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The role of German universities in a system of joint knowledge generation and innovation
A social network analysis of publications and patents with a focus on the spatial dimension

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10. Empirical Results concerning the three different Groups of German Universities

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10. Empirical Results concerning the three different Groups of German Universities

Chapter ten provides a detailed overview and impression of the development path of the knowledge, innovation and collaboration activity of the German universities concerning their different functional orientation as classified before. Of course, it also highly focuses on proximity patterns and explores whether there are significant differences when the three different groups of German universities are looked at and compared with each other in this regard, too.

10.1. Publication and Cooperation Activity concerning the three different Groups of German Universities

There is no doubt that the overall publication activity of the German universities has highly increased over the past ten years. Before coming to the different behavioural patterns of the three groups of German universities regarding their collaboration activities, a nonparametric median test proves whether they possess significant differences regarding their publication activity from 2000 and from 2009. The results are as follows:

Nonparametric Median Test of Publication Activity, 2000						
	Elite	Non-Elite	Technical	Non-Technical	Medical	Non-Medical
Median	1494,5	333	553	553	972	228,5
Level of Significance	0,001***		0,95		0,001***	
Standard errors: *p≤0,05, **p≤0,01 and ***p≤0,001						

Table 16: Nonparametric Median Test of Publication Activity, 2000 (own illustration).

Nonparametric Median Test of Publication Activity, 2009						
	Elite	Non-Elite	Technical	Non-Technical	Medical	Non-Medical
Median	2572,5	691	1097	898	1708	420,5
Level of Significance	0,001***		0,538		0,001***	
Standard errors: *p≤0,05, **p≤0,01 and ***p≤0,001						

Table 17: Nonparametric Median Test of Publication Activity, 2009 (own illustration).

As can be seen from above tables, the group of elite and non-elite universities as well as the group of medical and non-medical universities possesses highly significant values regarding their medians of the publication activity. In fact, it is the elite and the medical universities that have generally published more often compared to their counterparts. This does not apply for the technical universities as they have a similar median as the non-technical universities. Hence, up to this point, it is obvious that the elite and medical universities were more likely engaged in publishing compared to the non-elite and non-medical universities.

Further, being aware of the fact that co-authorship has also highly increased over the past ten years, it is now interesting to examine whether this circumstance also differs if the three different groups of the German universities are looked at and compared with each other. In

this context, it is of special interest whether there are differences within the group of technical and non-technical universities as they have not possessed a significant result regarding the median test of their publication activity. However, to statistically confirm whether there is a significant difference within the specific groups of German universities, the aforementioned chi-squared test on a fourfold table is applied. The results are as follows:

Results of the Chi-Square Test regarding the Cooperation Activity of the different Groups of German Universities, 2000-2009, P-Values				
	2000	2003	2006	2009
Elite vs. Non-Elite	0,11475	0,288640	0,239360	0,112630
TU vs. Non-TU	0,001***	0,001***	0,001***	0,001***
Med vs. Non-Med	0,001***	0,558860	0,456020	0,001***
Standard errors: *p≤0,05, **p≤0,01 and ***p≤0,001				

Table 18: Results of the Chi-Square Test regarding the Cooperation Activity of the different Groups of German Universities, 2000-2009, P-Values (own illustration).

The table illustrates the p-values of the different German university samples with regard to their cooperation activity. It is apparent that in most cases the null hypothesis can be rejected as both variables are not independent from each other. In this special case, it is proved whether cooperation activity does not depend on the specific type of German university compared to its counterpart. However, this finding does not hold in the case of the elite and non-elite universities, as they do not possess any significant differences within their data sets during the past ten years. Thus, it can be stated that the elite universities have indeed published more often as the non-elite universities, but their share of

single- and co-authored publications is quite similar so that they can be neglected in this regard. In contrast, it is especially interesting to discover that the group of technical and non-technical universities possesses high significant results during all the time. Hence, they were in fact equally engaged in publishing but they have highly significant differences regarding their shares of single- and co-authored publications. Last, the medical and non-medical universities have a highly significant difference in their particular data sets within the first time period but not within the two subsequent ones. It is not until the last time period where they have again highly significant differences in their data sets regarding single- and co-authorship.

But, which type of German university is rather engaged in single-authored publications and which one is more involved in close network collaborations? The following table illustrates the share of co-authored publications of the technical and non-technical universities from 2000 until 2009:

Share of Co-authored Publications, Technical vs. Non-Technical Universities, 2000-2009				
	2000	2003	2006	2009
Technical	53%	63%	65%	68%
Non-Technical	56%	66%	69%	72%

Table 19: Share of Co-authored Publications, Technical vs. Non-Technical Universities, 2000-2009 (own illustration).

First of all, it is of course eye-catching that both groups have seen high growth rates regarding their co-authored publications. However, it is further obvious that the non-technical universities have always possessed higher rates of co-authored publications compared to the technical universities. It can be seen that in 2000, the share of the co-authored publications has been 56% for the non-technical universities compared to 53% for the technical ones. Within the last time period, the difference between single- and co-authorship has even become somewhat larger for the group of non-technical universities. Thus, while both types of universities were equally engaged in publishing, the non-technical universities have more often cooperated with others than the technical universities.

