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Interaction as Moderators of the Diversity-Performance**

Link:

An Analysis of University Research Groups

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**Knowledge Production Process, Diversity Type and Group Interaction as
Moderators of the Diversity-Performance-Link:
An Analysis of University Research Groups**

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In our paper, we explore the diversity-performance link in knowledge production and argue it to be the result of two countervailing effects (resource vs. process perspective). Theoretically, we show that the relative strength of the two effects crucially depends on moderating factors that relate to specificities of the knowledge production process, the type of diversity and group interaction. We empirically test our hypotheses based on an original data set of 45 university research groups from different disciplinary fields which are by nature expected to produce new knowledge and are faced with complex tasks. Employing traditional OLS regressions as well as non-parametric LOWESS analyses, our hypotheses are largely born out by the data. In particular, we find a U-shaped relation between cultural diversity and performance in research groups from the humanities & social sciences and a negative link between functional diversity and performance in research groups from the natural sciences. As the disciplinary fields proxy different underlying knowledge production processes, the implications of our study can be generalized to other settings and help derive general conclusions for the management of diversity and future competitiveness strategies in knowledge intensive economies.

Keywords: diversity, performance, knowledge production process, group interaction

In the past two decades, group diversity and its impact on performance has become one of the foremost topics of interest to managers and business scholars. However, the empirical evidence on the performance effects of group diversity is “weak, inconsistent or both” (Harrison, and Klein (2007: 1199)—in spite of a vast and growing body of literature (e.g., Pelled, Eisenhardt, and Xin, 1999; Ely, and Thomas, 2001; Reagans, Zuckerman, and McEvily, 2004 or Gibbson, and Gibbs 2006). Also with respect to research groups, existing evidence on the di-

iversity-performance link is mixed (see e.g., Porac et al., 2004 or Hollingsworth, 2002), leading Porac et al. (2004: 675) to conclude that “much more research” is needed in order to better understand the relation between research team configurations and performance (see Bell, and Kravitz, 2008: 301 for a similar claim).

From a theoretical perspective, the mixed and partly contradictory empirical findings are likely to be the result of two countervailing effects: On the one hand and highlighted by the so-called resource perspective (see, e.g. Gruenfeld et al., 1996; Hambrick, and Mason, 1984), diversity might have positive effects on performance if team members possess distinct knowledge bases or abilities that are relevant for the production process. On the other hand, the process perspective (see, e.g. Byrne, 1971; Tajfel, 1974, 1981; Turner, 1975, 1987) emphasizes that diversity might also negatively affect team performance since, in heterogeneous groups, communication between team members might be endangered, conflicts might arise and group cohesion might be reduced. Accordingly, diversity is a “two-edged sword” (Milliken, and Martins, 1996) or a “mixed blessing” (Williams, and O’Reilly, 1998).

While the general net effect of diversity on performance remains unclear, there is evidence that the performance effects of diversity depend on the type of diversity: Concerning demographic diversity (e.g. diversity with respect to age, gender or ethnicity), it has repeatedly been argued that this type of diversity will have a negative net impact on team performance as it is likely to enhance communication problems and increase the potential for emotional conflicts, thus reducing group cohesion (see, e.g. Jehn, Northcraft, and Neale 1999; Pelled, Eisenhardt, and Xin, 1999; Smith et al., 1994). In contrast, what is often called task-related diversity (e.g. diversity with respect to functional background, education or tenure) is often regarded as having the potential of being net performance-enhancing as it is less likely linked to identity than demographic characteristics and consequently less apt to lead to social categorisation while at the same time providing the potential of integrating task relevant

different knowledge bases and abilities (see e.g. Ancona, and Caldwell, 1992a; Jehn, Northcraft, and Neale, 1999; Pelled, Eisenhardt, and Xin, 1999).

Moreover and as highlighted by Harrison and Klein (2007), the literature has focused on contextual mediating and moderating factors of the diversity-performance link. The contextual factors analysed cover a broad range of variables, ranging from a group's diversity perspective (Ely and Thomas, 1999), its interpersonal congruence (Polzer, Milton, and Swann, 2002), team members' personality traits (Flynn, Chatman, and Spataro, 2001), participation (Ely 2004, Clark, Anand, and Roberson, 2000), work cultures, strategies, and HR practices (Jehn, and Bezrukova, 2004), team leadership (Klein et al., 2011), outcome interdependence, group longevity, and reflexivity (Schippers et al., 2003), task complexity, team size, tenure and dispersion (Stahl et al., 2010) to task type and interdependence (Jehn, Northcraft, and Neale, 1999). Concerning task type, Jehn, Northcraft, and Neale (1999) show educational and functional background diversity, to be more likely to increase workgroup performance when tasks are complex rather than when they are routine. Regarding task interdependence, i.e. the extent to which group members rely on one another to complete their jobs, Jehn, Northcraft, and Neale (1999) show the potentially disruptive effects of diversity with respect to gender and age, to be exacerbated when tasks were interdependent.

In our paper, we contribute to these recent advances that search for potentially intervening and moderating factors of the diversity-performance link while at the same time distinguishing between different types of diversity. Referring to the work by Harrison and Klein (2007), we define "diversity" in the sense of "variety", i.e. we focus on differences in kind among the group members regarding their information, knowledge or experience. Specifically, we study diversity with respect to the study background of the members of the research group ("functional diversity") as a form of allegedly more productive task-related type of diversity on the one hand and "cultural diversity" with respect to the cultural world region the research group

members come from as a form of potentially more problematic relation-oriented type of diversity on the other. As we will show, however, it will crucially depend on a set of moderating factors whether a specific type of diversity will rather positively or negatively affect performance.

Concerning the potential moderators of the diversity-performance-link, we identify a first group of moderators that relate to the specificities of the knowledge production process which are characteristic for the disciplinary field a research group belongs to (i.e. its paradigmatic nature, degree of codification & specialization, its cultural specificity & language sensitivity, and its degree of task interdependence). As we will argue, this first group of moderators will differently affect the diversity performance link—depending on the type of diversity (functional vs. cultural diversity). A further moderating variable, the research group’s potential for interaction & discourse, will positively affect the diversity-performance link—irrespective of the diversity type and the specificities of the knowledge production process.

