotting nodes and edges of the network into a subspace – linking the respective field positions – allows us to re-evaluate the network

[2] See Schmitz et al. (2019) and Schmidt-Wellenburg & Schmitz (2024) for a description and contextualization of the data gathering process.

[3] The data on theories, methods, and research foci was collected within an iterative process, based on website information as well as on qualitative inspection for visible patterns within publications.

[4] The comparatively low number of publications per author (1.7) can be attributed to the fact that Scopus only indexes a small number of German-language publications, in particular books and book chapters (Vera-Baceta et al. 2019) and the fact that our dataset also includes early Ph.D. students.

structure – the manifest relationships – of the subspace. By rearranging the nodes according to the latent structures of the field, a spatial rearrangement of the network-block is proposed. Based on this, we can then identify, investigate and interpret the subspace specific form of the network graph and abductively derive interpretations on subfield specific association forms and association strategies. Further, this opens up the possibility to compare manifest co-authorship structures, i.e. particular network forms between the different symbolic and material structures of subspaces/blocks.

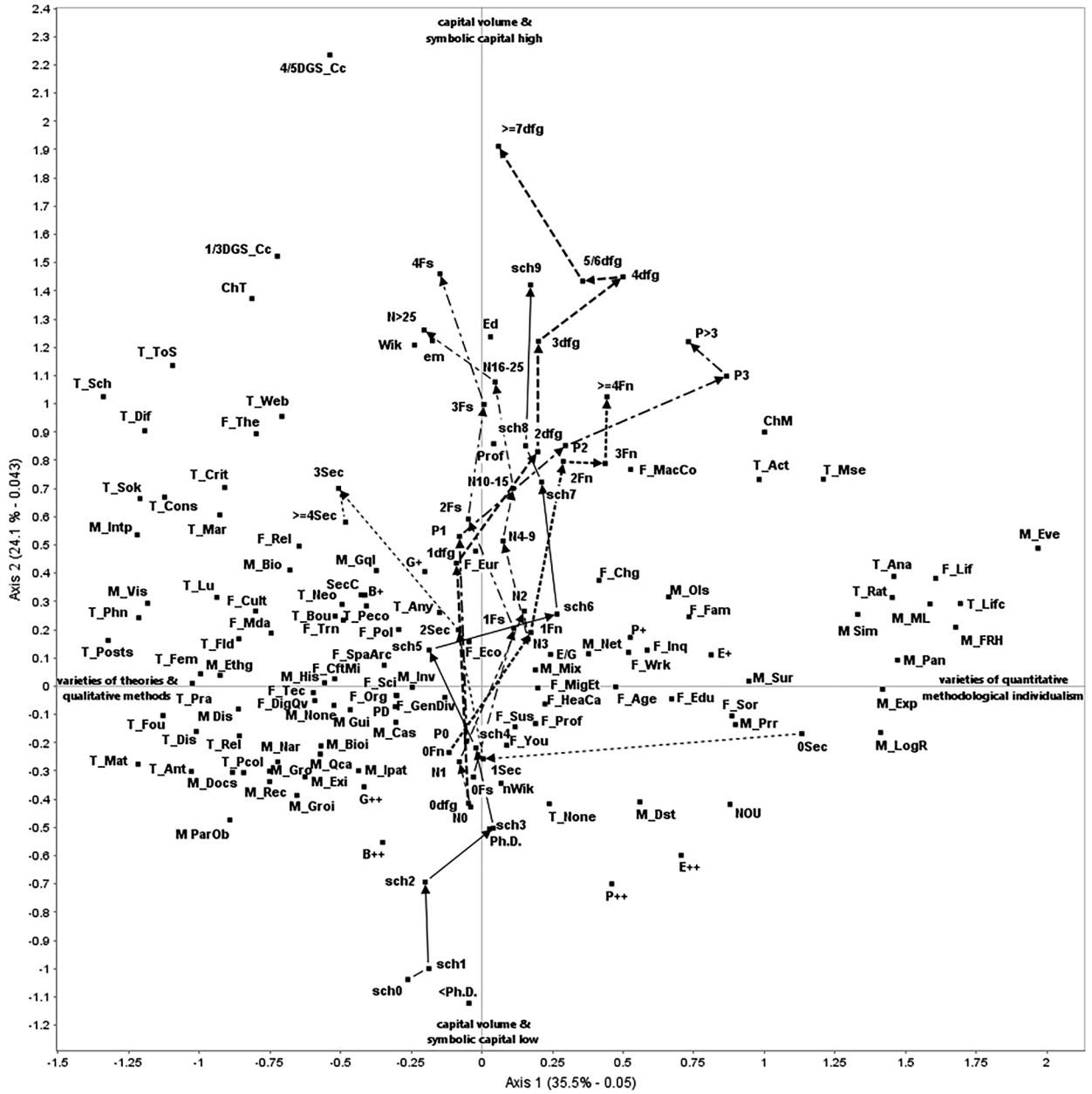

Fig. 1. MCA Field of German Sociology (active).

4. Empirical findings

4.1. The German field of sociology (MCA)

Overall, the field of German sociologists can be described by two dimensions (see Fig. 1 for active and online appendix figure A2 for passive categories).[5] On the outer right side of the x-axis (35.5 % explained variance) we see a pronounced presence of methodological individualism, comprising different theoretical perspectives of bounded rationality (T_Rat, T_Lifc, T_Ana)[6] and individualistic quantitative methodology (M_Eve, M_Sim, M_FRH, M_ML), while the left outer side comprises a variety of different theories (T_Sch, T_Sok, T_Cons, T_Crit, T_Posts, T_Fou, T_Ant) and qualitative methodologies (M_Intp, M_Ethg, M_Dis, M_ParOb). Importantly, however, between these two extreme poles, plenty of different theories, methods, and research topics are present (and combined), making contemporary German sociology a rather pluralist field. Thus, overall, the first dimension grasps the distribution of *theoretical, methodological, and research issues* or *research cultures*.

At the top of the y-axis (24.1 %), we find the distribution of *volume of capital/symbolic capital*, i.e. the presence of financial and human resources (increasing number of DFG grants, 2dfg to ≥7dfg, and other sources of funding, 2Fn to ≥4Fn), high numbers of citations (sch7 to sch9) and prestigious positions such as (former) membership in the German research foundation council (1DFG_C and 2_DFG_C, passive, online appendix figure A2), and their relative absence at the bottom.

Interpreting the space along its diagonals, we see, from the bottom left to the top right, increasing individualised based power, i.e., rising numbers of academic prizes (P2 to P > 3) and membership in prestigious learned societies (SciAc, passive, online appendix figure A2). From the bottom right to the top left we concern the accretion of institutional power linked to the DGS, i.e. the number of sections one is member of increases (0Sec to ≥4Sec), and in the upper left quadrant we find being head of a section (SecC), important roles in DGS Council (1/3DGS_Cc and 4/5DGS_Cc), and having been member of the steering committee (1/2DGS_Sc, >03DGS_Sc, passive, online appendix figure A2), whereas not holding such positions is to be found in the lower right quadrant, albeit close to the centroid (not plotted here).

Thus, overall, the field is characterized on its first axis by a variety of different research styles that combine specific methods and theories to investigate certain research objects, spanning from individualistic methodologies to the right linked to quantitative methods to a variety of theoretical approaches affiliated with qualitative methods to the left, with in-between a vast variety of styles located in fairly average than extreme positions of the field. On its second axis dominant positions at the top are opposed to dominated positions at the bottom, showing a clear academic hierarchy linked to publications and funding. The two diagonals indicate, that this hierarchy draws on a more individualistic base of power to the top right and a more institutionalist base to the top left.

4.2. Cooperation-clusters of German sociologists (block model analysis)

Table 1
Cooperation-groups (block model)

Group	*#*	*Name*	*Nodes (n)*	*Edges*	*Density*	*Segregation*
Blocks	b_1	contemporary quantitative methods and canonical legacy	36	65	0.103	0.708
	b_2	quantitative cultural sociology and methodological individualism	77	94	0.032	0.824
	b_3	life-course and standard (quantitative) methods	38	75	0.106	0.575
	b_4	classical qualitative methodologies & theories vs. modern relational methods	111	149	0.024	0.937
	b_5	empirical-analytical sociology	147	238	0.022	0.811
Peripheral groups	b_6	theoretical diversity and qualitative methodologies	9	12	0.333	1.000
	b_7	feminist, gender, and intersectionalist approaches	11	11	0.200	1.000
	b_8	discourse analysis & theory	15	15	0.142	1.000
	b_9	empirical political economy	10	12	0.266	1.000
Residual groups	n_block	no block	309	73	0.001	-
	n_scopus	not in Scopus	245	-	-	-

In the overall network, there is one main component, with a minimum of cooperations, containing 71.6 % of the nodes and 85.5 % of the edges. However, a substantial subset of nodes and edges maintains no connection to this core structure. Moreover, within this main component, we detect five blocks (b_1-b_5, Table 1) out of which two large groups (b_4, n = 111 and b_5, n = 147) are clearly separated from the overall network and highly distinct from each other (online appendix figure A1). There are also two smaller groups (b_1 and b_3) exhibiting strong internal cooperation, and a medium-sized group (b_2) with less internal cooperation, which, thanks to its betweenness, acts as a moderate bridge between the two larger groups.

Beyond that, we also identified and preserved the periphery of the network, i.e. those groups with no sufficient connection to the largest component and emerging before final convergence (b_6–b_9). Thereby, we grasp those more fluid and volatile forms of cooperation that could represent weaker or less established forms of cooperation or indicate differences in the forms of cooperation

[5] Online appendix table A2 also gives information on the variance decomposition (Benzécri modification)
[6] For abbreviations and contributions, see online appendix table A1.

between core and periphery, such as publication in closed teams or the preference for solo authorship or smaller teams. We see that the peripheral blocks are notably smaller but denser connected, indicating closed co-author circles without social relationships to the core of the network. Further, we include isolated authors who do not belong to any block and do not show collaborative ties within the network (n_block) as well as those scientists that are not represented in the Scopus database (n_scopus), thus grasping possible blind spots of the data (cp. Volle et al., 2024). Overall, German sociology can be described as a socially disintegrated discipline in terms of co-authorship represented by a loosely integrated, clustered core and a fragmented periphery.

4.3. Localization of network-blocks within field (passive projection & concentration ellipses)

We now passively project the groups into the previously constructed field and depict concentration ellipsis[7] for each block (see Fig. 2). It turns out that the centre of gravity of groups b_1, b_2, b_3, and b_5 are located to the right side of the centre of the field, while block b_4 and the majority of the peripheral groups as well as the n_block and n_scopus group are located to the left. Thus, regarding the overall localisation, we can induce that the co-authorship groups can be distinguished according to the distribution of theoretical, methodological, and research issues, with one set of groups being organised more around methodological individualism, analytical sociology, and individualistic quantitative methodology and the other sets being organised towards various theories and qualitative methods. In case of blocks b_5 and b_3 on the right hand and b_4 on the left hand, we can see no intersection of the concentration ellipses, indicating two large, highly segregated clusters of co-authors that differ significantly in terms of their scientific dispositions and practices.