Coming now to the group of medical and non-medical universities, the following table illustrates their shares of co-authored publications from 2000 until 2009 as well:

Share of Co-authored Publications, Medical vs. Non-Medical Universities, 2000-2009				
	2000	2003	2006	2009
Medical	55%	65%	68%	71%
Non-Medical	57%	65%	68%	66%

Table 20: Share of Co-authored Publications, Medical vs. Non-Medical Universities, 2000-2009 (own illustration).

Again, as can be seen from above table, the share of co-authored publications has of course also highly increased for the medical and non-

medical universities. However, in this special context, it is eye-catching that in 2000, the non-medical universities were more likely engaged in co-authored publications, while in 2009, it is the group of medical universities that has cooperated more often with other partners. Hence, the behavioural pattern in this regard has changed in favor of the medical universities within the last time period. In 2009, 71% of all publications are co-authored within the group of medical universities compared to 66% in the group of non-medical universities.

How can the changing development regarding the sample of medical and non-medical universities be properly explained? By means of the value of normalized degree centrality, it is now shown whether the medical universities have been less centralized within their knowledge networks within the first time period, and whether they could improve in this regard over the past ten years.

Nonparametric Median Test of normalised Degree Centrality, Medical vs. Non-Medical Universities, 2000 and 2009				
	2000		2009	
	Medical	Non-Medical	Medical	Non-Medical
Median	0,0233507	0,0061369	0,0327465	0,0048958
Level of Significance	0,001***		0,001***	
Standard errors: *p≤0,05, **p≤0,01 and ***p≤0,001				

Table 21: Nonparametric Median Test of normalized Degree Centrality, medical vs. non-medical universities, 2000 and 2009 (own illustration).

First of all, it is obvious that the medical universities have possessed a higher median of normalized degree centrality in both time periods even though the non-medical universities were more likely engaged in co-authored publications in 2000. But, while the median of normalized degree centrality has highly increased for the medical universities over the past ten years, it has even declined for the non-medical universities. From this, the changing development of the cooperation activity of both university types can be drawn.

To sum up, hypothesis 4a can only be partially confirmed by the findings made in this regard. It is the group of non-technical universities that have rather tended to publish in cooperation compared to their counterparts. Thus, above hypothesis is not being proved by the above findings. Further, as nowadays it is the sample of medical universities that are stronger engaged in co-authored publications, above hypothesis can at least be confirmed today in this regard.

Up to this point, it is well established that the publication and cooperation activity of the German universities has highly increased over the past ten years. Additionally, first differences regarding the particular publication and cooperation behaviour of the three different groups of the German universities could be observed, i.e. some of the German universities were generally more engaged in publishing than others, and some of them have tended to rather publish in cooperation than other did.

Further, being aware of the institutional distribution of the German university co-authors, it is now interesting to look again at the different groups of German universities, and at their individual cooperation partners. In order to statistically confirm whether there is a significant difference within the specific groups of German universities, the aforementioned chi-squared test on a fourfold table is applied. Thereby, it compares the share of private enterprises to the one of universities and research institutes as it has already been discovered that especially university-industry interactions have increased over the past years. The results are as follows:

Results of the Chi-Square Test regarding the institutional Distribution of the German University Co-Authors, 2000-2009, P-Values				
	2000	2003	2006	2009
Elite vs. Non-Elite	0,96656	0,98043	0,72839	0,84282
TU vs. Non-TU	0,001***	0,001***	0,001***	0,001***
Med vs. Non-Med	0,00751**	0,001***	0,001***	0,001***
Standard errors: *p≤0,05, **p≤0,01 and ***p≤0,001				

Table 22: Results of the Chi-Square Test regarding the institutional Distribution of the German University Co-Authors, 2000-2009, P-Values (own illustration).

Table 22 now illustrates that the null-hypothesis can be rejected again in most of the cases, except of the group of the elite and non-elite universities as they do not possess any differences regarding the institutional distribution of their cooperation partners. In contrast, the other two groups offer again highly significant differences regarding the institutional distribution of their co-authors. The following table shows

the share of co-authorships with enterprises of the technical and non-technical universities from 2000 until 2009:

Share of Co-Authorships with Enterprises, Technical vs. Non-Technical Universities, 2000-2009				
	2000	2003	2006	2009
Technical Universities	8,2%	9,6%	9,7%	9,9%
Non-Technical Universities	5,3%	6,0%	5,5%	6,8%

Table 23: Share of Co-Authorships with Enterprises, Technical vs. Non-Technical Universities, 2000-2009 (own illustration).

Hence, according to the table, it can be proved that the technical universities have cooperated more often with enterprises than the non-technical universities. This finding holds for all four time periods. Even though the share of enterprises has only slowly increased over the past ten years regarding the technical universities, the share of enterprises has even declined from the second to the third time period regarding the non-technical universities. However, the next table now shows the share of co-authorships with enterprises of the medical and non-medical universities from 2000 until 2009:

Share of Co-Authorships with Enterprises, Medical vs. Non-Medical Universities, 2000-2009				
	2000	2003	2006	2009
Medical Universities	5,7%	6,5%	6,0%	7,2%
Non-Medical Universities	7,0%	8,2%	8,6%	9,2%

Table 24: Share of Co-Authorships with Enterprises, Medical vs. Non-Medical Universities, 2000-2009 (own illustration).