Empirically, we analyse the diversity-performance link and its moderators in a sample of 45 university research groups of, on average, 24 junior researchers who are jointly supervised by a team of senior researchers. Since by nature such research groups are expected to produce innovative outputs and are faced with a complex task, they represent an ideal case to investigate into the diversity-performance link in innovative environments. Further, our data is well suited to explore the potential moderators of the diversity-performance link by being able to distinguish between different disciplinary fields. Employing traditional OLS regressions as well as non-parametrical LOWESS analyses, we find support for our hypotheses. In particular, we find clear evidence for a curvilinear, U-shaped relation between cultural diversity and research group performance (as measured by the doctoral completion rate) in the humanities & social sciences and clear evidence for a negative link between functional diversity and performance in the natural sciences. Further, we find empirical support for the view that group

interaction strengthens the benefits of diversity and reduces its costs—irrespective of diversity type and disciplinary field. As the disciplinary fields in our study represent different underlying knowledge production processes, we are able to derive general implications and conclusions from our analysis that will hopefully inspire further studies on the diversity-performance link in other team contexts.

THEORETICAL BACKGROUND AND HYPOTHESES

The Potential Benefits & Costs of Diversity in Research groups

Concerning theory, there are (at least) two basic perspectives on the diversity-performance link: the so-called resource perspective on the one hand which builds, among others, on information & decision making theory highlighting the potential benefits of diversity (see, e.g. Gruenfeld et al., 1996; Hambrick and Mason, 1984), and the so-called process perspective on the other which builds on the similarity attraction paradigm and social categorization theory highlighting the potential costs of diversity (see, e.g. Byrne, 1971; Tajfel, 1974, 1981; Turner, 1975, 1987).

Following the resource perspective, group diversity might in fact positively affect group performance: if a higher degree of group diversity is linked to broadening the knowledge base of the group (the “range” in the notation of Reagans, Zuckerman, and McEvily, 2004) and if the additional expertise brought in by the diverse group members is of use for the group production process, diversity is apt to increase group performance. With respect to research groups, the fact that PhD students come from a different study background (in what follows we will call this type of diversity “functional diversity”) would clearly result in differing kinds of expertise being brought into the group (see, e.g. Keller, 2001: 547; Rip, 2000; Hagedoorn, Link, and Vonortas, 2000) and might hence benefit its performance. Also, adding Ph.D. students from another cultural background (i.e. increasing a research group’s cultural diversity)

might—depending on the research topic—add a new and fruitful expertise to the group (see e.g. Bantel and Jackson, 1989; Wiersema and Bantel, 1992) and is hence apt to enhance performance. Thus, both, functional and cultural diversity might in fact positively affect research group performance.

Following the process perspective, however, research group diversity might also negatively affect performance: in a diverse group, communication between group members may be hampered, conflicts may arise and group cohesion reduced (or, in the notation of Reagans, Zuckerman, and McEvily, 2004, “density” in the group is reduced). Again, the potential costs of diversity in research groups might refer to both, functional and cultural diversity: In culturally as well as functionally diverse groups, the use of different (national or scientific) languages might render within-group communication more difficult and misunderstandings more likely to occur. Correspondingly, for researchers that work on interdisciplinary tasks, Brown, and Duguid (1998: 101) resume: „Different precepts and different attitudes [...] make interchange [...] remarkably difficult, and thus they invisibly pressure disciplines to work among themselves rather than to engage in cross-disciplinary research.”

If and to what degree research groups will actually profit from the potentially enlarged expertise in a diverse group (its range) and also to what degree the potential costs of diversity (in the sense of a reduced density) will come into effect, will depend—as we will argue—on the characteristics of the knowledge production process in the disciplinary field. In a first step of our theoretical analysis, we will further elaborate on the potential benefits of diversity as highlighted by the resource perspective and will argue these to be in general higher in research groups from the humanities & social sciences than in research groups from the natural sciences. We distinguish between the humanities & social sciences on the one hand and the natural sciences on the other because—as we will show—the two disciplinary fields are substantially different in their knowledge production processes, but also because of data avail-

ability. In the second step of our theoretical analysis, we will show that also the costs of diversity highlighted by the process perspective will vary between the two disciplinary fields and that they will further vary between the two types of diversity. In a final step of our theoretical analysis, we will analyse whether the benefit-cost-relation with reference to functional and cultural diversity in research groups is apt to be influenced by the group's potential for interaction and discourse.

Knowledge Production in the Two Disciplinary Fields: The Diverging Benefits of Diversity

The humanities & social sciences on the one hand and the natural sciences on the other differ in a multitude of aspects that are relevant for the knowledge production process and that are hence apt to influence the diversity-performance-link. While the differences between the humanities & social sciences on the one hand and the natural sciences on the other have already been highlighted by Snow (1964) in his monograph on “the two cultures”, they are still agreed on even today (Black, and Stephan, 2008). Admittedly, there are of course also differences between the different sub-disciplines within each of the two disciplinary fields, but these should in general be smaller and less fundamental.

One first important difference between the two disciplinary fields under consideration concerns the fact that the humanities & social sciences are less paradigmatic as a disciplinary field than the natural sciences: While in the humanities & social sciences, there is a plurality of theoretical and methodical approaches (see Wanner, Lewis and Gregorio 1981: 249), the natural sciences are often dominated by a one central research paradigm and hence less open to different methodologies and competing theoretical explanations. The less paradigmatic nature of the humanities & social sciences clearly increases the productive potential of diversity: in the humanities & social sciences, a more diverse research group has access to a larger pool

of theoretical and methodological perspectives than a less diverse group. Given its non-paradigmatic nature, the additional expertise brought in by PhD students with a different functional or cultural background is likely to be put to a productive use. To the contrary, within the natural sciences, the spectrum of theoretical and methodological perspectives is smaller to start with, and (marginally) enriching the spectrum by adding students from another background will not necessarily be regarded as being productive or helpful for the incumbent PhD students' research.

Further, knowledge in the humanities and social sciences is to a lesser degree codified than knowledge in the natural sciences, and as a result, implicit and tacit knowledge is more important (see Audretsch, Lehmann and Warning 2004: 195). Much like its less paradigmatic nature, the higher relevance of tacit and implicit knowledge in the humanities & social sciences is also apt to increase the potential benefits of diversity. If knowledge is less codified and rather implicit, it is harder for PhD students to access this knowledge without someone from a different functional or cultural background literally bringing it to the group and sharing it. As a result, in the humanities & social sciences, a diverse group might well outperform a non-diverse one, whereas in the natural sciences, a larger group diversity with respect to the functional or cultural background of its members will less likely result in a better performance as the additional knowledge brought to the group (if of any worth at all) might also be accessed otherwise.