Yet, importantly, the majority of both sets is still close to the middle of the space and cannot be assigned to the extreme poles, but

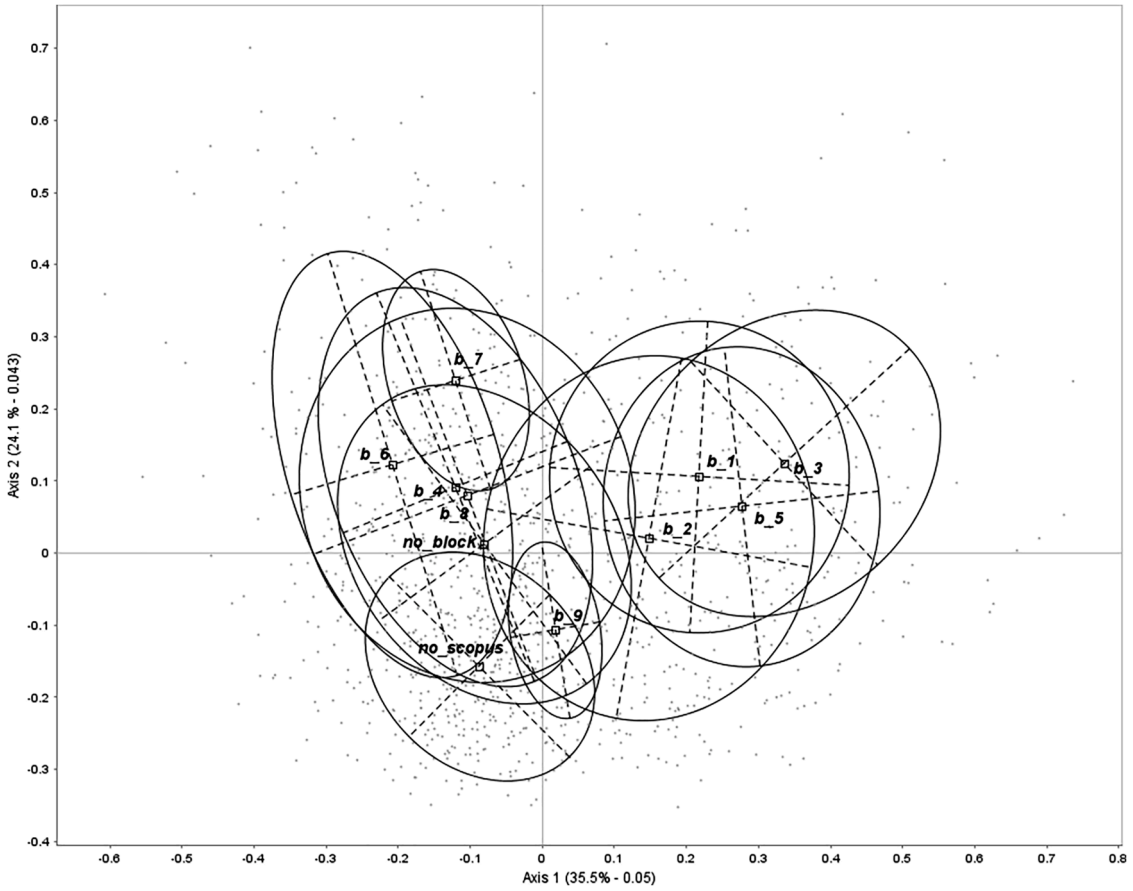

Fig. 2. Position and concentration ellipses of blocks, peripheral groups, and residual groups (passive).[8]

[7] We here use 'median' concentration ellipses with a kappa of 1.177 that for a normally-shaped cloud contain 50% of the cloud's population (Le Roux & Rouanet 2004: 99f.).

[8] For a more comprehensive coloured version of Fig. 2 see online appendix figure A3.

rather to different forms and extents of integrating theories, methods, research topics, etc. Accordingly, the dispersion of most groups is considerably strong, indicating a most notable amount of paradigmatic variation that is represented in each co-authorship block, and, presumably, publication. Focusing on the n_scopus ellipse, we see that, overall, publishing as documented in the Scopus database is more prevalent among sociologists located to the right of the centroid. We also find the no_block group on the left, indicating their low level of involvement in co-authorships. This insight can be related to the different research styles present in the field, with sociologist to the left publishing more (German) books and co-authorship being traditionally less of a common practice for those devoted to social theory or qualitative methods.

Regarding the second dimension, i.e. the differences along capital volume and symbolic capital, it turns out that the majority of groups is located above the origin of the field, i.e. closer towards power positions. One group (b_9) is located below this average and, remarkably, this is the one that is the least clearly assignable to the poles of the x-axis. This group is comprised of rather young, early career sociologists (only 2 out of 10 are professors), that mostly work on research topics of regional and agricultural sociology without particular financial or institutional resources. Below that, the group of those scientists who are not present in the Scopus database (n_scopus) is located, indicating their rather weak capital endowment. This is a crucial indication of the bias inherent in publication databases, a bias that can be revealed based on our multimodal data design. Evidently, the dispersion of all blocks tends to spread more along the y-axis, which can be interpreted as co-authorship spanning differences in resource and symbolic capital. In the simplest case, one may think of collaborations between department chairs, post-doctoral members of staff, and doctoral students.

Notably, employing a superficial notion of field theory, one might expect that a cluster of cooperating scientists could be more clearly assigned to one point in a field. Yet, upon inspecting the concentration ellipses, we find considerable variation of the cluster members and their cooperation across the field. Nevertheless, there are also discernible limits of cooperation, which seem to be more defined by paradigmatic rather than hierarchical differences. Likewise, we find considerable overlap between different clusters, which is also in line with field theory that assumes that proximity in a field can foster distance in interaction.

4.4. Structure of subspaces (CSA) and their internal network structure (projection)

Table 2
Subspace orientations of five blocks to overall space (angles and cosines in brackets between first two axis of CSA and MCA)

	b_1	*b_2*	*b_3*	*b_4*	*b_5*	*b_7*
MCA1 – CSA1	74° (0.27)	57° (-0.54)	69° (-0,36)	82° (-0.14)	86° (-0.07)	83° (0.12)
MCA2 – CSA2	70° (0.35)	42° (0.741)	88° (-0.04)	86° (0.08)	71° (-0.32)	86° (-0.08)
MCA1 – CSA2	77° (-0.23)	77° (-0.22)	86° (-0.07)	72° (0.30)	64° (-0.45)	88° (0.03)
MCA2 – CSA1	73° (0.30)	78° (-0.21)	76° (0.24)	58° (-0.53)	72° (-0.31)	83° (0.12)

Given the blocks' considerable dispersion, the average position in the overall field cannot adequately represent any respective block within the overall field. We shall now investigate the latent structure of each cooperation group using CSA. Table 2 yields the according angles between main- and subspace dimensions. The smaller the angles are between an axis of the subspace and the main space, the more a relative similarity and thus homology vis-à-vis the main space can be assumed, the more angles between axes of the sub- and main-space are to 90°, the more a considerable *Eigenstructure* and extent of heterology is indicated. Taking into account the angles between the first and second axes of MCA and CSA, subspace b_2 is the most homologous and subspace b_7 the most heterologous to the main space when compared to the other subspaces.

4.4.1. Subspace b_3: life-course and standard (quantitative) methods

We shall begin with block b_3, which is the furthest to the right and thus closest to the pole of methodological individualism, designated by bounded rationality, analytical sociology, and individualistic quantitative methodology.

On the left of this subspace (Figs. 3 and 4), we find the successful group of sociologists around an authoritative German research manager, representing life course research and theory (F_Lif, T_Lifc) with event history analysis (M_Eve) as their standard tool and education (F_Edu) and macro comparisons (F_MacCo) as main research topic. They have a considerable amount of funding from seven and more DFG grants (≥7dfg) and from three, four and more other funding sources (3Fn, ≥4Fn), hold foreign degrees (F_deg, passive), and more than three academic awards (P>3), are highly cited (sch9) and visible in the media (n>25). On the right, we find a pole with scholars engaging in general quantitative methods (M_Gqn, passive), process data (M_Prr), mixed methods (M_Mix) and, at the top right, sophisticated action theories (T_Mse, T_Act); the bottom right is populated by those who employ no specific theory (T_None). Main research topics to the right are age (F_Age) and health (F_HeaCa). Remarkably, the pole around the core researcher mentioned above is associated with no memberships in DGS sections, whereas the right hand is characterized by engagement as DGS section chair (SecC) and steering committee member of the AS (AS_Sc, passive). This can be interpreted as little interest of this camp in the national struggles of the discipline, and, to the right, as vested interest in exactly these very issues. Overall, the first axis of the CSA depicts differences in a similar way as the first dimension of the overall space (69°, Table 2): a dimension of clear-cut life-course paradigm to

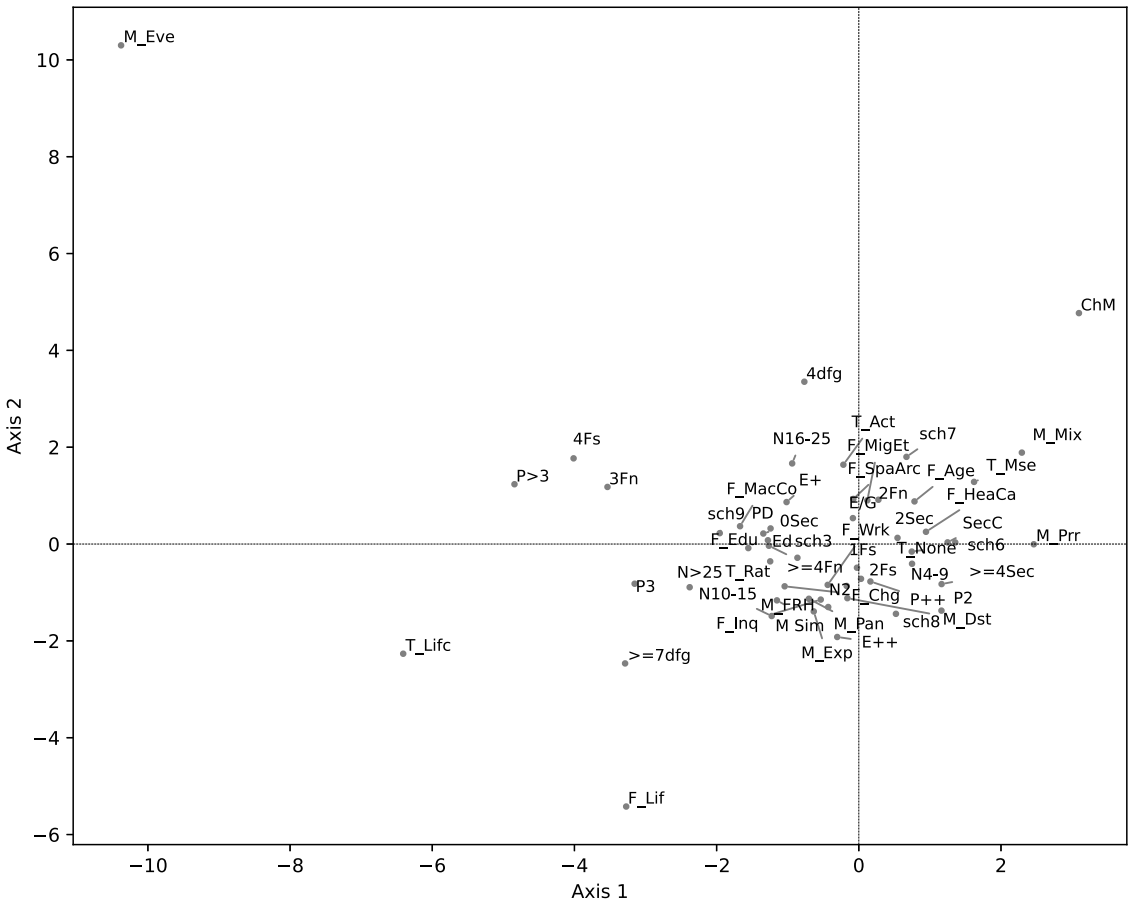

Fig. 3. Block b_3 (active).

more theoretical and more various forms of sociology and methodology.

The second axis expresses a divide between those, at the top, employing event history analysis (M_Eve), holding a methods chair (ChM), engaging in macro comparison (F_MacCo), migration studies (F_MigEt), and the sociology of age (F_age) and health (F_HeaCa), as well as holding a position in extra university institutes that are members of the highly reputed Leibniz Gemeinschaft (Leib, e.g. WZB, passiv). At the bottom, we find life-course research (F_Lif), panel data analysis (M_Pan), experiments (M_Exp), simulations (M_Sim), causal analysis (M_FRH), and overall, a more 'micro' focus on inequality (F_Inq), welfare states (F_Wel, passive), and poverty (F_Poo, passive), as well as having a position at important research institutes, e.g. the Mannheim Centre for European Social Research (MZES, passive) associated to Mannheim University or the German Youth Institute (DJI, passive). In sum, the second axis expresses an institutional dimension with more macro oriented research also based at highly recoginzed extra-university institutes at the top vs. more micro oriented research with links to university associated and slightly less prestigious extra-university institutes at the bottom. This structuring principle was not represented in the second dimension of the main space, as the divergent angles attest (88° and 86°, Table 2).