As can be seen from the table, the non-medical universities have had more linkages to enterprises over the past ten years compared to the medical universities. This finding is not surprising as it can be assumed that medical universities tend to cooperate more likely with any other knowledge-intensive institutions due to a higher degree in basic research-intensive bias. While the non-medical universities have experienced consistent increasing growth rates regarding their enterprise linkages, the medical universities have even seen declining rates of enterprise interaction from the second to the third time period.⁶⁷

Hence, hypothesis 4b regarding the institutional distribution of the German university co-authors can be largely confirmed as the technical universities are rather engaged in close network collaborations with enterprises compared to their counterparts, and in contrast the medical universities have had more interaction to knowledge-intensive institutions than the non-medical universities. The elite and non-elite universities did not offer any differences in their cooperation behaviour with regard to the institutional distribution.

⁶⁷ The group of elite and non-elite universities has had no significant differences regarding the institutional distribution of their cooperation partners.

10.2. Innovation and Collaboration Activity concerning the three different Groups of German Universities

Coming to the innovation and collaboration activity of the three different groups of German universities, it is beyond question that they could overall increase their number of filed patents as well as their number of co-applicant networks. However, it is still questionable whether all German universities have developed equally in this regard. Hence, by means of the value of betweenness centrality, it is shown whether there are differences regarding close network collaborations between the three different groups of German universities. The results are as follows:

Nonparametric Median Test of Betweenness Centrality, Co-Applicant Networks, 2007-2008						
	Elite	Non-Elite	Technical	Non-Technical	Medical	Non-Medical
Median	0,0240416	0	0,00551905	0	0,0073643	0
Level of Significance	0,003**		0,107		0,011**	
Standard errors: *p≤0,05, **p≤0,01 and ***p≤0,001						

Table 25: Nonparametric Median Test of Betweenness Centrality, Co-Applicant Networks, 2007-2008 (own illustration).

It can be observed that all counterpart universities have a median of zero regarding the median of betweenness centrality. First of all, it has to be stated that the overall patenting activity of the German universities is still comparably low. Second, the differences regarding the median of betweenness centrality between the three different groups of German universities have only been significant in the case of

elite and non-elite universities as well as in the case of medical and non-medical universities. Hence, the elite and the medical universities have been more important as central links within the innovation networks compared to their counterparts. Overall, hypothesis 4a is confirmed for the elite and medical universities, but needs to be rejected for the technical universities.

Further, as it has been done for the publication data, it is also proved for the patent applications whether there are significant differences in the distribution of their cooperation partners when the different groups of German universities are explored and compared with each other. Before coming to the results of the chi-square test, the following figure firstly refers to the distribution of the distinct cooperation partners of the elite, technical and medical universities in order to provide an overview in this regard:

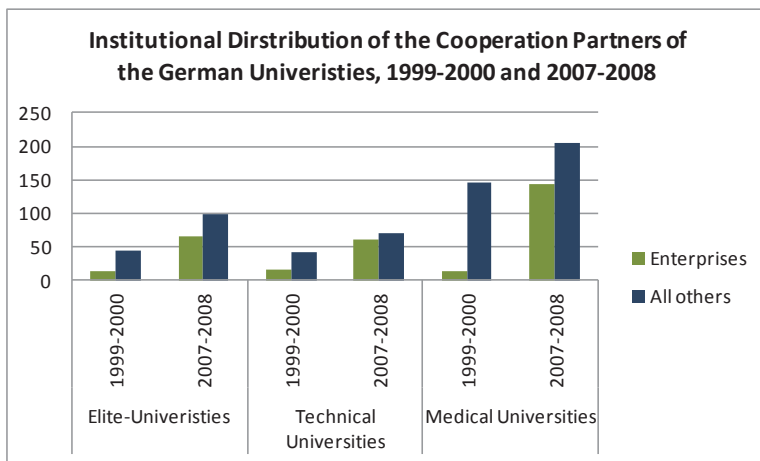


Figure 29: Institutional Distribution of the Cooperation Partners of the German Universities, absolute numbers, 1999-2000 and 2007-2008 (own illustration).

As each group of German universities consists of a different number of universities, it is of course not reasonable to compare the absolute numbers of cooperation partners of the three different German university groups. But, it is of interest to have a look at the development of the number of partnerships, either to enterprises or to all others, of each single group itself. Hence, it is obvious that the increase of private enterprises is very strong in each group, and always much stronger than the rise of all other institutional partners. While the elite universities could increase their partnerships with private enterprises by 400%, and the technical universities by around 250%, it is striking that the medical universities have experienced the largest increase of private enterprises as institutional partners which amounts to 1,000%. But, in comparison to all other cooperation partners, it is the elite and technical universities

that have more likely cooperated with enterprises. The rise of all other partners is relative similar in each of the three groups and ranges from 40% up to 125%. Nonetheless, private enterprises seem to require more academic knowledge which is expressed through the number of partnerships.