Lastly, also the comparatively broader and less specialized graduate education in the humanities & social sciences (see, e.g. Audretsch, Lehmann and Warning 2004: 196; Hagstrom 1964: 194) and that research projects are less narrowly defined (see Hagstrom 1964: 194) should contribute to the benefits of diversity being potentially larger in the humanities & social sciences. Both, a broader education and less specified research projects allow PhD students in the humanities & social sciences to more easily think their ways into the projects pursued by

their fellow students from a different functional (or cultural) background and give input and feedback.

To conclude, we expect the potential benefits of diversity to be in general more pronounced in the humanities & social sciences than in the natural sciences. Elaborating on how the potential benefits of the different types of diversity relate to the costs will allow us to derive differentiated hypotheses on the diversity-performance link in the two fields.

Cultural Specificity and the Role of Language: The Diverging Costs of Cultural Diversity in the Two Disciplinary Fields

Concerning the potential costs of cultural diversity, the often culture-specific nature of research projects and the importance attached to language and wording (e.g. when it comes to the interpretation of texts) in the humanities & social sciences, are likely to play a role. Unlike it is the case in the natural sciences, in the humanities & social sciences, PhD students cannot rely on a quasi-universal language (such as “mathematics”), leaving room for language barriers to substantially and adversely affect group performance. Together with the fact that research projects in the humanities & social sciences are often culture specific and require in-depth knowledge of the specific culture to be studied, we would hence expect the costs of cultural diversity to be particularly high in the humanities & social sciences.

As cultural diversity might however also positively affect group performance in the humanities & social sciences (see above), the link between cultural diversity and performance in the humanities & social sciences does depend on the specific cost-benefit relation and how it links to increasing degrees of diversity. If—as has been plausibly argued by Kanter (1977a, 1977b) for the case of gender diversity—it needs a certain minimum degree of diversity (the “critical mass”) for the benefits of diversity to accrue, then the relation between cultural diversity and performance in research groups in the humanities & social sciences might well be U-

shaped with increasing diversity levels first reducing performance but then eventually, after some critical level of diversity has been reached, increasing performance.

To the contrary, the high degree of formalization as well as the concentration on mathematics as the basic “language” in the natural sciences clearly limits the costs of language-based misunderstandings in this disciplinary field. As we do not expect the benefits of cultural diversity in the natural sciences to be particularly high (see above), we hence postulate cultural diversity and performance not to be linked in research groups from the natural sciences.

Concluding, we expect the diversity-performance link with respect to cultural diversity to be effectively moderated by the culture-specificity and the importance of language and wording in the respective disciplinary field. With the culture-specificity and importance of language and wording being considerable more pronounced in the humanities & social sciences, our first set of hypotheses reads:

Hypothesis 1 (Cultural Diversity): If and how cultural diversity affects the performance of a research group crucially depends on the disciplinary field: **(a)** In the natural sciences, cultural diversity does not affect research performance. **(b)** In the humanities & social sciences, the link between cultural diversity and performance is U-shaped.

Task Interdependence: The Diverging Costs of Functional Diversity in the Two Disciplinary Fields

Turning next to functional diversity and its potential costs for the knowledge production process in the two disciplinary fields, the differing degree of task interdependence in the two fields is expected to play a prominent role. As for the two fields under consideration, the literature consistently points to the fact that in the natural sciences, task interdependence is particularly high: While PhD projects in the humanities & social sciences are more or less “lonely activities” (Gellert, 1993: 59)—which does not preclude that they profit from the feedback and in-

put of others—Ph.D. students in the natural sciences often literally rely on the cooperation of others in their research (see Warning, 2004: 395; Knorr-Cetina, 1992: 133), and cooperation is often not a choice, but rather a necessity (see Breneman, 1976: 26f.; Stephan, 1996: 1222; Wanner, Lewis and Gregorio, 1981: 249). While an increased cooperation between members of a group might enhance both the potential benefits of diversity as well as its costs, Jehn, Northcraft, and Neale (1999) have shown the potentially adverse effects of diversity to be more pronounced when tasks are interdependent, i.e. when group members literally rely on one another to fulfil their tasks.

Following Jehn, Northcraft, and Neale (1999), we expect task interdependence to negatively affect the diversity-performance link in the natural sciences. While the high degree of formalization as well as the concentration on mathematics as the basic “language” in the natural sciences clearly limits the costs of language-based misunderstandings in the case of cultural diversity (see above), a different study background (e.g. theoretical physics vs. applied mechanical engineering) might in fact substantially hamper cooperation in the natural sciences and raise the costs associated with a higher degree of diversity. Together with the expectedly low benefits of diversity in the natural sciences, the arguably high costs associated with functional diversity in the natural sciences lead us to postulate an overall negative relation between the functional diversity of research groups in the natural sciences and their performance.

For the humanities & social sciences, again, there will be benefits as well as costs of functional diversity, but as the costs are expected to be low as compared to the potential benefits accruing from the specificities of the knowledge production process (see above), we postulate the diversity-performance link to be positive.

Concluding, we expect the diversity-performance link with respect to functional diversity to be effectively moderated by the degree of task interdependence in the respective disciplinary

field. With task-interdependence being significantly higher in the natural sciences, our second set of hypotheses reads:

Hypothesis 2 (Functional Diversity): If and how functional diversity affects the performance of a research group, crucially depends on the disciplinary field: **(a)** In research groups from the natural sciences, functional diversity and performance are negatively related. **(b)** In research groups from the humanities & social sciences, the link between functional diversity and performance is positive.

Group Interaction and the Diversity-Performance Relation

The discussion of potential moderators of the diversity-performance link has repeatedly referred to a friendly communication climate being an essential pre-condition for the potential benefits of diversity to materialize: In lack of interaction in a group, the different perspectives, theories and methodologies that its members bring in, can—almost by definition—not benefit the group.

Correspondingly, Gibson and Gibbs (2006) have shown a psychological safe communication climate (see Edmondson 1999 for more details on the concept) to mitigate the adverse effects associated with national diversity in the case of virtual teams. Also, the study by Gibson and Vermeulen (2003) showing that differences associated with cultural diversity could in fact be bridged when (mild) subgroups evolved providing a psychologically safe communicative environment, hints at the positive role communication and interaction might play when it comes to reaping the benefits of diversity.

Other than, e.g. Ancona and Caldwell (1992b), we do not focus on the link between communication or interaction on the one hand and group performance on the other, but rather ask whether a group's potential for interaction and discourse might act as a moderator of the di-

iversity-performance link (see e.g. Smith et al 1994; Hambrick, and D’Aveni 1992 for a similar approach).