We will now inspect the manifest relationship of this subspace in order to identify the collaborative structures that make up this subspace. Fig. 5 shows the weighted most frequent ties (edge weight above 0.5) of this block. The main proponent of the life-course paradigm (see online table A3 for tf-idf values of this subspace) is a figure that is central to this cooperation network, located in a powerful periphery of the field. Linked with this position are strong ties to the top and bottom of the subfield, and thus to well reputed extra-university institutes. This can be interpreted as the outcome of strategic placement of successors in institutes with more applied and data-oriented (bottom) or more general and scientifically legitimate (top) research foci. Another manifest cooperation pattern seems to be relevant for this subspace: While there are not many direct links at the top between the

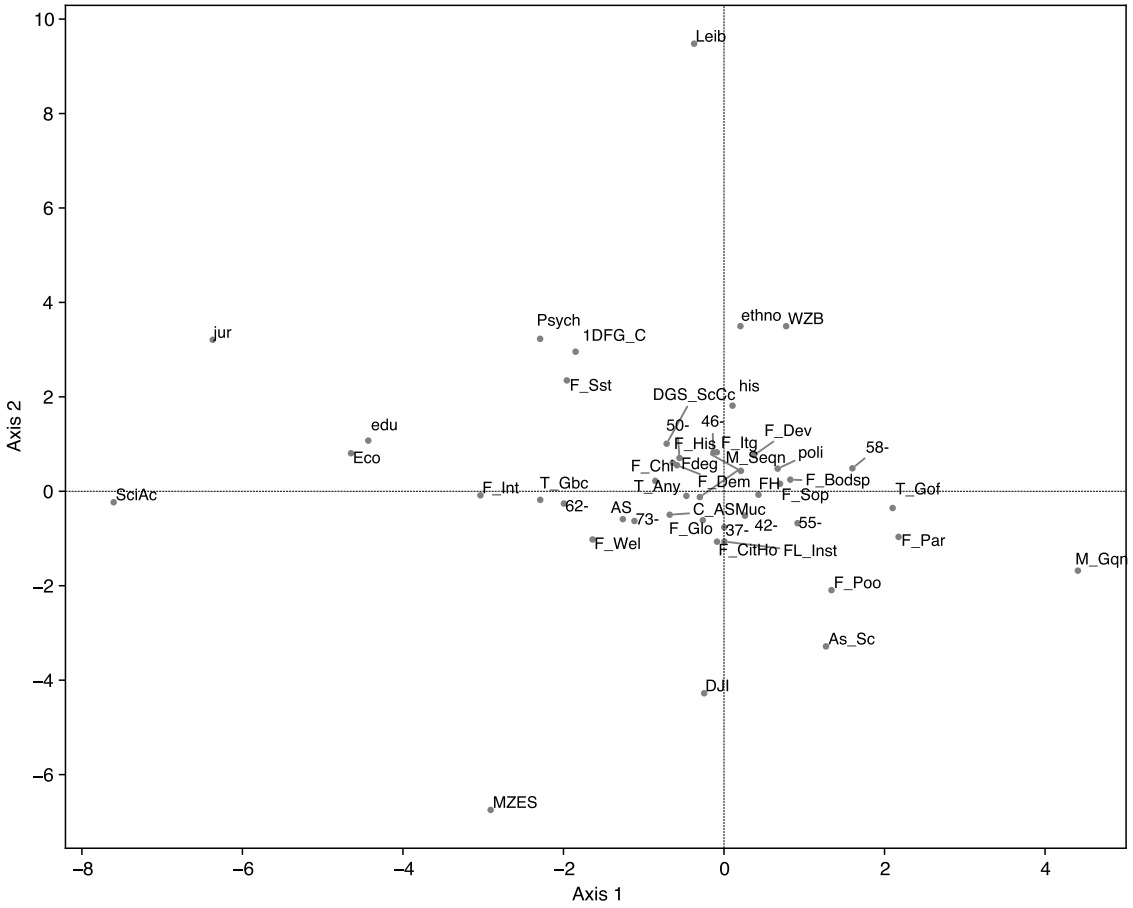

Fig. 4. Block b_3 (passive).

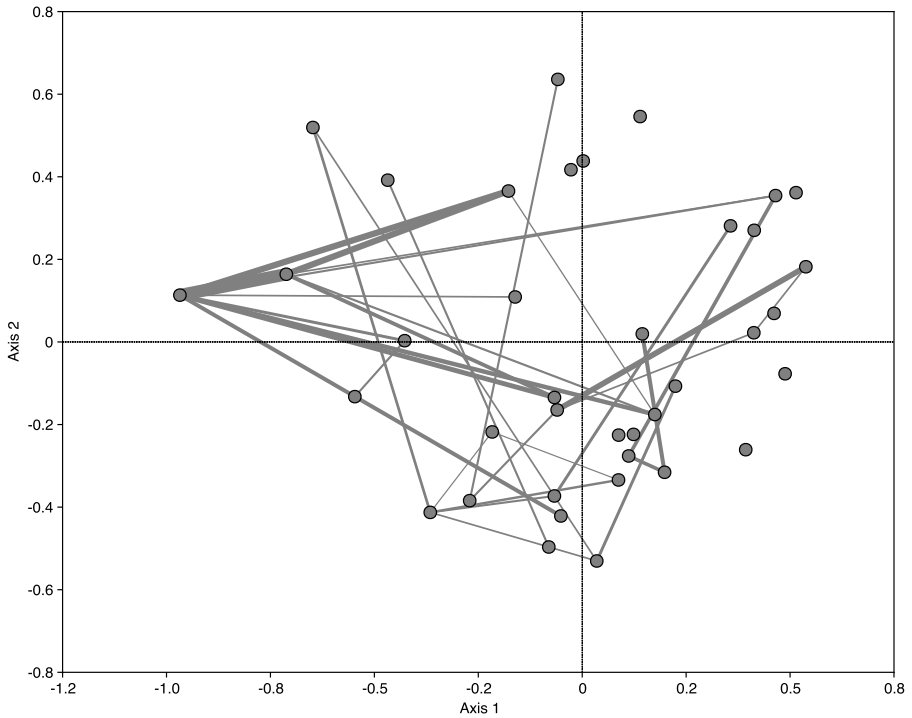

Fig. 5. Network structure of block b_3.

left and the right (theoretically embedded, mixed methods, methods chairs), this cooperation is being established indirectly through actors located at the bottom. Consequently, those engaging in life-course research with a method focus on panel data analysis, experiments, simulation, causal analysis, and overall with a more 'micro' conception on inequality link with those who hold methods chairs, engage with individualistic theory and advanced methods, research health and age, but not within the confinements of life-course sociology. Thus, while the power and reputation of the life-course paradigm seems to be constitutive for this subspace, despite spatial proximity at the top, hardly any ties are extant, so that this subspace shows a U-shaped chain pattern of cooperation.

4.4.2. Subspace b_5: empirical-analytical sociology

Block b_5 is located more closely to the origin of the overall space than the previous block and shows a heterologous latent dimensional structure (Figs. 6 and 7). To the right of this subspace, we find an engagement in the main theoretical currents of methodological individualism with variants of rationality: model of sociological explanation (T_Mse), analytical sociology (T_Ana), rational choice (T_Rat), game theory (T_Gam, passive) and methods such as simulation (M_Sim), experiments (M_Exp) (bottom right) and OLS (top right). Further, we see many DFG research projects (≥7dfg), an engagement in the DFG-research funding committee (1DFG_C, 2DFG_C) and highly prestigious scientific academies (SciAc, passive), adding up to high level of academic capital. It is here that we also find membership in the AS steering committee (AS_Sc, passive).

To the left, we find the engagement with panel (M_pan), multi-level (M_ML) and event history (M_Eve) data, and their analyses, or logistic regressions (M_LogR), life-course theory (T_Lifc), and research interest in macro-comparison (F_MacCo), youth (F_You), and regions (F_Reg, passive). The left side is further described by positions in extra-university empirical research institutes such as Gesis, IAB, MZES, WZB, LifBi and DJI. On the right side, in contrast, we find positions in the MPI for social sciences, perceived in German sociology as the most theoretically oriented of the mentioned institutes (all passive). Overall, the first axis expresses the difference between rational (bounded) methodological individualism (university) and individualistic forms of quantification (extra-university).

At the top, scholars are located that hold a methods chair (ChM) or are emeriti (em_yes), with several projects funded by the German research foundation (≥7dfg) and many citations (sch7, sch8, sch9). These sociologists conduct empirical research using interview data (M_Inv, M_Exi), or process data (M_Prr) and simple linear regression (M_Ols) or mixed methods (M_Mix). At the bottom,

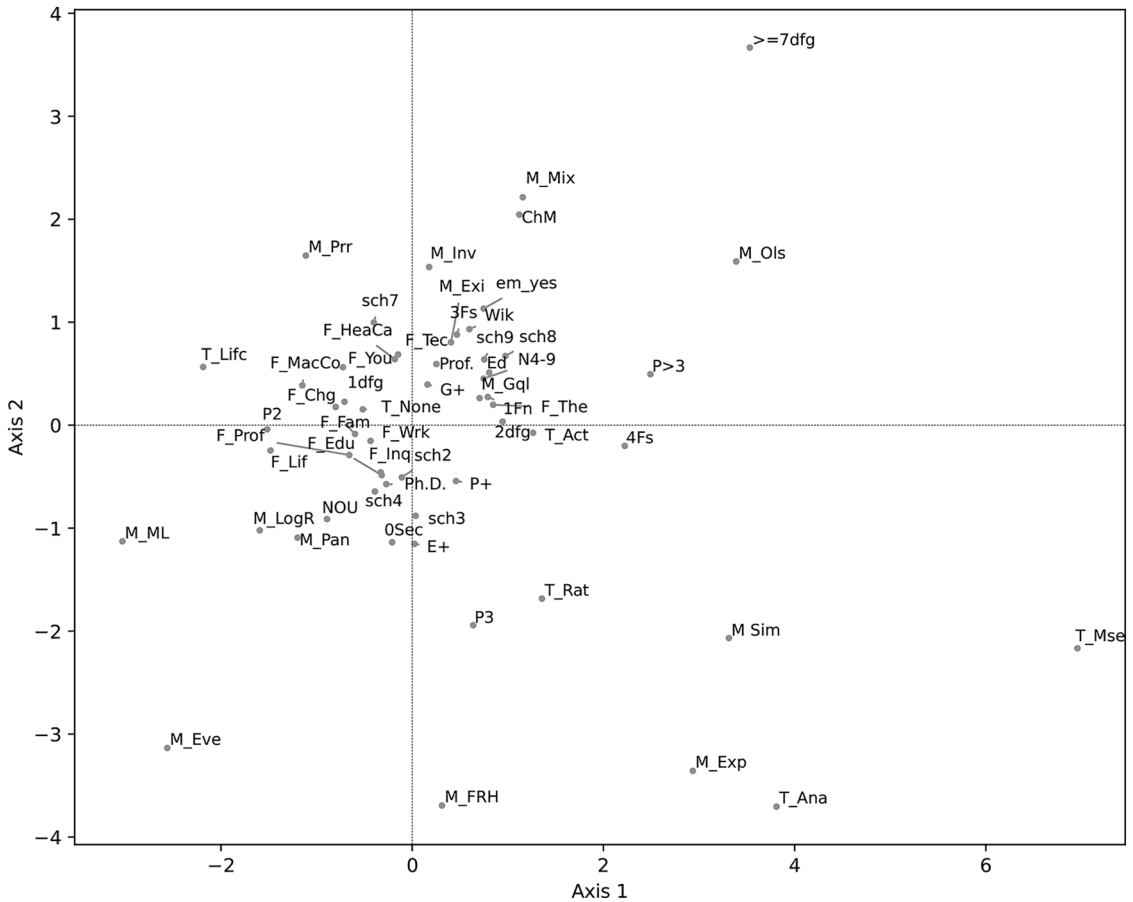

Fig. 6. Block b_5 (active).