In the following, the results of the chi-square test are illustrated for the three different German university samples; thus, it is statistically shown whether there are significant differences in the distribution of their cooperation partners. The test is done for the first, third and fifth time period. The results are as follows:

Results of the Chi-Square Test regarding the institutional Distribution of the German University Co-Applicants, P-Values of three Time Periods			
	1999-2000	2003-2004	2007-2008
Elite vs. Non-Elite	0,02521**	0,18004	0,86869
TU vs. Non-TU	0,001***	0,18457	0,10432
Med vs. Non-Med	0,001***	0,80868	0,48959
Standard errors: * $p \leq 0,05$, ** $p \leq 0,01$ and *** $p \leq 0,001$			

Table 26: Results of the Chi-Square Test regarding the institutional Distribution of the German University Co-Applicants, P-Values of three Time Periods (own illustration).

While the table shows highly significant values for each German university sample within the first time period, this finding cannot be confirmed within the last time period. However, in order to explore which groups of the German universities have rather tended to cooperate with enterprises compared to their counterparts, the

following figure shows the absolute numbers of co-applicants of each German university group:

Institutional Distribution of the German University Co-Applicants, 1999-2000 and 2007-2008						
1999-2000	Elite	Non-Elite	Technical	Non-Technical	Medical	Non-Medical
Enterprises	13	15	17	14	13	18
All others	43	124	41	137	146	32
Share Enterprises (%)	23	12	29	9	8	36
2007-2008	Elite	Non-Elite	Technical	Non-Technical	Medical	Non-Medical
Enterprises	65	122	60	129	144	43
All others	98	178	70	211	204	71
Share Enterprises (%)	40	41	46	38	41	38

Table 27: Institutional Distribution of the German University Co-Applicants, absolute numbers, 1999-2000 and 2007-2008 (own illustration).

Figure 28 indicates that there are significant differences within the three German university samples for the first time period. Thus, it is interesting to show which group of German universities has rather tended to cooperate with enterprises or with other institutional partners⁶⁸. It is illustrated how all groups behave regarding their co-applicants. In the group of elite universities, around 23% of all co-applicants were among the enterprises compared to only 12% within the group of the non-elite universities. Thus, from 1999 until 2001, the German elite universities have rather cooperated with enterprises than the non-elite universities. However, this finding has changed over time, as during the last time period, the share of the enterprises has been similar in both groups. This finding also holds for the group of medical

⁶⁸ In this context, other institutional partners include other universities, research institutes and private persons.

and non-medical universities. While within the first time period, the share of enterprises was 36% in the group of non-medical universities, compared to only 8% within the other group of medical universities, the share of enterprises as co-applicants is nowadays quite similar in both groups. Thus, it is obvious that especially the medical universities have started to cooperate with enterprises. Besides, the examination of the technical and non-technical universities looks a bit different, as there are still slight significant differences in both samples regarding the share of enterprises as institutional co-applicants. In the first time period, cooperations of the technical universities with enterprises have accounted for around 30%, while the share of enterprises within the group of non-technical universities has only been 9%. Nowadays, the share of private enterprises has highly increased within the group of non-technical enterprises, too. Overall, hypothesis 4b is largely confirmed in terms of patents by above findings.

10.3. Proximity Patterns concerning the three different Groups of German Universities

This subchapter now highlights proximity patterns concerning again the three different groups of German universities, in order to prove whether the elite, technical or medical universities are more likely to cooperate with supra-regional partners compared to their counterparts or the other way round. Thereby, it is firstly looked at the distribution of the

German university co-authors based on their geographical coordinates. Afterwards, it is illustrated how they are linked to others based on country codes.

However, being aware of the fact that supra-regional cooperation partners are at least as important as regionally located partners, it is further highly interesting to examine which groups of the German universities tend to rather cooperate with partners that are supra-regionally located or not. Thus, in the following, it is proved whether there are significant differences regarding the spatial distribution when the three different German university groups are examined and compared with each other.

The following figure firstly presents an overview of the development of the co-authors of the elite, technical, and medical German universities for 2000 and 2009⁶⁹.

⁶⁹ It is again not reasonable to compare the absolute numbers of the regional and supra-regional located co-authors of each group as they are of different size. Thus, it is interesting to compare how the relation of regionally located to supra-regionally located co-authors has developed over the past ten years.

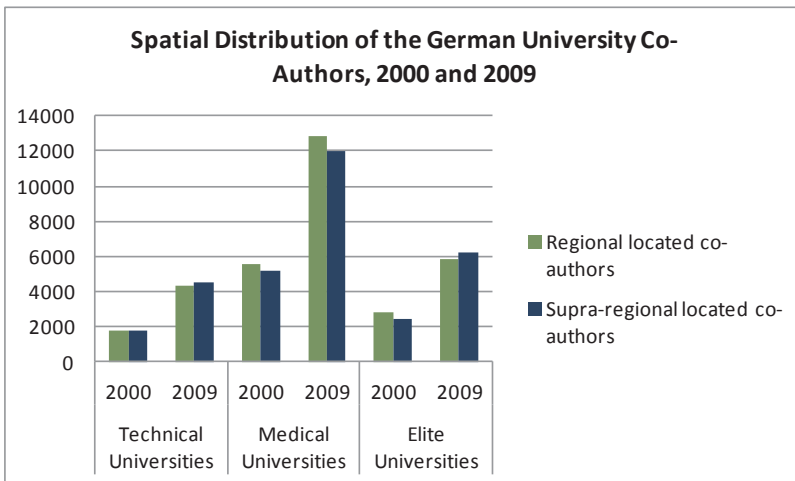


Figure 30: Spatial Distribution of the German University Co-Authors, 2000 and 2009 (own illustration).