Specifically, we argue that a group’s potential for interaction and discourse will positively affect the diversity-performance link in that it mitigates its costs and helps reap its benefits—irrespective of the disciplinary field and irrespective of diversity type. Hence, we formulate our third and final hypothesis:

Hypothesis 3 (Interaction): In both of the two disciplinary fields and irrespective of diversity type, a group’s potential for interaction and discourse will positively affect the diversity-performance link.

METHODS

Sample

Our empirical analysis is based on a hand-collected data set of 45 university research training groups (“Graduiertenkollegs”) funded by the German Research Foundation (DFG). Research training groups were established as a new form of governance for PhD education in Germany where for a long time the “master-apprentice-model” of PhD supervision dominated (see Schneider and Sadowski 2010). The research groups are run by a group of cooperating researchers and include a structured study program.

Our data set comprises all research training groups established at one single location from the humanities & social sciences and the natural sciences that were in their second funding period and had submitted an application for a third funding period to the German Research Foundation between October 2004 and October 2006. 22 of the 45 research groups in our data set belong to the humanities & social sciences, 23 belong to the natural sciences.

Our data set is unique in many respects. First, it allows us to analyze the relation between diversity and performance in two different disciplinary fields: the humanities & social sciences on the one hand and the natural sciences on the other. As we have argued, these two disciplinary fields differ in a range of characteristics that are relevant for the knowledge production process and are hence apt to influence the diversity-performance link. Second, our data set allows us to analyse two different types of diversity: cultural diversity as one form of demographic, relation-oriented diversity on the one hand and functional diversity concerning the study fields of the research group students on the other. Third, our data set contains information on variables that might give an indication of a research group's potential for interaction and discourse.

Measures

Performance: The performance of a research training group is measured by doctoral completion rate as one obvious output measure not only for research in universities but also for research and knowledge production in other fields. Although one might argue that the doctoral completion rate is not a research or knowledge production output per se (which would rather be the number of inventions or innovations), we argue that it is nevertheless an important outcome variable because 'finishing a project' is the most important prerequisite for an invention or innovation to become successful. Of course, for an invention to become successful it needs more, so completion rate is not a sufficient condition, but incomplete projects will never become successful. Thus, the completion rate can be considered as an important necessary condition or a lower performance bound. Furthermore, one might argue that the doctoral completion rate is not a team output, but rather an individual output and is hence the wrong level of analysis. However, even though writing a doctoral thesis might not in general be regarded as being the outcome of a team production process, empirical evidence

shows that the scientific environment proves to be increasingly important for an individual researcher's success (see Carayol and Matt, 2004; Stephan, 1996) with the trend towards more collaboration manifesting itself—among others—in a steady increase of co-publications (see e.g. Rigby and Edler, 2005: 785; Adams et al., 2005) and an increased significance of acknowledgements (Giles and Councill, 2004: 17603f.). Thus, finishing a dissertation is also to be regarded as being the result of efficient group processes. In our analysis, we regard the group of fellow PhD students as representing one significant part of a young researcher's scientific environment. The doctoral completion rate is measured per funding year in order to control for varying research group sizes and for varying degrees of student fluctuation among research groups.

Diversity: To capture diversity in the sense of variety, we follow the suggestion by Harrison, and Klein (2007) and use Blau's (1977) heterogeneity index defined as

$$H = 1 - \sum_{i=1}^n s_i^2$$

with n representing the total number of categories of a variable, and s_i representing the fraction of team members falling into category i (see also, e.g., Polzer, Milton, and Swann, 2002; Gibson, and Gibbs, 2006; Reagans, Zuckerman, and McEvily, 2004). The figures were standardized on the interval [0,1] with "1" representing maximum heterogeneity (see Alexander et al. 1995: 1466, or Harrison, and Klein, 2007: 1212, for the procedure).

Moderators: Concerning potentially moderating variables of the diversity-performance link, we (1) distinguished between different disciplinary fields: the humanities & social sciences on the one hand and the natural sciences on the other. While, among others, the former are less paradigmatic in nature, but more likely to be culture-specific and language-sensitive, the latter are characterised by a larger degree of task interdependence—all of which should affect the diversity-performance link. Further, we (2) differentiated between two different types of

diversity. For our measure of functional diversity, we distinguish 22 different study fields according to the International Standard Classification of Education (ISCED). For our measure of cultural diversity, we distinguish nine cultural regions according to the classification by Huntington (1996). Lastly, we (3) accounted for two potentially moderating factors with respect to a research group's potential for interaction and discourse: (a) the time research group students jointly spent in research seminars ("seminars") given them the opportunity to interact and (b) the commitment and engagement of supervisors as judged by research group students ("supervisors") indicating the intensity of interaction between junior and senior researchers. Both variables were collected in an encompassing online survey of the junior researchers in the research groups and were measured as follows: The time jointly spent in research group seminars was measured by the number of extra hours per term research group students spent as participants in research seminars organized by the research group (on top of the compulsory course program offered by the research training group). The commitment of the senior researchers as the supervisors of the groups was measured by the following question: "How do, in your opinion, research group students in your research group assess the commitment of the supervising senior researchers in the research group?" Answers on this latter question reached from "very high" (coded 4), "high" (coded 3), "rather low" (coded 2) to "low" (coded 1).

Data Analysis

We tested our hypotheses both, non-parametrically and using OLS, with the log of the doctoral completion rate as the dependent variable. We used OLS instead of TOBIT because the log of the doctoral completion rate takes a wide range of values between 0 and 1 but hardly the boundary ones.

RESULTS

Descriptive Statistics

Table 1 displays the means, standard deviations, minimum and maximum values for all outcome, predictor and moderating variables—separately for the two disciplinary fields.

Table 1: Means, standard deviations, minimum and maximum values

	Humanities & social sciences				Natural sciences			
	mean	s.d.	Min	Max	mean	s.d.	min	Max
Doctoral completion rate	.13	.09	.00	.30	.17	.11	.00	.38
Functional diversity	.34	.18	0	.66	.21	.27	0	.79
Cultural diversity	.18	.18	0	.68	.33	.21	0	.71
Seminars	16.11	10.16	4.33	40.68	14.44	8.36	2	29
Supervisors	2.65	.56	1	4	2.98	.47	2.22	4

Source: Own data.

Table 2 delivers the correlations among all variables, again separately for the disciplinary fields (see Panel A for the humanities & social sciences, and Panel B for the natural sciences).