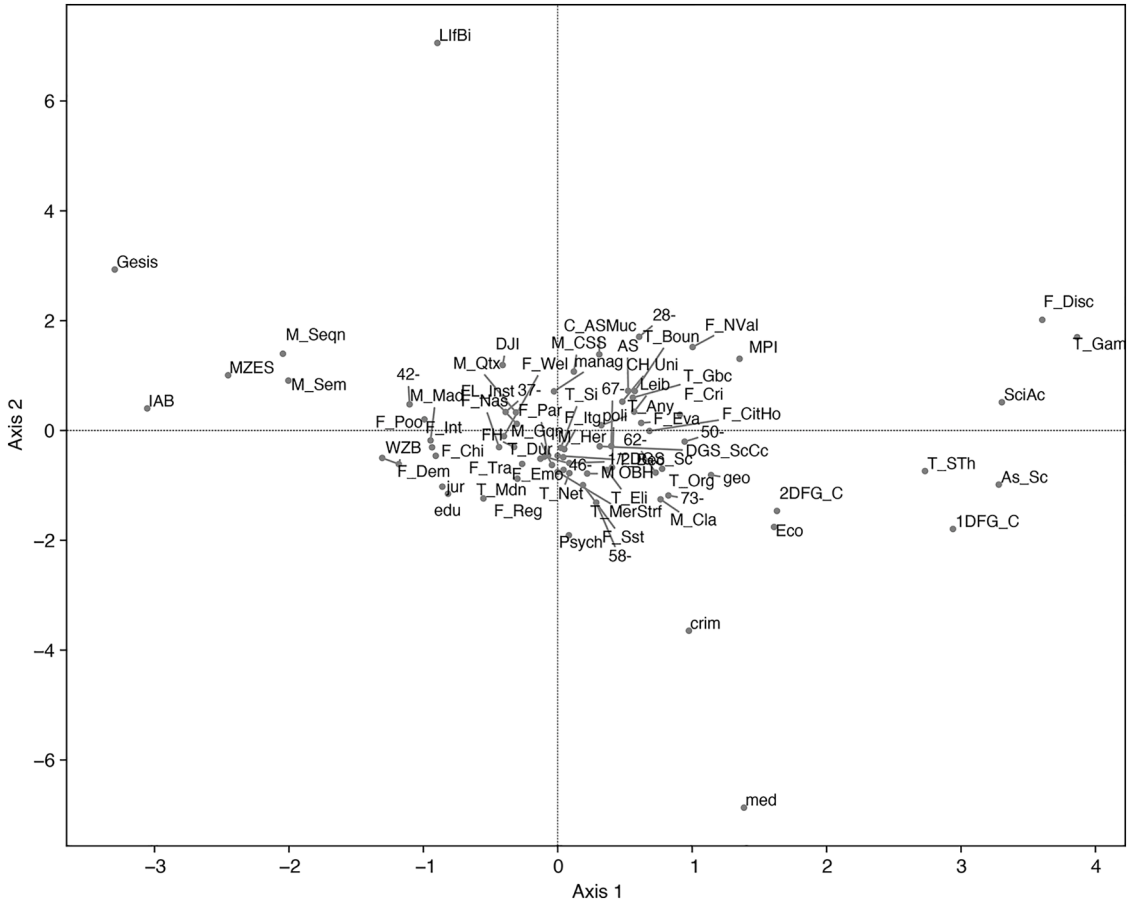

Fig. 7. Block b_5 (passive).

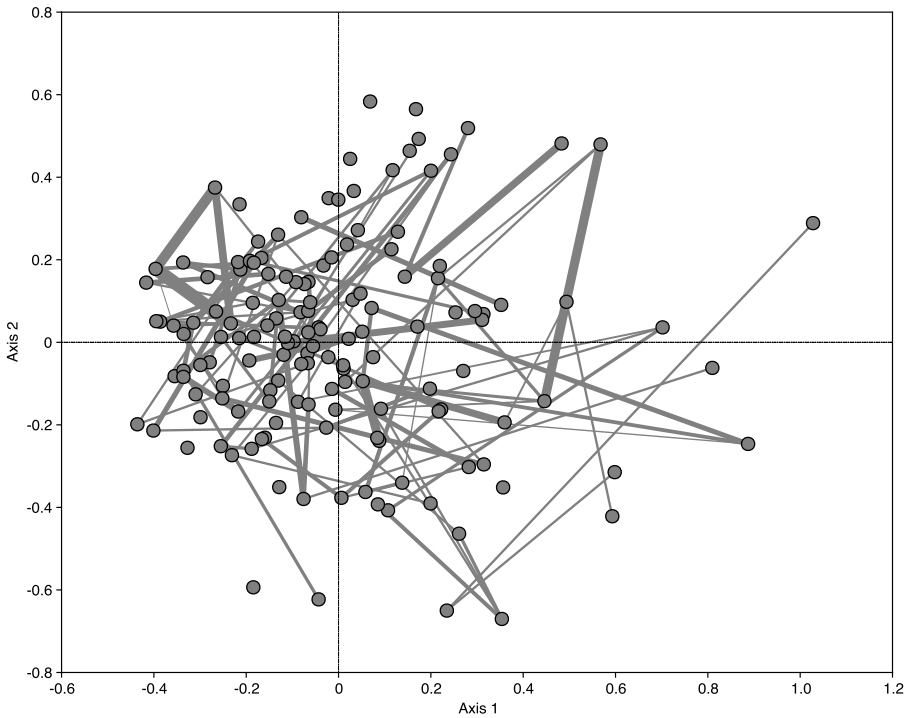

Fig. 8. Network structure of block b_5.

we find (younger) researchers (PhDs) who do not engage in DGS sections (0sec) but in theoretical reasoning in rational variants of methodological individualism (T_Ana, T_Mse, T_Rat). They also apply simulations (M_Sim), experiments (M_Exp) (to the right), different quantifying methods such as multilevel analysis (M_ML), event history analysis (M_Eve), and/or panel analysis (M_Pan) (to the left). The dimension expresses a power difference: between professors holding methods chairs with many citations, many funded DFG projects and interdisciplinary cooperations vs. (younger) researchers/PhDs that advance individualistic regression models and respective theories.

Comparing the subspace to the overall space using the angles of CSA to MCA axes, it turns out that the first dimension is almost orthogonal to the first dimension of the general space with an angle of 86° (Table 2). Accordingly, the difference between individualistic theory and individualistic quantification, which cannot be seen in the main space, is a structuring principle that is highly specific to this subspace. In contrast, the angle of 64° (Table 2) between the second CSA and the first MCA axis (the lowest of all blocks between those two axes) indicates some commonality, since dimension 2, here, expresses a paradigmatic oppositional structure as well, however, here, between rational theories and different methods.

To better understand the actual collaboration in this block, we will again inspect the manifest network structure of this subspace (see Fig. 8). This subspace's manifest cooperation structure clearly differs from the previous one in that we find less dense connections than in b_3 (density 0.022, Table 1), more weakly connected cliques with strong internal cooperation, and less quadrant-spanning collaborations. Many actors are only weakly connected to this network, especially at the top, indicating their incidental rather than stable collaboration. Especially, the top left and the bottom right of this subspace show no strong ties, which indicates that there is particularly scarce cooperation between applied quantitative research (top left) and the modern movement of analytical sociology (bottom right). By contrast, the one integrating structure of this subspace can be located to the left of the origin, showing dense cooperation between data gathering institutes, applied empirical quantitative research, social reporting, and methods professors. This subspace is structured by the difference between using quantitative individualistic methods (to the left) and engaging in individualistic analytical theory building (to the right), which cannot be identified in the main space, where these practices appear as a common research style.

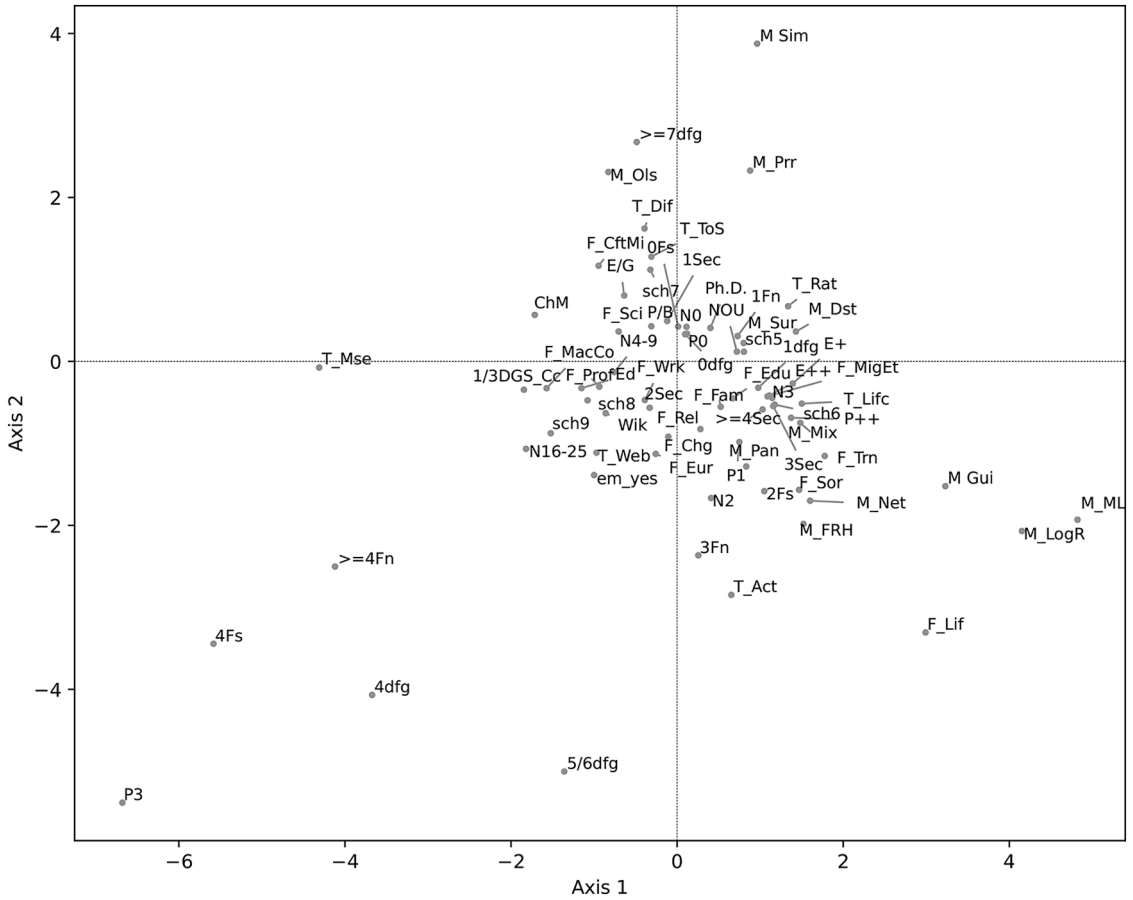

Fig. 9. Block b_1 (active).

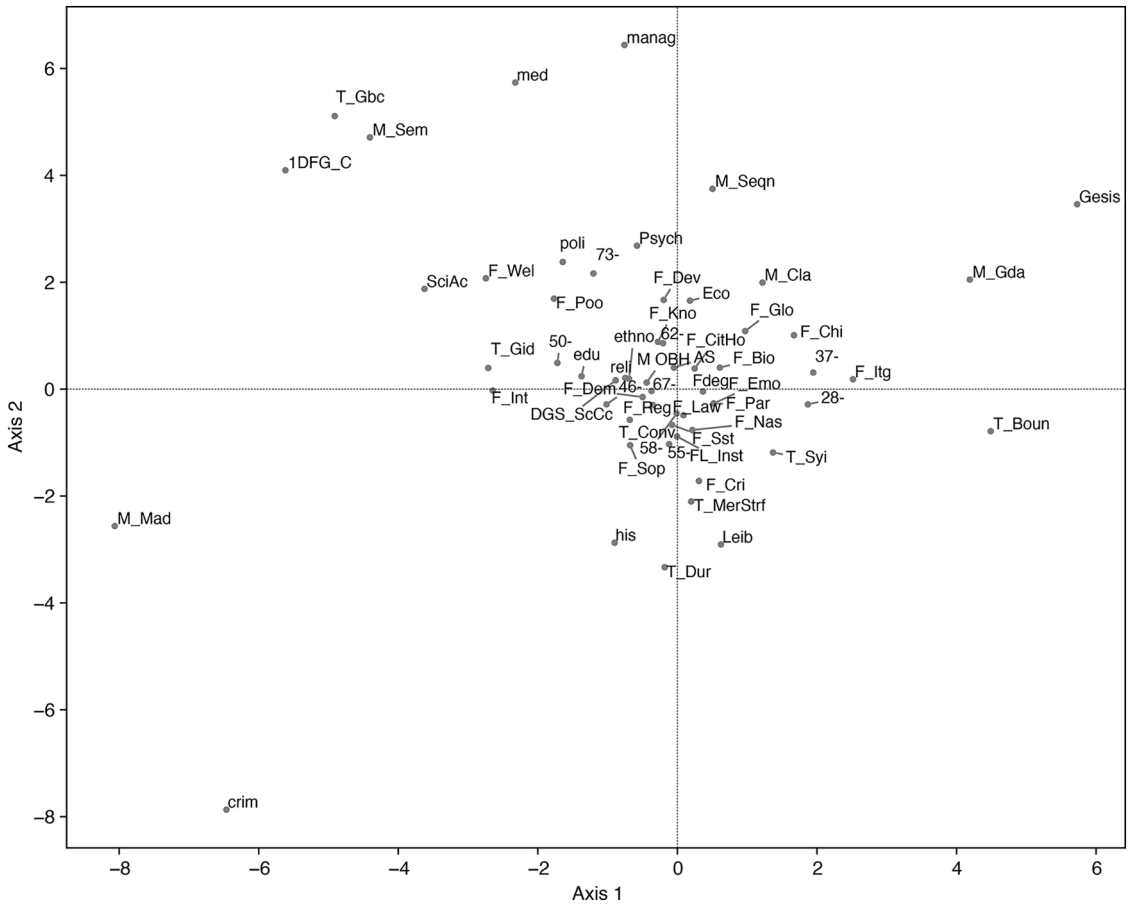

Fig. 10. Block b_1 (passive).