It is apparent that within the first time period, the share of regionally located co-authors is always higher than the share of supra-regionally located ones. But, over the past years, this finding has partially turned to the opposite as in 2009 the share of supra-regionally located co-authors is slightly higher regarding the technical and elite universities. But, the medical universities are still more likely to cooperate with regionally located co-authors as above figure illustrates. While regionally located co-authors have increased by around 130% on average from 2000 until 2009, the rise of supra-regionally located co-authors has amounted to around 140% on average during the same time period.

The following table now illustrates the p-values of the three different groups of German universities regarding the spatial distribution of their cooperation partners. Thereby, it has been proved if the variables proximity and type of German university are independent from each other or not. The results are as follows:

Results of the Chi-Square Test regarding the spatial Distribution of the German University Co-Authors, 2000-2009 (P-Values)				
	2000	2003	2006	2009
Elite vs. Non-Elite	0,7831	0,001***	0,001***	0,001***
TU vs. Non-TU	0,001***	0,001***	0,001***	0,001***
Med vs. Non-Med	0,001***	0,001***	0,001***	0,001***
Standard errors: *p≤0,05, **p≤0,01 and ***p≤0,001				

Table 28: P-Values of different German University-Samples, regional versus non-regional Activities, 2000-2009 (own illustration).

As can be seen from the table, the null-hypothesis can be rejected in almost all cases, thus, the German university groups behave differently regarding the spatial distribution of their particular co-authors. It is only the group of elite versus non-elite universities that did not offer any significant results within the first time period. However, it is now interesting to explore which group has tended to cooperate more with supra-regionally located partners.

The following figure now firstly refers to the spatial distribution of the cooperation partners of the elite and non-elite universities from 2000 and 2009:

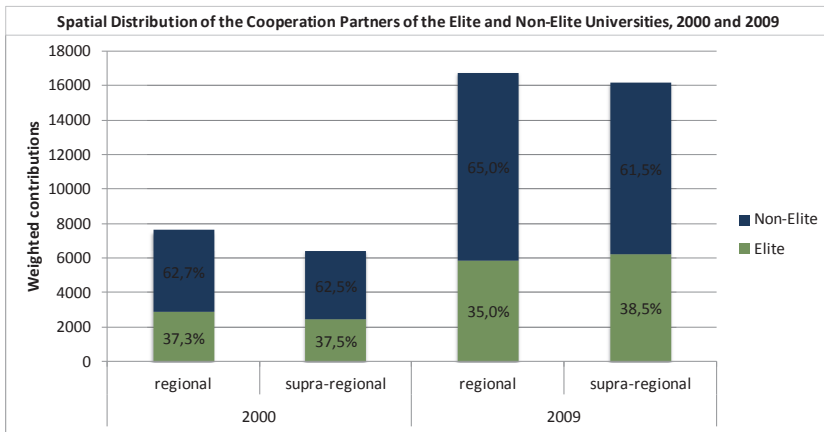


Figure 31: Spatial Distribution of the Cooperation Partners of the elite and non-elite universities from 2000 and 2009, weighted Numbers (own illustration).

As can be seen from the figure, while there are no significant differences between the elite and non-elite universities regarding the spatial distribution of their cooperation partners in 2000, the bars of the last time period illustrate that the elite universities are more likely to cooperate with supra-regionally located partners compared to the non-elite universities. In 2009, 38.5% of the cooperation partners of the elite universities were supra-regional located compared to smaller share (35.0%) that were regional located. The distribution of cooperation partners of the non-elite universities was the other way round. While 61.5% were supra-regionally located, a higher proportion (65.0%) was regional. Hence, above derived hypothesis in this regard can be confirmed for the elite universities.

The following figure shows the spatial distribution of the cooperation partners of the technical and non-technical universities in order to clarify the above results of the chi-square test:

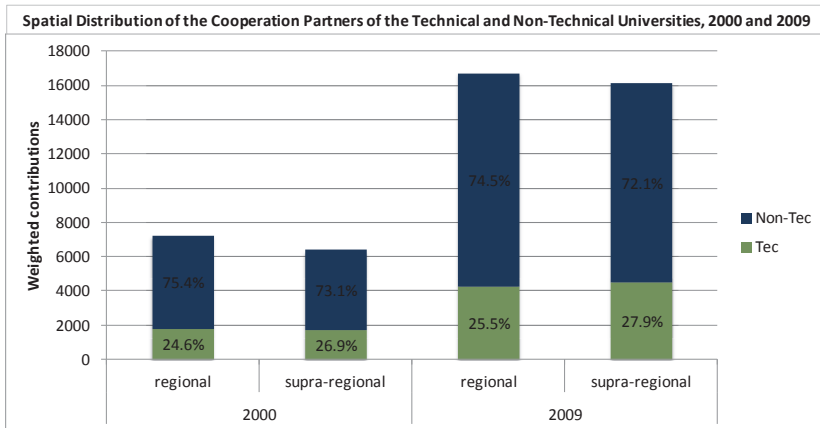


Figure 32: Spatial Distribution of the Cooperation Partners of the Technical and Non-Technical Universities, 2000 and 2009, weighted Numbers (own illustration).