Table 2: Correlations

	Panel A: Humanities & social sciences				
	(1)	(2)	(3)	(4)	(5)
(1) Doctoral completion rate	1				
(2) Functional diversity	-0.12	1			
(3) Cultural diversity	-0.14	-0.21	1		
(4) Seminars	0.48**	-0.53**	0.04	1	
(5) Supervisors	-0.06	-0.29	-0.12	0.49**	1

	Panel B: Natural sciences				
	(1)	(2)	(3)	(4)	(5)
(1) Doctoral completion rate	1				
(2) Functional diversity	-0.41*	1			
(3) Cultural diversity	0.17	-0.07	1		
(4) Seminars	-0.28	0.09	0.04	1	
(5) Supervisors	-0.04	-0.05	-0.03	-0.25	1

Source: Own data.

Concerning the relation between our dependent variable (doctoral completion rate) and the main explanatory variables (functional diversity on the one hand and cultural diversity on the other), our data only displays one significant correlation: In the natural sciences, functional diversity is negatively related to the doctoral completion rate ($r=-0.41^*$).

As regards potential problems of multicollinearity, we reviewed the correlations between each of the diversity measures and the potentially moderating factors (shaded areas). There is only one significant correlation: Functional diversity in the humanities & social sciences is negatively correlated with the number of hours students jointly spent in research group seminars ($r= -0.53^{**}$). As noted by Tsui, Egan, and O'Reilly (1995: 1531), “[t]here is no definitive criterion for the level of correlation that constitutes a serious multicollinearity problem. The general rule of thumb is that it should not exceed .75”. Further, and as a second check, we examined the variance inflation factors and found them to be all below 2, concluding that multicollinearity was not a serious problem in our analysis (Chatterjee and Hadi, 2006: 236).

The Link between Cultural Diversity and Performance in the two Disciplinary Fields

In a first step, we undertook a conventional OLS regression analysis with the log of the doctoral completion rate as the dependent variable and cultural or functional diversity as explanatory variable, each time testing for both, (i) a linear and (ii) a non-linear relation.

Table 3 shows the results of our analysis for cultural diversity, both for the humanities & social sciences (Panel A) and for the natural sciences (Panel B). Consistent with Hypothesis 1b, we find evidence of a U-shaped relation between cultural diversity and research performance in the humanities & social sciences. Research group performance in terms of the doctoral completion rate reaches a minimum at intermediate levels of cultural diversity (0.32), and only at very high levels of diversity (0.65 or above), research group performance surpasses

the performance level of culturally homogenous groups. However, the corresponding estimation is itself statistically non-significant—possibly resulting from the low number of cases.

In the natural sciences, as hypothesized in Hypothesis 1a, there is no clear relation between cultural diversity and research performance: Neither the coefficient on cultural diversity in the linear model nor the coefficients on cultural diversity and cultural diversity² in the non-linear model are statistically different from zero. Further, the models themselves are statistically not significant.

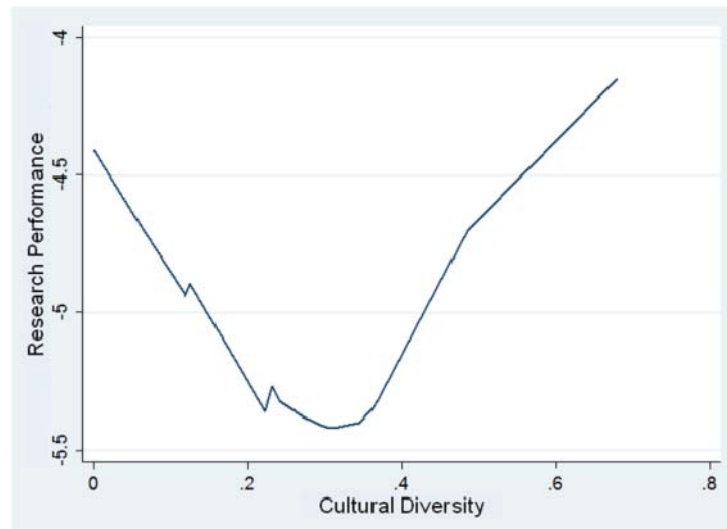
Table 3: Cultural Diversity and Research Performance

	Panel A: Humanities & social sciences		Panel B: Natural sciences	
	(i)	(ii)	(i)	(ii)
Cultural diversity	-1.21	-7.00*	1.15	6.12
Cultural diversity ²		10.83*		-7.19
Constant	-4.73***	-4.38***	-5.15***	-5.71***
R ²	0.03	0.17	0.02	0.05
Prob χ^2	0.42	0.18	0.49	0.60
N	22		23	

Source: Own data.

To further investigate into the functional form of the non-linear relation between cultural diversity and performance in the humanities & social sciences, we apply the non-parametric locally weighted scatterplot-smoother (LOWESS) predicting performance by weighted regressions (see Hamilton 2006, 219f.; Cleveland, 1994). The non-parametric approach has the advantage that it renders an unbiased picture of the diversity-performance link, not “forcing” the relation in a particular function. As Figure 1 shows, also the non-parametric analysis renders evidence of the diversity-performance link to be non-linear and U-shaped—further supporting Hypothesis 1b and making our test even stronger.

*Figure 1: Cultural Diversity and Research Performance in the Humanities & Social Sciences:
Results from the Non-parametric Analysis (LOWESS)*



Source: Own data.

Concluding, we find cultural diversity to be unrelated to performance in the natural sciences (as postulated in Hypothesis 1a), and we find evidence for the relation between cultural diversity and performance in the humanities & social sciences to be non-linear and U-shaped (Hypothesis 1b).

The Link between Functional Diversity and Performance in the two Disciplinary Fields

Table 4 next shows the results of our OLS analysis for functional diversity, again separate for the humanities & social sciences (Panel A) and for the natural sciences (Panel B). For the humanities & social sciences, we find no clear relation between functional diversity and performance. Also, neither of the two estimations (linear and non-linear) is statistically significant. Accordingly, we conclude that other than postulated in Hypothesis 2b, there is no clear relation between functional diversity and performance in the humanities & social sciences.

In the natural sciences, to the contrary and as postulated in Hypothesis 2a, we find clear evidence of a negative linear relation between functional diversity and research performance as

measured by the doctoral completion rate. The corresponding estimation is statistically highly significant.