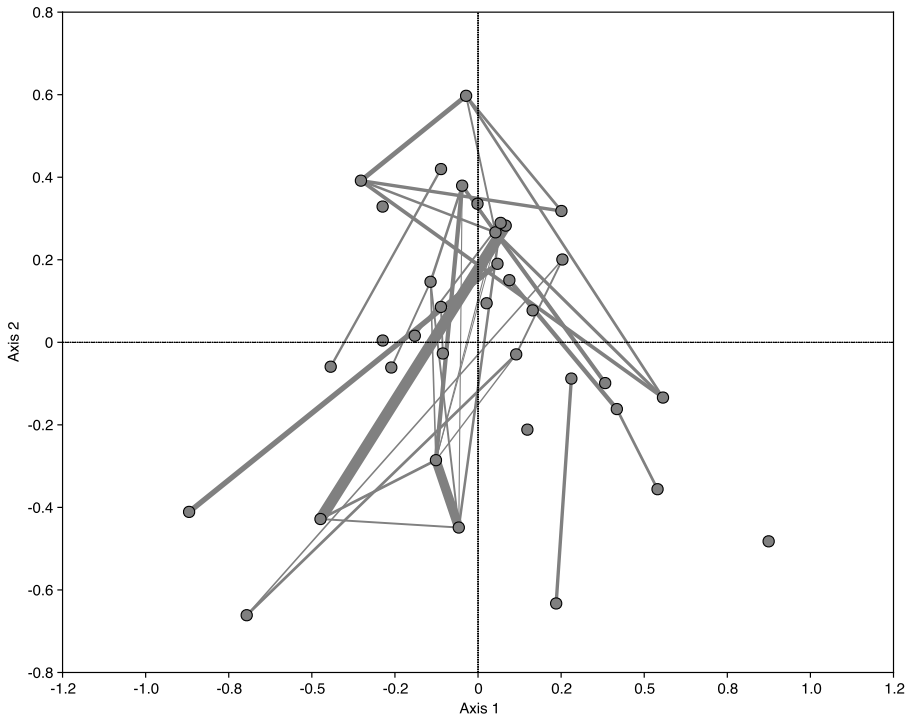

Fig. 11. Network structure of block b_1.

4.4.3. Subspace b_1: contemporary quantitative methods and canonical legacy

Subspace b_1 is located closer to the origin of the overall space as the previous blocks and shows a different internal structure. Although this block overlaps with its neighbours in the general space, which might give rise to the assumption of same internal structures, it has a different overall orientation with no strong resemblance to the first plane of the overall space (all angles between 70° and 77°; Table 2). On its right hand side of axis one (Figs. 9 and 10) we find young researchers (-28, -37, passive) that use methods such as logistic regression (M_LogR), multi-level analysis (M_ML), or causal analysis (M_FRH), guided interviews (M_Gui), often in the context of life course research (F_Lif), transnationalisation (F_Trn), and migration and ethnicity (F_MigEt). On the left, one finds older researchers (-50, -73, passive) high in citations (sch9), prominent in the media (N16-25), with a Wikipedia entry (wiki), and grants by more than four other funding institutions (≥4Fn) apart from DFG funding (4dfg, 5/6dfg), many stays abroad (4FS), three academic awards (P3), position in the DGS council (1/3DGS_Cc), and a methods chair (ChM). The first axis thus represents the difference between established scientists and younger scholars, specialised in modern quantification.

The second axis differs between (top) seven and more DFG projects (≥7dfg), a relatively high google scholar index (sch7), theories of differentiation (T_Diff), theory of society (T_ToS), simulation (M_Sim), process or register data (M_Prr), and descriptive statistics (M_Dst) and (bottom) four, five and six DFG projects (4dfg, 5/6dfg), three, four and more sources of founding beyond the DFG (3Fn, ≥4Fn), different quantitative techniques (M_FRH, M_Net, M_Pan), action theory (T_Act), life course research (F_Lif), and foreign stays (2Fs, 4Fs). Overall, this axis expresses the difference between research on society at large and empirical applications.

Inspecting this subspace's manifest network structure (Fig. 11), we identify a V-shape form and, at the top, a rather closed triadic structure affiliated with empirical research. Those on top employ a macro-societal view (given methodological individualism) and show ties to the lower right, where younger sociologists engage in specific regression models and to the lower left, i.e. with elder, highly reputed scientists (often their former PhD advisors). Those at the bottom, i.e. younger and elder scholars form no direct relationships with each other. Rather, the subspace is structured by an interlinked cooperation chain between teachers and students spanning more than one generation.

4.4.4. Subspace b_2: quantitative cultural sociology and methodological individualism

Subspace b_2 is located closer to the left and the origin in the overall space and shows a high degree of homology to the structure of

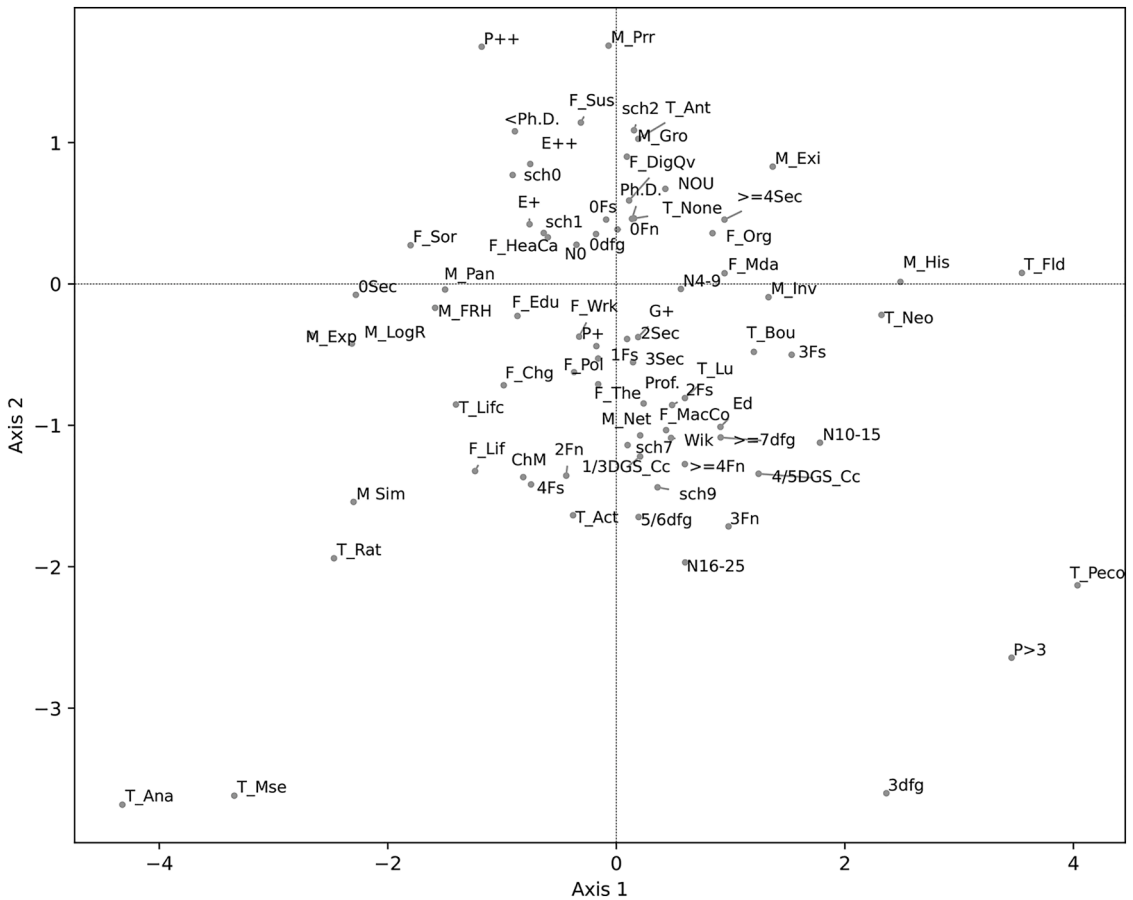

Fig. 12. Block b_2 (active).

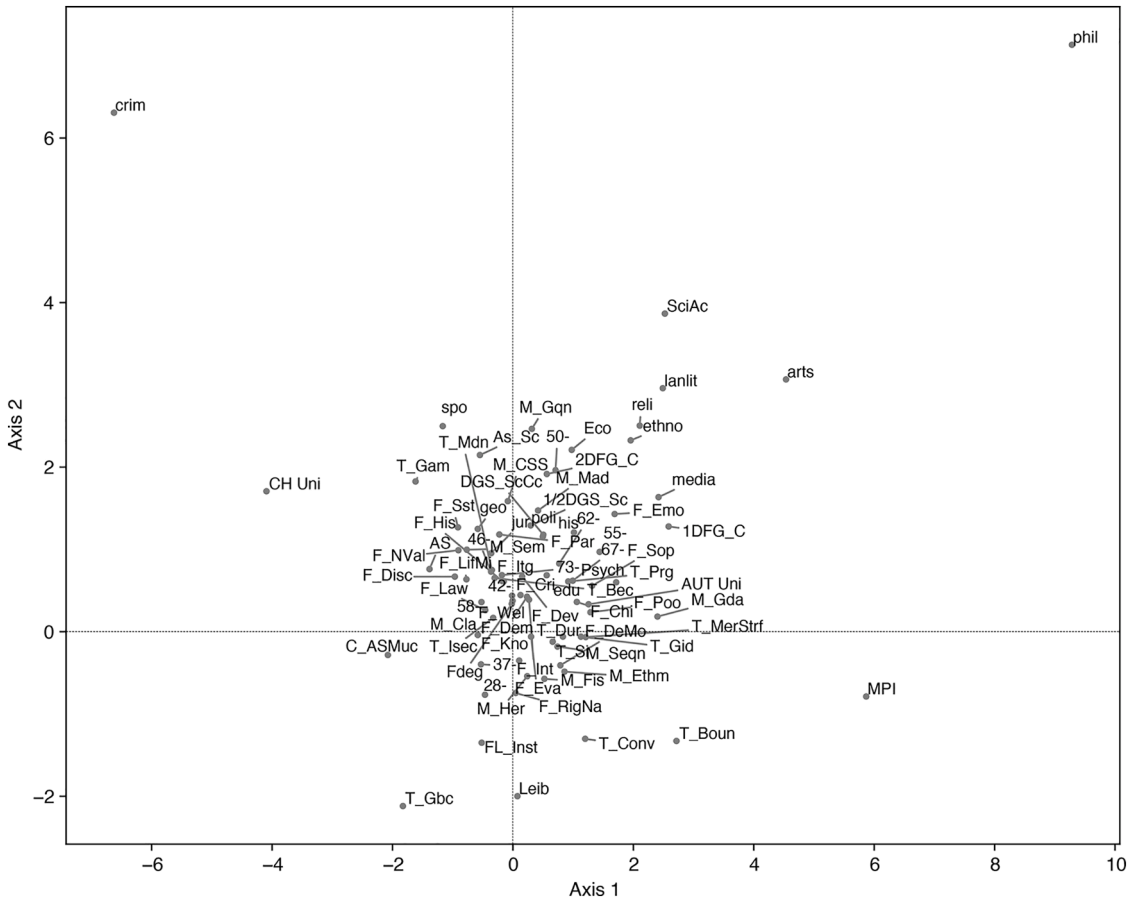

Fig. 13. Block b_2 (passive).

the overall field compared to the other subspaces. The fact that their orientation deviates less from the total space can be seen in the lowest angles between the first CSA and first MCA axis (57 %) and the second CSA and second MCA axis (42 %) of all blocks (Table 2).