The technical and non-technical universities have offered significant differences regarding the spatial distribution of their cooperation partners in all time periods. Within the first one, it can be seen from the figure that the share of the regional located co-authors of the technical universities was smaller, and the proportion of the supra-regionally located ones was larger compared to the non-technical universities. The same finding holds for the last time period. Thus, above hypothesis can be also confirmed for the technical universities as they were more likely

to cooperate with supra-regionally located partners compared to their counterparts.

Finally, the next table provides information on the spatial distribution of the co-authors of the medical and non-medical universities for 2000 and 2009:

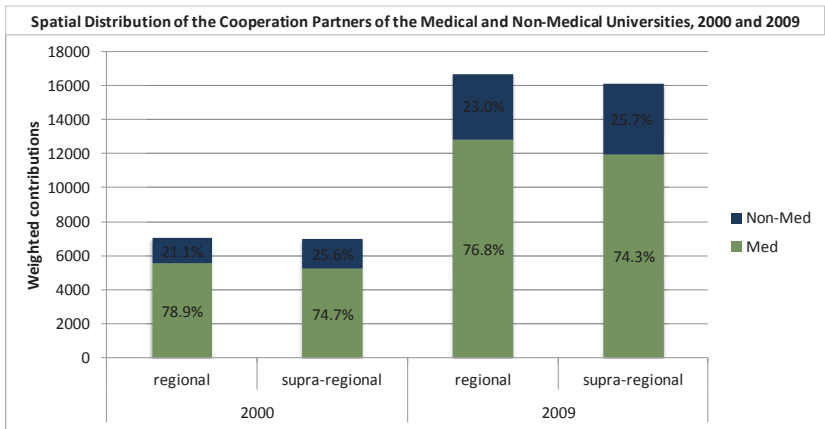


Figure 33: Spatial Distribution of the Cooperation Partners of the Medical and Non-Medical Universities, 2000 and 2009, weighted Numbers (own illustration).

As it holds for the group of technical and non-technical universities, the medical and non-medical ones have also possessed highly significant differences regarding the spatial distribution of their cooperation partners during all the time of assessment. In contrast to the other two groups of German universities, the medical universities were more likely to cooperate with regionally located partners compared to the non-medical universities. This finding counts for both time periods. Thus, the

findings of this PhD thesis also confirm the hypothesis that due to the important role of trust in medical knowledge collaborations, proximity patterns still highly matter.

Up to this point, it is well known that the elite and the technical universities have rather tended to cooperate with supra-regionally located partners compared to their counterparts. In contrast, the medical universities have been more likely to cooperate with regionally located partners than the non-medical universities. Hence, hypothesis 4c is entirely confirmed by above findings. Further, as already discussed, the share of supra-regionally located universities could have been increased most, while the share of supra-regionally located enterprises and research institutes has even decreased over the past ten years. Last, it is also known that the technical universities have more likely cooperated with enterprises and the medical universities have been more engaged with research institutes.

Keeping this in mind, it is very likely that the elite and technical universities have been rather engaged with supra-regionally located enterprises, and the medical with regionally located research institutes and universities. Hence, it is further examined which institutional cooperation partners have been rather regionally or supra-regionally located concerning again the different functional orientation of the German universities. In order to shed light on this line of thought, the

chi-square test is applied again. The test has been made three times, for the enterprises, for the research institutes as well as for the universities.

The next table refers to all interactions with enterprises. The results are as follows:

Results of the Chi-Square Test regarding the spatial Distribution of the Enterprises, 2000-2009, P-Values				
	2000	2003	2006	2009
Elite vs. Non-Elite	0,18176	0,00677**	0,24178	0,0562*
TU vs. Non-TU	0,74948	0,69506	0,00415**	0,03148*
Med vs. Non-Med	0,01272**	0,27837	0,16645	0,05445*
Standard errors: *p≤0,05, **p≤0,01 and ***p≤0,001				

Table 29: Results of the Chi-Square Test regarding the spatial Distribution of the Enterprises, 2000-2009, P-Values (own illustration).

First of all, the results of the spatial distribution of the enterprises are displayed. As can be seen from the table, there are no consistent significant results. The group of elite and non-elite universities has possessed differences in their particular distributions in 2003 and in 2009, the group of technical and non-technical universities within the last two time periods, and finally, the group of medical and non-medical within the first and within the last time period. However, in 2003 and 2009, the elite universities have cooperated more often with supra-regionally located enterprises compared to their counterparts. Hence, while the elite and non-elite universities have not offered any significant results regarding the overall distribution of their cooperation partners, the elite universities have been indeed more engaged with supra-

regionally located enterprises than the non-elite universities. In 2006 and 2009, it has been the non-technical universities that have rather cooperated with supra-regionally located enterprises. Thus, above hypothesis has to be rejected in this regard. The technical universities have been more engaged with enterprises and with supra-regionally located cooperation partners, but not with supra-regionally located enterprises. Finally, in 2000 and 2009, the non-medical universities have tended to rather publish with supra-regionally located enterprises compared to the medical universities, even though the difference has become smaller. Thus, above drawn hypothesis can be confirmed in this regard.

Further, the following table shows the results of the chi-square test regarding the spatial distribution of the research institutes from 2000 until 2009.