Table 4: Functional Diversity and Research Performance

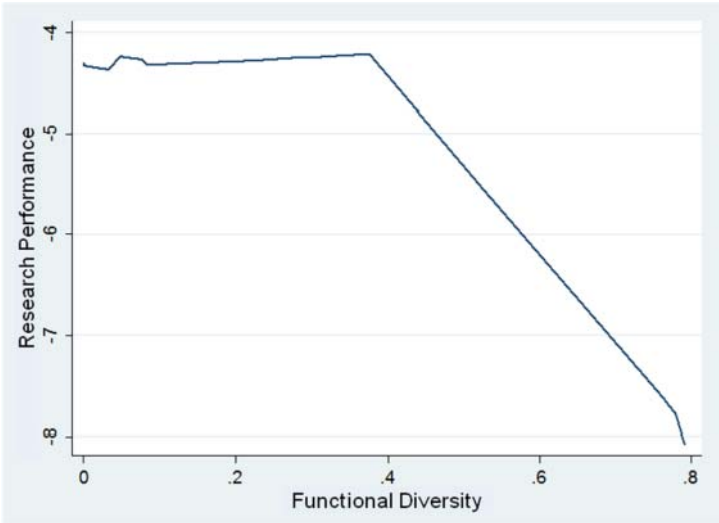
	Panel A: Humanities & social sciences		Panel B: Natural sciences	
	(i)	(ii)	(i)	(ii)
Functional diversity	-1.30	-5.61	-3.78***	4.54
Functional diversity ²		6.98		-11.50***
Constant	-4.51***	-4.08***	-4.00***	-4.40***
R ²	0.04	0.08	0.44	0.63
Prob χ^2	0.39	0.48	0.00	0.00
N	22		23	

Source: Own data.

In Figure 2 we further explore the apparent negative link between functional diversity and performance in the natural sciences: we again find evidence for the link being clearly negative—rendering further support to Hypothesis 2a.

Figure 2: Functional Diversity and Research Performance in the Natural Sciences:

Results from the Non-parametric Analysis (LOWESS)



Source: Own data.

Concluding, with respect to functional diversity, we find it to be unrelated to performance in the humanities & social sciences (other than expected in Hypothesis 2b), but—in support of Hypothesis 2a—negatively related to performance in the natural sciences.

Group Interaction and the Diversity-Performance-Link

Turning next to the hypothesized moderating effect of a group’s potential for interaction and discourse on the diversity-performance link, we concentrate on the two hypothesized relations that manifested themselves in the data: the apparent U-shaped link between cultural diversity and performance in the humanities & social sciences and the apparent negative link between functional diversity and research performance in the natural sciences. Again, in each case we start with traditional OLS regressions and then further substantiate our results with the help of a non-parametric analysis.

Analysing the hypothesized moderating role of a group’s potential for interaction and discourse on the U-shaped link between cultural diversity and research performance in the humanities & social sciences, we first re-ran the non-linear OLS-model from Table 3, separately for a high and a low level of (a) hours jointly spent in seminars and (b) supervisor engagement. Concerning (a), we differentiate between research groups where students spend comparatively few hours in joint seminars (i.e., below the median of 12 hours per term) and research groups where students spend comparatively many hours in joint seminars (i.e., above the median of 12 hours per term). Concerning (b), we differentiate between research groups where students rate their supervisors’ engagement to be rather low (below the median of 2.7 on a 4-point scale) and research groups where students rate their supervisors’ engagement to be rather high (above the median of 2.7). Table 5 shows the results of our analysis.

Table 5: Cultural Diversity and Research Performance in the Humanities & Social Sciences:

The Moderating Role of a Group’s Potential for Interaction & Discourse

	(a) Time spent in seminars		(b) Supervisor engagement	
	below median (<12 hours)	above median (>12 hours)	below median (<2.7)	above median (>2.7)
Cultural diversity	-15.42**	-5.56	-20.09***	0.438
Cultural diversity ²	21.70**	13.14	27.03***	2.96
Constant	-4.21***	-4.21***	-3.40***	-4.90***
R ²	0.50	0.28	0.73	0.30
Prob χ^2	0.06	0.26	0.01	0.24
N	11	11	11	11

Source: Own data.

Apparently, the negative and positive effects of diversity are levelled out in research groups (a) where students spend comparatively many hours in seminars and (b) where supervisors are judged to be rather engaged. For both subgroups, we do not find a significant relation between cultural diversity and performance, and the corresponding estimations are statistically non-significant.

To the contrary, in research groups where junior researchers spend comparatively few hours in seminars, and in research groups where supervisors are judged to be less engaged, the U-shaped relationship between cultural diversity and research performance becomes more pronounced. Even at the highest levels of cultural diversity in research groups from the humanities & social sciences in our data set (0.68), the corresponding research group does not reach the performance level of a culturally homogeneous one. I.e., our empirical evidence supports the view that—unless interaction among students and supervisors is not enhanced through joint research seminars and engaged supervisors—the negative effects of cultural diversity in research groups of the humanities & social sciences will dominate the positive ones.

In order to further account for potential interaction effects between diversity and a group's potential for interaction & discourse, in a next step, we regressed the log of the doctoral completion rate on cultural diversity and cultural diversity² and subsequently controlled for (a) hours spent in seminars and (b) supervisor engagement, including the respective interaction effects

(see Table 6). What we find is that the interaction between diversity and the indicator for a group’s potential for interaction & discourse is positive in both cases implying that the positive effects of cultural diversity on research performance in the humanities & social sciences are stronger (a) the more hours research group students spend in joint seminars and (b) the better research group students judge the engagement of their supervisors. Hence, as postulated in Hypothesis 3, a group’s potential for interaction & discourse is apt to strengthen the positive effects of cultural diversity in the humanities & social sciences.

Table 6: Cultural Diversity and Performance in the Humanities & Social Sciences: Testing for Interaction Effects with a Group’s Potential for Interaction & Discourse

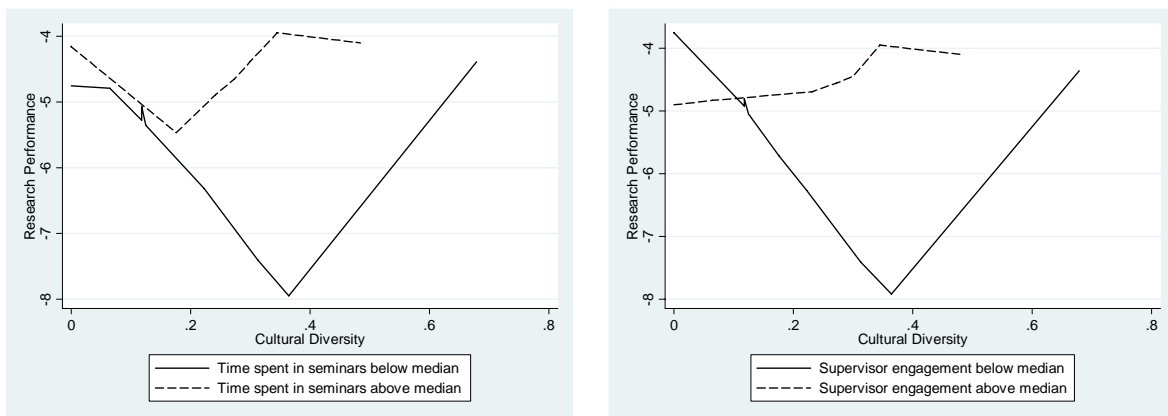
	Time spent in seminars	Supervisor engagement
Cultural diversity	-13.59***	-40.49**
Cultural diversity ²	15.31**	21.87***
Time spent in seminars	0.01	
Cultural diversity x Time spent in seminars	0.26*	
Supervisor engagement		-1.08
Cultural diversity x Supervisor engagement		10.88**
Constant	-4.43***	-1.25
R ²	0.49	0.38
Prob χ^2	0.02	0.07
N	22	

Source: Own data.