To the left of this subspace (Figs. 12 and 13), we see experiments (M_Exp) and simulation (M_Sim), panel data/analysis (M_Pan), causal models (M_FRH), logistic regression (M_LogR) and interdisciplinary DFG projects with criminology, sports, and geography (crim, spo, geo, all passive); at the bottom left, we find an engagement with analytical sociology (T_Ana), the model of sociological explanation (T_MSE), and rational choice (T_Rat) and an engagement with the AS and its steering committee (AS_Sc, passive), but no engagement with sections of the DGS (0Sec). Main research topics are general empirical social research (F_Sor), life course (F_Lif) and education (F_edu). To the right, we find field theory (T_Fld), Bourdieu (T_Bou), Luhmann (T_Lu), political economy (T_Peco), neo-institutionalism (T_Neo), historical analysis (M_His), and interdisciplinary collaborations in DFG-research projects with humanities (philosophy (phil), arts (arts), language and literature (lanlit), religion (reli), anthropology (ethno) and media studies (media, all passive), and more than three awards (P>3). The first dimension of this subspace shows a readily identifiable structural homology to the overall space's first dimensions, namely the distribution of theoretical, methodological, and research issues along a (shorter) paradigmatic continuum.

The second axis, close to the overall space's second axis, forms a dimension of capital volume. At the top, we find young sociologists (-28, -37, passive) holding only a PhD or not even a PhD (20,78 % in this block, average of all blocks 10.57 %), no or only few citations (sch0, sch2), no foreign stays (0Fs), no grants (0DFG, 0Fn) and publishing only English papers (E++, P++), pointing to early career scientists with few publications. Research here concerns sustainability (F_Sus), digitalisation and quantification (F_DigQv), methods used are expert interviews (M_Exi), grounded theory (M_Gro), process and register data (M_Prr), and theories comprise ANT (T_Ant), convention (T_Conv), and boundary theory (T_Boun), and no theory (T_None). The second axis is also an axis of gender, with a nearly

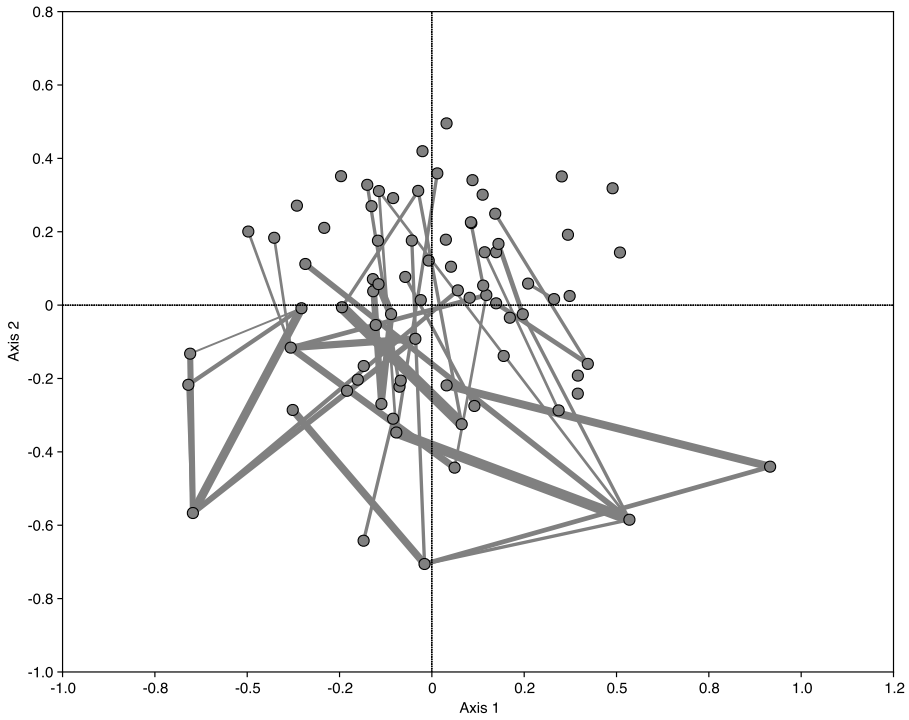

Fig. 14. Network structure of block b_2.

notable deviation of 0.45 SD between female sociologists (F) located above the centroid and slightly to the left and male sociologists (M, both passive) below. At the bottom, we find professors (Prof) and a considerable number of DFG projects (3 and 5/6) and grants from two, three or four and more other funding institutions (2Fn, 3Fn, ≥4Fn). Methods used are general quantitative research (M_Gqn) and network analysis (M_Net). Institutional positions are memberships in the DFG funding review board (1DFG_C, passive), the DGS council and steering committee (3/4DGS_Cc; DGS_Sc, passive) and in the steering committee of the AS (As_Sc, passive). In addition, we see indicators of symbolic capital, such as being highly cited (sch7, sch9), having foreign research stays (1Fs, 2Fs, 4Fs), being most present in the media (N16-25), having a wikipedia page (wiki), having been awarded more than three academic prizes (P>3), and being member of prestigious scientific academies (SciAc). Further, the bottom is characterised by engaging with action theory (T_Act) and the model of sociological explanation (T_Mse).

Inspecting the network of subspace b_2 (Fig. 14), we identify a clustered hierarchical network structure: Independent (groups of) core figures with high resources and symbolic capital are located at the bottom of the space, with no ties between each other, indicating pronounced paradigmatic difference between those three established groups, as well as internal cooperation along the same dimension. Yet, they also maintain links to actors with lower capital endowment and less pronounced paradigmatic stances. The ties running from bottom to top are tilted from the extremes to the inner areas of the field: to the left, less reputed and younger scholars bring in methods to the collaborations, and to the right, less reputed and younger cooperation partners bring in theoretical advances.

Along the second axis, the edge weights decrease, indicating stronger co-authorship relations between sociologists at the bottom, which can be interpreted as stemming from these researchers' respectively relationships' seniority. Notably, those at the top do not show any strong cooperation, yet, when inspecting the full network (online appendix figure A1) it turns out that they and their thin ties are constitutive for the integration of this block. Apparently, here, younger scientists with less capital volume bridge the established and manifested paradigmatic differences at the top of the hierarchy by positioning themselves less extremely on the paradigmatic axis and thus increasing the probability of manifest cooperation among themselves.

4.4.5. Subspace b_4: classical qualitative methodologies & theories vs. modern relational methods

Subspace b_4 is located at the left of the origin in the overall space, and stands in opposition to the previous blocks (Figs. 15 and 16). To the right are professors (prof), chair holders (ChT), and emeriti (em_yes). They have many DFG-projects (≥7dfg), are often members of the DFG funding review board (1DFG_C, 2DFG_C, passive), the DGS council, and steering committee (DGS_ScCc, 1/2DGS_Sc, ≥3DGS_Sc, all passive). They are frequently cited (sch9), have a Wikipedia page (wiki), have received numerous awards (P2, P>3), and have been present in the media (N>25). Those researchers engage with theories such as constructivism (T_Cons), Phenomenology

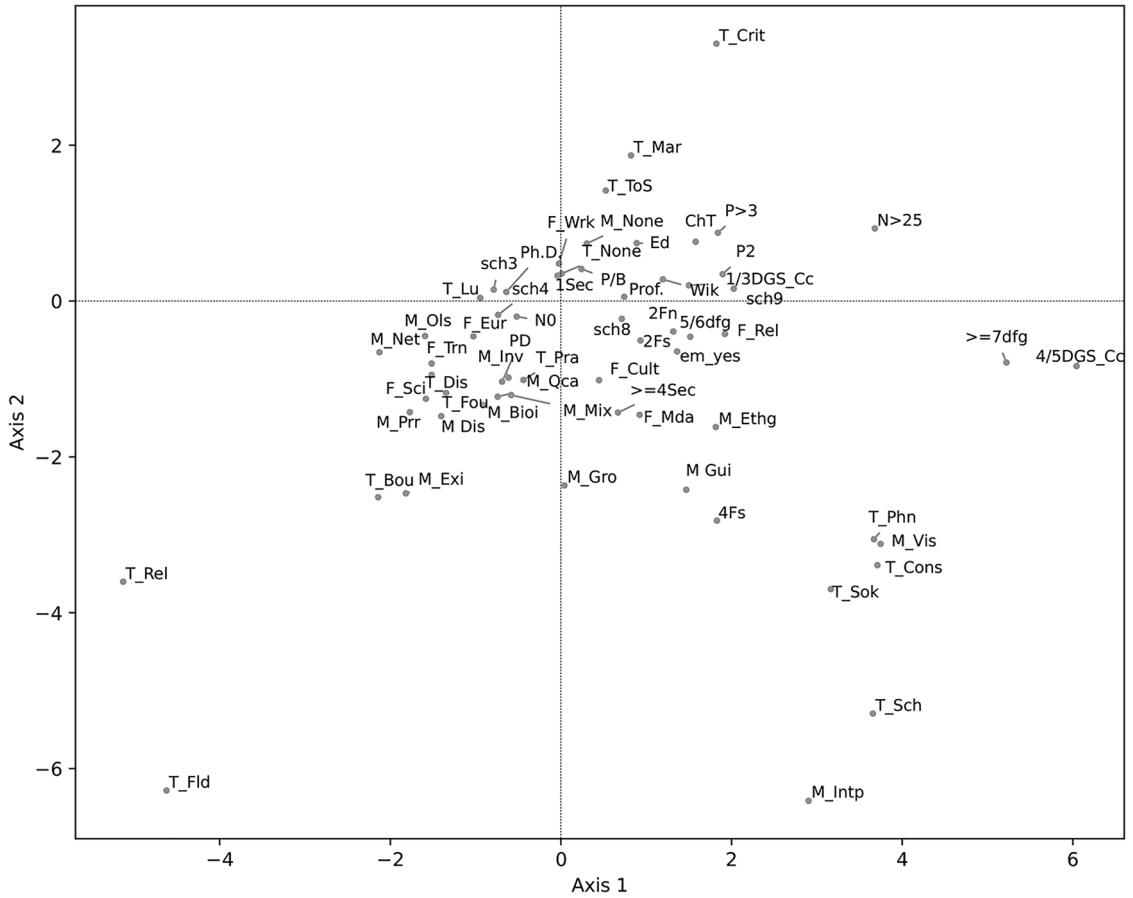

Fig. 15. Block b_4 (active).

(T_Phn), Schütz (TSch) and the sociology of knowledge (T_Sok) and they use ethnography (M_Ethg) and visual methods (M_Vis). This pole constitutes the legitimate and dominant theoretical mainstream of this area of the overall field. To the left, we find younger scholars with PhD, no DFG projects (0dfg) and no mention in the news (N0), that are more often female (notable deviation of 0.69 SD along this axis). They engage in relational sociology (T_Rel), network theory (T_Net), discourse theory (T_Dis), Foucault (T_Fou), and Elias (T_Eli), use methods such as discourse analysis (M_Dis), network analysis (M_Net), process data (M_Prr), OLS (M_Ols), and conduct research in the areas of sociology of science (F_Sci), transnationality (F_Trn), and Europe (T_Eur). Thus, this dimension, which is close to the first dimension of the overall space (58°, Table 2) expresses an entanglement of power and specific paradigmatic differences (relatively modern relational theories, and quant and mixed methods versus sociology of knowledge and specific qualitative traditions).

At the top, we find abstract critical theories (M_Crit), Marxism (T_Marx) and the French sociology of critique (T_Conv, passive) combined with an interest in theories of society (T_ToS) and no methods (M_None). The bottom is characterised by theoretical approaches closely connected to certain quantitative and/or qualitative methods and respective established methodological packages: to the left, field theory (T_Fld) and Bourdieusian sociology (T_Bou) close to Elias (T_Eli, passive) connected to expert interviews (M_Exi), geometric data analysis (GDA, passive), quantitative text analysis (M_Qtx, passive) and computational social science (M_CSS, passive); to the right, Schütz (TSch), hermeneutics (M_Her, passive) and interpretative methods (M_Intp), sociology of knowledge (T_Sok) close to constructionism (T_Cons) and phenomenology (T_Phn), close to ethnography (M_Ethng) and group interviews (M_Gui).