Results of the Chi-Square Test regarding the spatial Distribution of the Research Institutes, 2000-2009, P-Values				
	2000	2003	2006	2009
Elite vs. Non-Elite	0,12035	0,56401	0,48587	0,49741
TU vs. Non-TU	0,09906	0,001***	0,001**	0,91921
Med vs. Non-Med	0,001***	0,04826*	0,001***	0,00873**
Standard errors: *p≤0,05, **p≤0,01 and ***p≤0,001				

Table 30: Results of the Chi-Square Test regarding the spatial Distribution of the Research Institutes, 2000-2009, P-Values (own illustration).

At the first glance, it is obvious that the elite and non-elite universities have never possessed any differences in their spatial cooperation

manner with regard to the research institutes. But as they have not possessed any significant differences regarding the overall distribution of their cooperation partners, the finding is not too surprising in this regard. Besides, the results of the chi-square test of the technical and non-technical universities are highly significant in 2003 and 2006, and the group of medical and non-medical universities has had consequently significant results regarding their particular cooperation behaviour. In 2003 and 2006, the technical universities have cooperated more often with supra-regionally located research institutes than the non-technical universities, even though the overall share of the supra-regionally located research institutes has highly decreased from 2003 until 2006. Even though the technical universities have been overall more engaged in collaborations with enterprises, they have been more likely to cooperate with supra-regionally located research institutes compared to the non-technical universities. Finally, it has been the medical universities that have rather cooperated with regionally located research institutes. Thus, above hypothesis can be confirmed in this regard. The medical universities have not only been more engaged with regionally located partners, they were also more likely to cooperate with regionally located research institutes.

The last table illustrates the results of the chi-square test according to the spatial distribution of the universities from 2000 until 2009.

Results of the Chi-Square Test regarding the spatial Distribution of the Universities, 2000-2009, P-Values				
	2000	2003	2006	2009
Elite vs. Non-Elite	0,11752	0,001***	0,001***	0,001***
TU vs. Non-TU	0,001***	0,001***	0,001***	0,001***
Med vs. Non-Med	0,001***	0,001***	0,001***	0,001***
Standard errors: *p<0,05, **p<0,01 and ***p<0,001				

Table 31: Results of the Chi-Square Test regarding the spatial Distribution of the Universities, 2000-2009, P-Values (own illustration).

It is very apparent that almost all results have been highly significant regarding the spatial distribution of the universities. Thereby, the elite universities have cooperated more often with supra-regionally located universities compared to the non-elite universities. Further, the technical universities have had more linkages to supra-regionally located universities than the non-technical universities. Thus, above derived hypothesis has to be rejected in this regard. Last, the medical universities have cooperated more often with regionally located universities than the non-medical universities so that the hypothesis is to be confirmed.

Up to this point, it is well known where about the German university co-authors are located. Further, it has also been shown how the German university cooperation partners have been institutionally located. Thereby, all explorations have been done for the three different German university groups in order to demonstrate differences in their particular cooperation behaviour. But, in this context, it is only differentiated whether they are regionally or supra-regionally located; thus,

information on the exact localisation of the German university co-authors is still missing. In the following, the geographical distribution of the German university co-authors depending on where they are coming from is presented; thus, it is a country-based analysis.

However, before coming to the three different groups of German universities, the following figure firstly shows the overall distribution of the German university co-authors according to their country codes. Thereby, due to the fact that the co-authors have come from around 140 different countries, six different groups have been developed as described in *chapter six*.

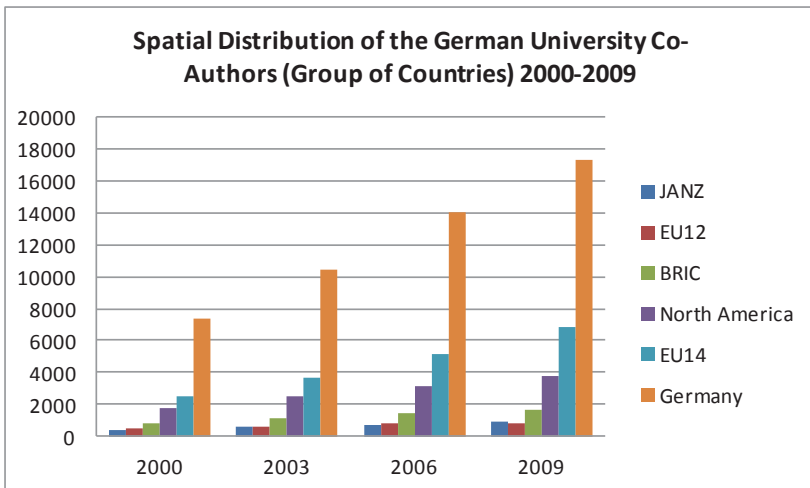


Figure 34: Spatial Distribution of the German University Co-Authors (Groups of Countries), weighted Numbers, 2000-2009 (own illustration).