In a next step, we further explored the diversity-performance link between cultural diversity and research performance in the humanities & social sciences with the help of a non-parametric analysis: In the left panel of Figure 3, we differentiate between research groups where students spend comparatively few hours in joint seminars and research groups where students spend comparatively many hours in joint seminars. In the right panel, we differentiate between research groups where students rate their supervisors’ engagement to be rather low and research groups where students rate their supervisors’ engagement to be rather high.

As can be seen, research groups where students spend more time in seminars as well as research groups where supervisors are judged to be more engaged both seem to better handle the potentially negative effects of diversity—while still leaving room for the positive effects.

Figure 3: Cultural Diversity and Research Performance in the Humanities & Social Sciences: The Moderating Role of A Group’s Potential for Interaction & Discourse (LOWESS)



(a) Time spent in seminars

(b) Supervisor engagement

Source: Own data.

Concluding, our parametric as well as our nonparametric analysis support Hypothesis 3 as far as cultural diversity in the humanities & social sciences is concerned: In research groups where the junior and senior researchers meet more often and where the senior researchers are judged to be more engaged, the (otherwise largely dominating) negative effects associated with a higher degree of cultural diversity are reduced, resulting in heterogeneous research groups catching up earlier with homogeneous ones or even surpassing them in their research performance.

Next we explored the potentially moderating effect of a group’s potential for interaction & discourse on the negative link between functional diversity and research performance in the natural sciences. First, we re-ran the linear OLS-model from Table 4, separately for a high

and a low level of (a) hours jointly spent in seminars and (b) supervisor engagement. Table 7 shows the results of our analysis. Apparently, in both cases, the negative effects of diversity are reduced in research groups where students spend comparatively many hours in seminars and in research groups where supervisors are judged to be rather engaged (with only the latter effect being statistically significant)—rendering further support to Hypothesis 3. Other than was the case for the effect of a group’s potential for interaction & discourse on the diversity-performance link in the humanities & social sciences, there are no interaction effects between a group’s potential for interaction & discourse and functional diversity in the natural sciences (see Table 8 for the corresponding analysis).

*Table 7: Functional Diversity and Research Performance in the Natural Sciences:
The Moderating Role of a Group’s Potential for Interaction & Discourse*

	(a) Time spent in seminars		(b) Supervisor engagement	
	below median (<14 hours)	above median (>14 hours)	below median (<2.9)	above median (>2.9)
Functional diversity	-3.86***	-3.65*	-4.84**	-1.56**
Constant	-3.98***	-4.03***	-4.00***	-4.07***
R ²	0.57	0.32	0.49	0.34
Prob χ^2	0.01	0.06	0.02	0.04
N	11	12	10	13

Source: Own data.

*Table 8: Functional Diversity and Performance in the Natural Sciences:
Testing for Interaction Effects with a Group’s Potential for Interaction & Discourse*

	Time spent in seminars	Supervisor engagement
Functional diversity	-3.64*	-10.59**
Time spent in seminars	-0.03	
Functional diversity x Time spent in seminars	0.00	
Supervisor engagement		-0.09
Functional diversity x Supervisor engagement		2.32
Constant	-3.66***	-3.75

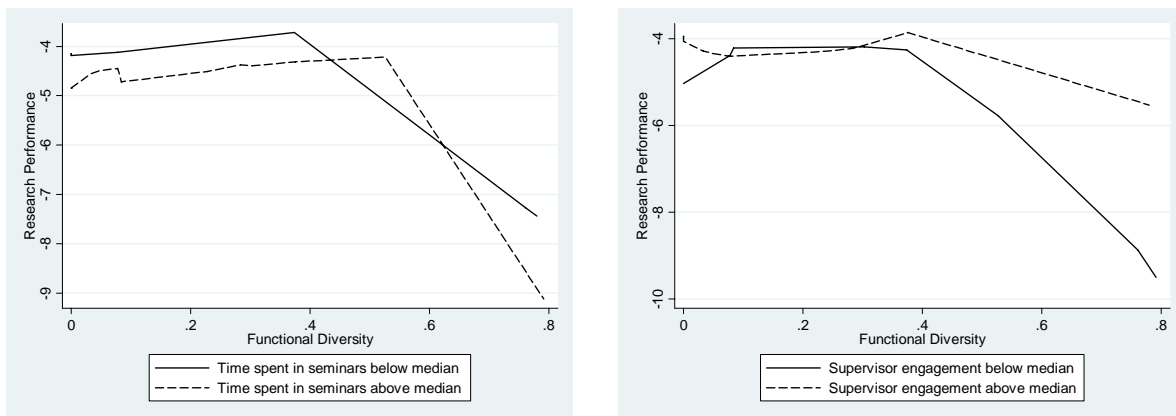
R ²	0.45	0.52
Prob χ^2	0.01	0.00
N	22	

Source: Own data.

Figure 4 next explores the potentially moderated diversity-performance link between functional diversity and research performance in the natural sciences with the help of a non-parametric analysis. As before, on the left hand side, we differentiate between research groups where students spend comparatively few hours in joint seminars and research groups where students spend comparatively many hours in joint seminars. On the right hand side, we differentiate between research groups where students rate their supervisors' engagement to be rather low and research groups where students rate their supervisors' engagement to be rather high. Judging supervisors to be more or less engaged appears to affect the diversity-performance link.

Figure 4: Functional Diversity and Performance in the Natural Sciences:

The Moderating Role of a Group's Potential for Interaction & Discourse (LOWESS)



(a) Time spent in seminars

(b) Supervisor engagement

Source: Own data.

Concluding, our parametric as well as our nonparametric analysis render partial support to Hypothesis 3 as far as functional diversity in research groups from the natural sciences are concerned: in research groups where supervisors are judged to be engaged, the adverse effects of functional diversity are apparently dampened.