Notably, this second dimension is not strongly related to the main space's second (86°) or first dimension (72°) (Table 2) and can hence be deemed rather heterologous from the main space. In this subspace, the opposition is defined between critical theories/no method and qualitative or quantitative-qualitative methodologies that are closely related to interpretative or relational theories. While in the main space, qualitative research and theory lie on top of each other, they split apart in this subspace, similar to before, when the

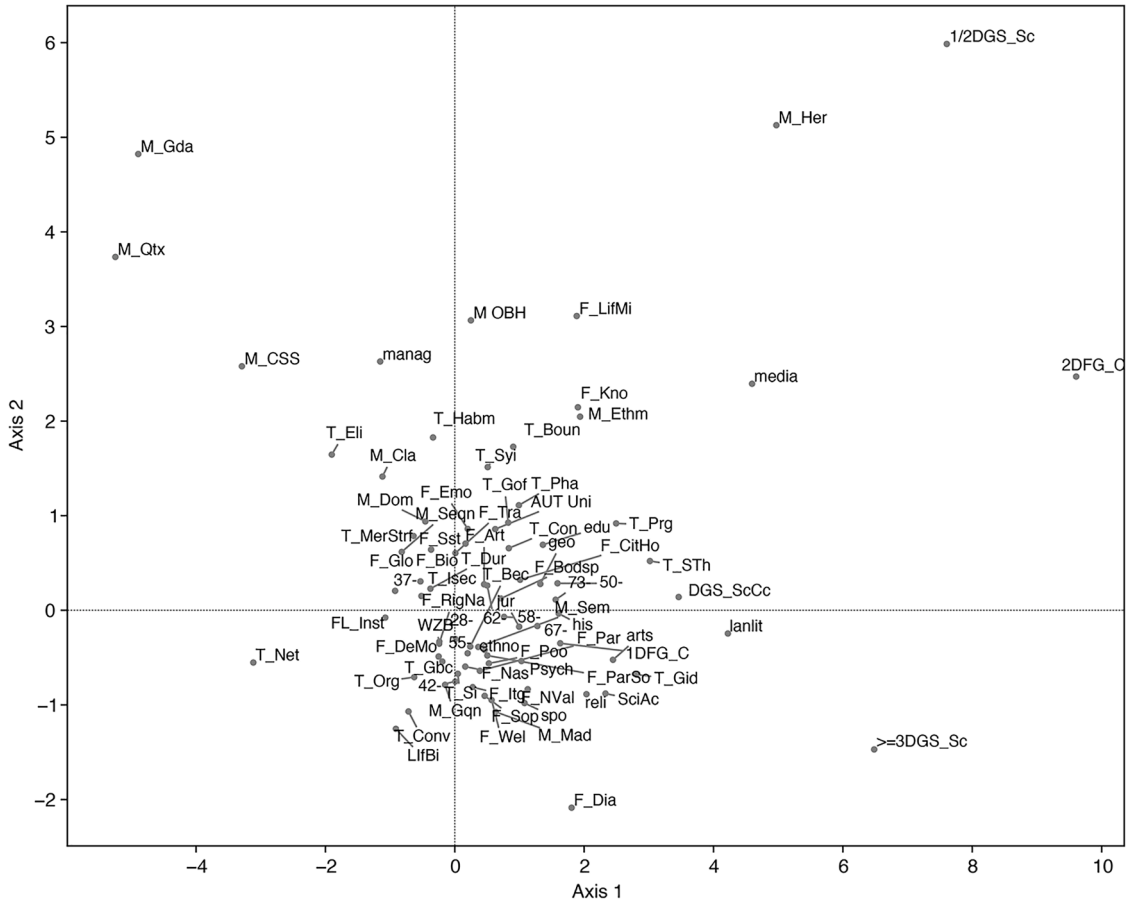

Fig. 16. Block b_4 (passive).

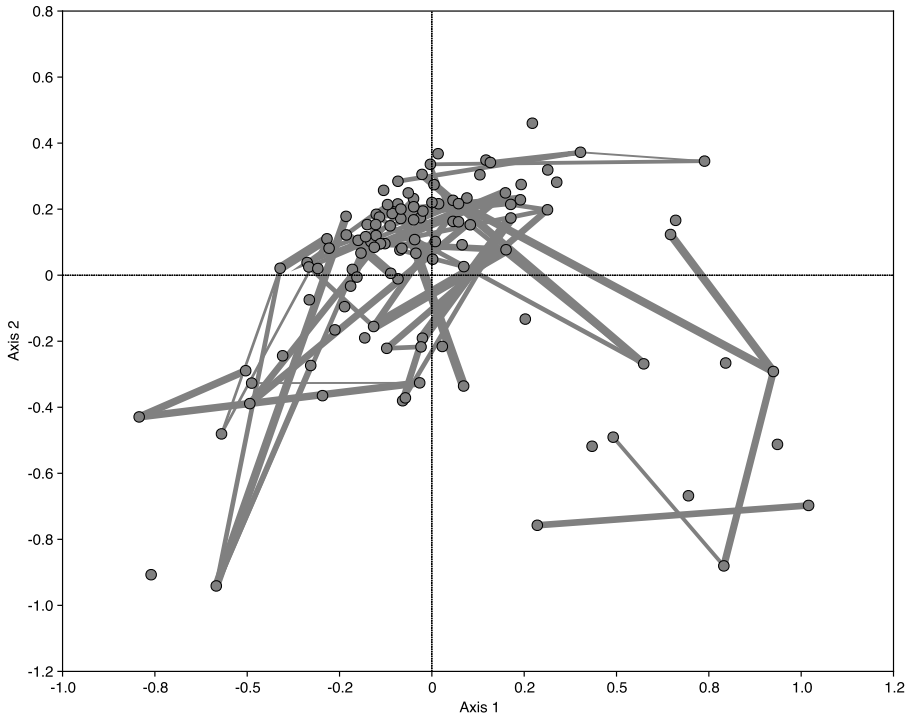

Fig. 17. Network structure of block b_4.

opposition between individualistic theory and methodology was revealed in subspace b_5.

Inspecting the network structure of block b_4 (Fig. 17), we again identify a U-shaped network. The network comprises co-authorships between the top (critical and theory of society) and the lower left (younger scholars with little capital endowment specialized in relational theories and methods,) or the lower right (elder scholars with (institutional) power working in the field of constructivism). The methodological approaches are not linked by cooperations with each other, which can be interpreted as material and scientific incommensurability of rather closed paradigms. Notably, this block is located to the left of the main space and owes his integration to the overall field mainly to the pole of younger relational sociologists. Without them, this large block would not be connected to the overall network (see online appendix figure A1).

4.4.6. Further subspaces

As further groups, the following should be mentioned briefly: b_7 (*feminist, gender, and intersectionalist approaches*) is the most heterologous of all subspaces with axes 1 and 2 having angles of above 83° (Table 2) compared to the main space's axes and the other subfields. The block consists of professors only, with 72.73 % women, and disproportionately high presence of DGS leadership. This group comprises researchers on feminism, intersectionality, and gender, but, when unfolded with the CSA perspective, we see that this actually constitutes a subspace with internal oppositions between these three stances and within a rather powerful area of the overall field.

The peripheral groups b_6 to b_9, in contrast, are completely segregated from the rest of the network (segregation = 1, Table 1), and form notably smaller, but internally denser connected groups. B_6 (*theoretical diversity and qualitative methodologies*) exclusively comprises actors in dominant positions linked to institutional (DGS and DFG) positions, rendering this subspace unaffected by internal power differentials. Its first axis opposes a variety of theories to a variety of qualitative methods, a subspace opposition not detectible in the main space (hence, the high dimensional heterology with an 85° angle between main and subspace's first dimensions, Table 2). The second axis contrasts interpretative and individualist approaches with reconstructive and structuralist approaches, an opposition that bears a certain resemblance to the MCA's first axis (69°, Table 2), albeit on a shorter continuum and without the opposition between qualitative methods and rationalist/analytical sociology. B_8 (*discourse analysis and theory*) represents a subfield of discourse analysis and discourse theory following more or less the main space's overall structure and b_9 (*empirical political economy*) is a highly heterologous subspace that integrates quantitative and qualitative methods in the context of research on political economy.

5. Discussion

The relational approach to the study of science in its cultural, social and material manifestations is now well established, given the ever-increasing availability of multimodal, relational data and the sophisticated theoretical and methodological relational approaches to their analysis. In this paper, we have proposed an integrated relational perspective and an iterative approach that combines MCA and network analysis for the analysis of multimodal data in order to obtain a differentiated picture of a specific scientific field. Based on either relational method, one will draw a specific representation of the social world. The geometric paradigm conceptualizes (scientific) fields as continuous spheres, suggesting that these fields are inhabited by various groups positioned along latent multidimensional axes. This perspective typically highlights the actors' and groups' distributions within fields, suggesting that different groups occupy specific locations based on their characteristics. In contrast, the network paradigm emphasizes discontinuous, manifest structures, including collaborative groups, shedding light on the presence and absence of ties and on cohesive clusters. Traditional use of MCA or network analysis alone might not capture the complex interplay between and within different (research) cultures. There are ways to address some of these limitations, such as clustering spatial dimensions or modelling network data spatially. However, our iterative mixed-method approach, which combines geometric data analysis with network analysis, provides a way to analyze both, the manifest structural relationships and the latent paradigmatic or resource-based division within a scientific field without prioritizing either relational notion of the social. In doing so, we gain a clearer understanding of how scientific communities are at once – externally – segmented and interconnected and – internally – integrated and differentiated.[9] To illustrate the effectiveness of our approach, we applied it to the case of German sociology, a field with a rich, diverse, and highly contested history. By analysing an integrated data set of scholars, their collaborations, and the symbolic goods they produce, we gain insights into the structure, cultural antagonisms, and intellectual currents within German sociology, that have broader implications for further research.

(1) The field as reconstructed with MCA is structured by latent *differences in power distribution among individuals and institutions, as well as differences in research cultures* defined by two outer poles: theoretical and/or qualitative practices and individualistic-rationalistic forms of quantification. The reduction of this diverse paradigmatic landscape to these poles is a common mistake and strategic narrative that has characterized the discipline's struggles from its beginnings to the present day. In contemporary German sociology, where the majority of those who are exclusively DGS members can be clearly located to the left of the field and the majority of AS members to the right, this polarisation is reflected institutionally. As demonstrated, a more detailed, relational analysis reveals the diversity of various research and publication cultures that structure German sociology. Our findings are similar to the U.S. case

[9] The proposed approach may also contribute to bridging field- and network-theoretical vocabularies. For example, the field-theoretical concepts of homologies and heterologies can be extended to understand the structural relationships between fields and networks, while the network-theoretical concept of betweenness, for example, can provide insights into the role of intermediary actors or clusters that connect spatially distant thought collectives and styles.

(Warczok & Beyer, 2021) and the Danish case (Kropp, 2011, 2013) with regard to the paradigmatic diversity in all three national sociologies following a continuum between hard sciences vs. humanistic sciences. Contrary to the Danish case, we did not find a strong opposition between symbolic power and restricted academic production vs. production for state, but, more in line with the US case, an opposition between more pure science vs. more applied science. For German sociology, this latter opposition manifests as a continuum ranging from varieties of theories and qualitative methods to methodological individualism and varieties of quantitative methods, with the whole diversity of sociological research styles in-between. Contrary to US and French sociology, we see a relative insignificance of elite higher education institutions as well as a decreased significance of the national sociological association (DGS as compared to ASA) as source of institutional power, two circumstances that might have fuelled recent struggles over the legitimate forms of symbolic power and furthers fissions in the German field of sociology (Schmitz et al., 2019; Schmidt-Wellenburg & Schmitz, 2023).

(2) The manifest co-authorship network structure exhibits high levels of segregation. In general, it is divided into a main component of scientists with a minimum of collaborations and a substantial subset of those without ties to this core. Thus, although we use a considerably comprehensive long observation window for the identification of co-authorship-blocks, there are hardly any pervasive ties. In contrast, co-authorship networks in other scientific disciplines such as biology, medicine, physics, and computer science typically exhibit higher density and integration (Newman, 2001) and have fewer and denser groups, while the humanities usually have an even more dispersed network structure with a broader periphery (Cugmas et al., 2016) and tend to contain an even greater number of loosely connected groups (De Stefano et al., 2011).

However, *within* the largest component, a highly clustered network structure can be seen consisting of two large homogeneous groups, which are highly distinct, clearly separated from the overall network, located at the periphery and largely unconnected to each other: scholars who focus on individualist-rationalist quantification and those who lean towards (relational and constructivist) theories and mixed methods. Thus, in terms of co-authorships, German sociology can be understood as an overall *socially disintegrated discipline* that is dominated – in terms of collaboration – by two groups, one strongly and the other weakly integrated. According to the work of Akbaritabar et al. (2020), Italian sociology, for example, is structured by a relatively small main component (26 % of nodes compared to 71.6 %) and is divided into five communities based on research areas, suggesting that it may be even more fragmented than German sociology. We assume this to be different in US sociology, for example, which might also appear as differentiated (Turner, 2006) but, given its high integration and a rather undisputed representative role of the ASA (Warczok & Beyer, 2021), might follow a clearer core-periphery structure than German sociology.