DISCUSSION

The purpose of our study was to further explore the diversity-performance link in knowledge production and its potential moderators and hence contribute to the recent literature that seeks to explain why the empirical results on the diversity-performance link are so weak and controversial. We studied diversity in the sense of “variety”, focusing on differences with respect to information, knowledge and experience of group members (see Harrison, and Klein, 2007). Specifically, we studied diversity in research groups and focused on “functional diversity” (i.e. diversity with respect to the study background of the research group members) and “cultural diversity” (i.e. diversity with respect to the cultural world region the research group members come from).

While the preceding literature has repeatedly argued the effects of “task-related” functional diversity to have more productive potential than “relation-related” cultural diversity, we showed that the effects of the different types of diversity crucially depend on the specificities of the knowledge production process in the disciplinary field a research group belongs to (humanities & social sciences vs. natural sciences): Whereas the humanities & social sciences are less paradigmatic in nature, to a lesser degree codified and less specialized as compared to the natural sciences, the natural sciences are characterized by a comparatively higher degree of task-interdependence and by a lower degree of cultural specificity and a lower importance of language and wording. Theoretically showing if and in how far these specificities each affect the diversity-performance link for the two different types of diversity under considera-

tion, allowed us to derive differentiated hypotheses on the diversity-performance link in the different disciplinary fields and for the two different types of diversity.

Specifically, with respect to cultural diversity, our theoretical analysis led us to expect the diversity-performance link in the humanities & social sciences to be U-shaped, while we did not expect a relation between cultural diversity and performance in the natural sciences. Further, with respect to functional diversity, we expected the diversity-performance link to be negative in the natural sciences and to be positive in the humanities & social sciences. Our hypotheses are in sharp contrast to the literature where functional diversity is generally judged to be more productive than cultural diversity. Further, we also analysed one moderating factor which has repeatedly been discussed in the literature: the research group's potential for interaction & discourse. In accordance with the literature, we expected it to positively affect the diversity-performance link—irrespective of diversity type and disciplinary field.

Empirically, we studied the diversity-performance link and its moderators with the help of a hand-collected original data set on 45 university research groups being comprised of junior researchers. Since by nature such research groups are expected to produce innovative outputs and are faced with a complex task, they represent an ideal case to investigate into the diversity-performance link in innovative environments. Besides traditional OLS regressions, we also investigated the diversity-performance link with the help of non-parametric LOWESS analyses, thus leaving open the functional form of the diversity-performance link.

Our hypotheses were largely born out by the data. In particular, we found support for the hypothesized U-shaped relation between cultural diversity and performance in research groups in the humanities & social sciences and for the negative link between functional diversity and performance in the natural sciences. As predicted, in research groups from the natural sciences, cultural diversity and performance are not related. Hence, our empirical analysis supports the view that the diversity-performance link with respect to different types of diversity

crucially depends on the specificities of the knowledge production process as proxied by the disciplinary field the research group belongs to. Further, we find a research group's potential for interaction & discourse to moderate the diversity-performance link by mitigating the adverse effects of diversity and by enhancing its productive potential—irrespective of diversity type and irrespective of the disciplinary field: In both, the humanities & social sciences and in the natural sciences, a research group's potential for interaction & discourse enhances the performance of diverse as compared to homogenous groups.

Contributions and Implications

Our research makes three important contributions. First, we contribute to the literature on potential moderating factors of the diversity-performance link. We do so, both, theoretically and empirically, by analysing the potential benefits and costs of diversity, taking into account the specificities of the knowledge production processes that are characteristic for the research group in a specific disciplinary field and further differentiating between two different types of diversity. While the literature has repeatedly differentiated between different types of diversity and while it has also increasingly discussed potential moderators and mediators of the diversity-performance link, we are not aware of any study that has brought these two aspects together as yet. As our analysis shows, however, moderators of the diversity-performance link for one type of diversity will not necessarily work in the same direction for another type of diversity.

Our second innovation which will hopefully inspire future work on the subject is our use of non-parametric analyses when exploring the functional form of the diversity-performance link. Unlike traditional OLS regressions, the subsequently performed non parametric LOW-ESS analyses allow us to investigate into the diversity-performance link—without prescribing what its functional form will be like. To the best of our knowledge, non-parametric analyses

have not been used as yet to explore the functional form of the diversity-performance link. The LOWESS analyses we performed in our study in fact support the view that the relation between cultural diversity and performance is in fact non-linear and U-shaped—strengthening our analysis and making us more confident about its results.

Third, our study on research groups in two different disciplinary fields allows us to derive general implications and conclusions that go beyond our particular field of application, since the disciplinary fields are no more than a proxy of the underlying specificities of the knowledge production process in the groups. For example, according to our analysis, we would expect diversity in groups whose task is not only less routine, but also less specialized, to have comparatively more productive potential. The same is true for groups that are likely to profit from tacit, non-codified knowledge: These, too, are more likely to profit from the potential benefits of diversity because tacit knowledge can by nature only be assessed when group members bring it to the group. Much in the same vein, groups that work in a less paradigmatic field, i.e. in a field characterized by a multitude of approaches on how a given problem may be solved, will more likely profit from the productive potential associated with diversity.

A further implication is that it will also depend on the type of diversity and how it relates to the knowledge production process and the specificities of the task to be accomplished, whether or not the productive potential of diversity outweighs its potential costs. As a result, there will not be one type of diversity generally outperforming another one and allegedly task-related functional diversity might not generally outperform demographic types of diversity, as is sometimes argued in the literature: as we have shown, depending on the context, functional diversity might in fact have adverse effects that are more pronounced than those of cultural diversity. It is the specific context that defines whether a given type of diversity is “task-related” or not. The general lesson would at this point be that researchers as well as practitio-

ners need to take a closer look at the potential interrelations between diversity type and the specificities of the knowledge production process in order to assess its performance effects.

Lastly, our analysis implies that a research group's potential for interaction & discourse substantially affects the diversity-performance link—primarily by mitigating potential adverse effects, but also by enhancing its productive potential. This is good news for practitioners who set up diverse groups in an attempt to reap the benefits of diversity.

Limitations and Future Research

As any study, our study also suffers from limitations, the most important one being that we develop and test our theory on the diversity-performance link in the specific setting of university research groups. However, such research groups should most certainly represent an interesting test case as innovativeness becomes more and more important for almost any type of organization. Future studies will need to show whether the implications we derived and the conclusions we drew are in fact generalizable and whether our results are robust to other settings and operationalizations.

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