(3) Switching back to the field perspective and plotting the blocks and their dispersions in the field indicates a horizontal order along the paradigmatic dimension, with blocks either being located more towards the extreme pole of theories and qualification or more towards the extreme pole of individualistic, rationalist quantification. On the basis of a perfunctory understanding of field theory, assuming homophily as the one and only logic of practice, one might expect a cluster of collaborating scientists to be rather unambiguously assigned to a particular location in the field. However, despite belonging to common blocks and thus to coherent scientific collectives, we find considerable spatial dispersion of the members of each cluster and hence of scholarly collaborations across the field. Likewise, a shared spatial position does not necessarily lead to collaboration and the emergence of an integrated thought collective. These findings are consistent with field theory, which suggests that proximity in a field can both reduce and promote distance in interaction (cp. Schmitz, 2017; Basov, 2020). Specifically, projecting the authors' dispersions into the main space reveals that the blocks are structured vertically along the power dimension. The co-authorship blocks can be understood as production contexts in which reputable scholars collaborate with less reputable scholars and older scholars with younger scholars, reproducing a twofold hierarchy*: the social hierarchy within the co-authorship contexts and the paradigmatic differences between the blocks*. German sociology, thus, seems to be structured by hierarchical student-teacher relationships.

The proposed switching procedure can also proceed with a different sequence and start, e.g., from separated network blocks, relate them into a common space using field indicators, and then investigate the network structure of this space. While we have employed a descriptive approach to both, the issue of relationally integrating relational methods and the field in question, the proposed iterative switching is just as suitable for more causal approaches, i.e. combinatory inference (Le Roux et al., 2019), which also allows to assess the (un)certainty of the blocks' positions. Further research can employ the proposed procedure to other national scientific fields. For example, regarding the Danish field of sociology for which Kropp (2011, 2013) has shown a diversity of research styles, one might assess if these become manifest in autonomous collaboration blocks as well or, for the US or France, one can employ the proposed approach to investigate whether and which co-authorship groups are shaped by their pronounced university hierarchies rather than inter-generational student-teacher relationships. Yet, the proposed approach is not restricted to the sociology of science but may as well be used for the construction of different fields of cultural production (such as arts or theatre) that are, at the same time, structured by latent dimensions and manifest interactional groups (rather than mere overall networks) (e.g. Serino et al., 2017).

(4) There is substantial dispersion of manifest (clustered) ties across the field, and considerable paradigmatic variation is present in cooperation-blocks at both ends of the spectrum, indicating that cooperation entails a certain amount of diversity, heterophily, and division of labour. Yet, there are also discernible *boundaries of variety*, which, on the whole, seem to be defined by paradigmatic rather than hierarchical differences. The limited dispersions indicate boundaries of legitimate and practicable cooperation of actors and combinations of ideas. For example, while the block *contemporary quantitative methods and canonical legacy* (b_1) exhibits considerable dispersion, including parts of the field's centre, the majority of methods and paradigms of the overall field, such as constructivist or critical theories, are still excluded. Likewise, the block *classical qualitative methodologies & theories* vs. *modern relational methods* (b_4) located to the left of the field comprises and integrates different forms of sociology, but not rationalist-individualistically framed quantification. Thus, we identify research cultures with specific boundary drawings that – in sum – indicate and perpetuate the incommensurability of sociological practices.

Further, qualitative research should assess the level of subjective and collective meaning behind boundary-drawing and how extra-paradigmatic elements pass these boundaries. For example, one might assume that the current generation of individualist-rationalist, quantitative sociologist has some strategic reason to endorse parts of the relational paradigm, such as methods of network and space construction, or their research fields in cultural sociology, while rejecting the corresponding theoretical and methodological underpinnings of relationalism.

(5) We find considerable overlap between different clusters, which indicates that there are *relatively autonomous collaboration groups at given spatial proximity*. Notably, four of the five blocks identified within the main component are located to the right, i.e. close to the individualistic, rationalist forms of quantification. However, although located close to each other, these cooperation clusters do not form a common 'analytical' or 'rational' or 'quantitative' thought collective or a monolithic paradigm (as often alleged by certain critiques), but rather specific practice forms. In this light, the relational sociology of science might contribute to a critique of scientific ideology, which, more often than not, tends to essentialize paradigms (cp. Volle et al., 2024).

(6) When switching back to the spatial perspective, the manifest blocks, unfolded as latent subspaces, differ in the extent they map onto the overall field, i.e. they show different *degrees of homology and, by implication, heterology* (Witte & Schmitz, 2020). They differ regarding the (relative) relevance of power and research culture, the main space's dimensions, and the very definition of what defines power and paradigmatic positions in each respective subspace. A particular homologous block is that of *quantitative cultural sociology and methodological individualism* (b_2), since its dimensional orientation is the closest to the main space. This co-author group is internally structured by the power hierarchies of the overall field and comprises a considerable diversity of research perspectives such as political economy, neoinstitutionalism, analytical sociology, or simulation. This block attests that cooperation spanning across the paradigmatic spectrum is possible and adds to the integration of the overall field. A particular heterologous group with a pronounced Eigenstructure, in contrast, is the group *feminist, gender, and intersectionalist approaches* (b_7), which is considerably independent from the overall space thanks to its specific internal dimensionality thereby expressing both, cooperation of gender, feminism, and intersectionality approaches and the presence of a (presumably rather new) field of struggles that is rather autonomous from the overall field.

In fact, future research should utilise the strengths of our multimodal data frame by examining the temporal dimension of block formation and distinguishing, for example, blocks that can be clearly assigned to a particular point in time from those that connect not only actors but also different time points (cp. Volle et al., 2024; Hjellbrekke & Jarness, 2022). Such a consideration can help characterising the blocks and the corresponding subspaces in terms of their temporal transformation and their respective stabilities and adaptations with respect to the overall space. The formalization of homology-heterology patterns using angles from GDA models can be instructive for the study and comparison of other national and international scientific subfields. For example, we assume that each national scientific field will also entail social subgroups and that these groups will most likely not be adequately understood as a collective of like-minded, equal, etc. scholars. Thus, further research should not only assess if autonomous collaboration blocks structure other national sociologies as well but also if these, when seen as subfields, tend to follow their national main field's structure and which heterologous relations might be extant.

(7) Still, the latent dimensions of the overall space are relevant in most subspaces. Yet, differences in power and research cultures are *refractioned by the autonomoi of the subspaces.* Refraction can result in a smaller scale of the original dimensions, for example, power is merely defined by a difference in seniority but not in accumulation of all resources in the block *contemporary quantitative methods and canonical legacy* (b_1). Likewise, as mentioned before, the range in paradigmatic diversity is shorter in the block *quantitative cultural sociology and methodological individualism* (b_2). Refractioning can also lead to different manifestations of the latent dimensions, such as when in the block *classical qualitative methodologies & theories* vs. *modern relational methods* (b_4) theoretical oppositions are differently defined (here, between relationalist and constructivist stances). Refractioning can also surface as differentiation of a dimension of the main space. The block *life-course and standard (quantitative) methods* (b_3), for example, shows a differentiation in power, namely more heteronomously vs. more autonomously defined scientific capital. Subspace refraction can also lead to an interpenetration of power and research culture. For example, in the block *classical qualitative methodologies & theories* vs. *modern relational methods* (b_4), a powerless relational position faces powerful constructivism and, in the block *empirical-analytical sociology* (b_5), analytical sociology and powerful university positions coincide. Thus, these subfield specific positions are most likely not adequately understood when assuming for them a general, shared mind-set and cooperation without conflict. Nevertheless, on the whole, these refractions and relative heterologies reflect and reinforce the structure of the overall field. Arguably, the group concerned with gender and feminist studies can be said to be particularly free from the cultural orientation of the overall field (cp. Basov, 2020). Still, even scholars in this strongly heterologous and refractioning subspace contribute to the polar structure of the field. They achieve this not by directly replicating the field's structure in their subspace, but rather by exclusively focusing on specific scientific concepts found only on the left side of the field, while completely disregarding the right side. Conversely, these scholars and their scholarly goods are not incorporated into the scientific practices of those on the opposite side of the field, resulting in an indirect reproduction of the field's polarized structure.

(8) The switch back to the network perspective demonstrates that the subspaces are structured by (considerably) different manifest relationship structures. Against the first intuition that one might have, namely that more or less all scientists of a co-authorship collaborate with each other, all subspaces show more or less *incompletely meshed network structures*. Thus, while, as a matter of course, all subspaces are characterized by a necessary extent of collaboration, they also show *structured absences of ties*. This spatial view is instructive for two specific research purposes. On the one hand, the dimension of the subfields can shed light on the block-specific collaborations. Despite and, in fact, due to different positions in the subspaces, scholars engage in co-authorships, thereby combining and integrating sometimes rather diverse research perspectives and power resources. On the other hand, when taking the dimensional structures into account, we can also reveal and interpret the absence of ties within a given collaboration-block with non-

cooperation between coherent research paradigms (due to paradigmatic, methodological, and generational differences), between those belonging to a certain thought collective and those who are more pluralist (due to different closeness to the charismatic figure and its industrial complex), between highly reputed scholars (due to paradigmatic competition), or between the generations (due to age and status differences). Thus, conceptually, not only are networks embedded in an overall field, but also in their own subspaces.

The question, then, arises as to why network-blocks emerge in the first place. While this issue transcends the current analysis, we regularly find that the incomplete networks seem to be integrated by a *tertium*: non-cooperation occurs between the two ends of a generational chain of co-authorship integrated by average cohorts, two opposing research programs show strong ties to advanced social theory, and non-collaborating highly reputed scholars collaborate with interconnected younger scholars. Brokers appear to be crucial for maintaining group cohesion and the relative integration of scientific subspaces, since without them, actors even in close proximity within a field may not develop block formations. Future research should investigate the role of these subspace specific brokers, such as how they foster internally shared meanings and stories that bridge social distance across the overall field (cp. Basov et al., 2021), while, at the same time contributing to the closure and consolidation of their respective thought collectives.

(9) By locating the results of block modelling in a field, we can contribute to *reflexive quantification in the sociology of science* through relating the degree of social and paradigmatic stability to field positions. The position in the overall field seems to correspond to the internal integration of the blocks and the extent of their stability. Overall, publishing, as documented in the Scopus database, is more prevalent among sociologists from quantitative-individualist research cultures. Notably, thus, the very method of identifying blocks works best for the variants of this practice. In contrast, all but one co-authorship group to the left of the space are rather loosely integrated and do not form stable blocks, or even no block at all, indicating the comparatively low level of German theoreticians' and qualitative researchers' involvement in co-authorships and suggesting that they are less socially and paradigmatic integrated. This block owes his relative stability and his integration to the overall field mostly to the pole of younger relational sociologists. Future research should address the extent to which social and paradigmatic integration is fostered by a culture of co-authorship, how bibliographic databases not only (over-)represent but also stabilize and drive this culture, and conversely, how other forms of scholarly practice may be underrepresented and increasingly inopportune in an increasingly metricized and standardized scientific landscape.

Finally, our approach also reveals an even more fundamental blind spot in literature database information, thus highlighting the added value of multimodal data frames: those who are not represented in Scopus are no random subgroup, but can be clearly located at the German national and dominated pole of the field. Although the n_scopus group cannot be considered a subspace, it is a residual category that can be become a group ex negativo, i.e. a publishing culture (such as in books) that is jointly excluded from economic, social and academic capital, which are increasingly necessary means of being represented and heard in times of academic capitalism.

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CRediT authorship contribution statement

Andreas Schmitz: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Christian Schmidt-Wellenburg:** Writing – review & editing, Visualization, Validation, Resources, Formal analysis. **Jonas Volle:** Visualization, Software, Formal analysis, Data curation.

Declaration of competing interest

All authors have seen and approved the final version of the manuscript being submitted. There are no conflicts of interest or competing interests. There is no financial/personal interest or belief that could affect our objectivity. Potential competing interests do not exist. The submitted work has been achieved thanks to generous project funding of the German research Foundation (DFG). The DFG was not involved in the scientific work itself.

Supplementary materials

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