As can be seen from the figure, each group has experienced high growth rates regarding their linkages to the German universities. It can be observed that the group of Germany is especially strong during all time periods, followed by the group of EU14 and North America. Besides, the number of cooperations to the other three groups of countries is still comparable low. However, the strongest increase of cooperations from 2000 until 2009 can be found within the group of the EU14 followed by Germany and JANZ. North America has occupied fourth place, BRIC fifth place, and finally, the EU12 sixth place regarding the increase of linkages to the German universities. The countries of the EU12 can rather be neglected as they even occupy last place in 2009, even though the group includes much more countries compared to the groups of JANZ and BRIC, and furthermore, they are much more closer located to the German universities. Thus, the groups of the EU14, North America, JANZ as well as the emergent countries of BRIC remain to be explored in more detail. First of all, it is shown whether the elite and non-elite, the technical and non-technical as well as the medical and non-medical German universities have rather cooperated with partners coming from North America or from EU14. A second step further proves if the three different groups of German universities have more likely cooperated with partners coming from North America, or with partners coming from BRIC or JANZ. The same analysis is further done for EU14 compared to BRIC and JANZ, too. The chi-square test is again used to observe possible differences in the particular distributions of the three

different German university groups. All tests are conducted for the first and the last time period.

The following table now shows if there are significant differences among the three groups of German universities regarding their linkages to cooperation partners coming from North America compared to those coming from EU14.

Results of the Chi-Square Test regarding the spatial Distribution, North America vs. EU14, 2000 and 2009, P-Values		
	2000	2009
Elite vs. Non-Elite	0,83582	0,37861
TU vs. Non-TU	0,00866**	0,52326
Med vs. Non-Med	0,03038*	0,00441**
Standard errors: * $p \leq 0,05$, ** $p \leq 0,01$ and *** $p \leq 0,001$		

Table 32: Results of the Chi-Square Test regarding the spatial Distribution, North America vs. EU14, 2000 and 2009, P-Values (own illustration).

While the group of elite and non-elite universities does not possess any significant results in this regard, the technical and non-technical universities have at least a significant result in 2000 and the medical and non-medical universities even in both time periods. Thereby, the technical universities have rather cooperated with partners coming from the EU14 compared to the non-technical universities, and the medical universities have more likely cooperated with partners from North America compared to their counterparts.

However, the following table illustrates the results of the chi-square test regarding the spatial distribution between the occurrence of co-authors coming from North America compared to BRIC and JANZ for each group for 2000 and 2009:

Results of the Chi-Square Test regarding the spatial Distribution, North America vs. BRIC & North America vs. JANZ, 2000 and 2009, P-Values				
	North America vs. BRIC		North America vs. JANZ	
	2000	2009	2000	2009
Elite vs. Non-Elite	0,001***	0,001***	0,61871	0,73268
TU vs. Non-TU	0,001***	0,001***	0,01566**	0,001***
Med vs. Non-Med	0,001***	0,001***	0,10803	0,03435*
Standard errors: *p≤0,05, **p≤0,01 and ***p≤0,001				

Table 33: Results of the Chi-Square Test regarding the spatial Distribution, USA vs. BRIC & USA vs. Janz, 2000 and 2009, P-Values (own illustration).

As can be seen from the table, the results of the chi-square test regarding the spatial distribution of the German university co-authors, either being in North America located or in BRIC, are for each group and for both years highly significant. Thereby, the elite universities have had more cooperation partners from North America, the technical universities have more often cooperated with partners from BRIC, and finally, the medical universities have had also more linkages to North American partners compared to their counterparts. These findings hold for both time periods. Regarding the collaborations with partners from North America compared to those coming from JANZ, the group of elite and non-elite universities does not offer any significant results. The technical and non-technical universities have differences in their data sets in both time periods, and the medical and non-medical universities

show differences at least within the last time period. It is the group of technical universities which has rather cooperated with partners coming from JANZ compared to the non-technical universities, and it is the medical universities that have had also more linkages to North America than the non-medical universities.

Finally, the following table shows the results of the chi-square test regarding the spatial distribution of co-authors coming from the EU14 compared to co-authors coming from BRIC and from JANZ for 2000 and 2009:

Results of the Chi-Square Test regarding the spatial Distribution, EU14 vs. BRIC & EU14 vs. JANZ, 2000 and 2009, P-Values				
	EU14 vs. BRIC		EU14 vs. JANZ	
	2000	2009	2000	2009
Elite vs. Non-Elite	0,001***	0,001***	0,61871	0,88805
TU vs. Non-TU	0,001***	0,001***	0,34899	0,001***
Med vs. Non-Med	0,001***	0,001***	0,69745	0,57447
Standard errors: *p≤0,05, **p≤0,01 and ***p≤0,001				

Table 34: Results of the Chi-Square Test regarding the spatial distribution, EU14 vs. BRIC & EU14 vs. JANZ, 2000 and 2009, P-Values (own illustration).

Again, the results of the chi-square test regarding the spatial distribution of the German university co-authors coming from the EU14 compared to those who are coming from BRIC are highly significant for each group and for both years. In this context, the elite universities have had more cooperation partners which have come from the EU14, the technical universities have more often cooperated with partners from BRIC, and finally, the medical universities have had also more linkages to the

European partners. These findings hold for both time periods. Regarding the cooperations with partners from the EU14 compared to those coming from JANZ, the groups of elite and non-elite as well as the medical and non-medical universities did not offer any significant results. It is only the group of technical and non-technical universities that have had significant differences in their particular data sets regarding the spatial distribution of their co-authors. Within the last time period, the technical universities have cooperated more often with partners coming from JANZ than from EU14 compared to the non-technical universities.

To sum up, the elite and non-elite universities possess less significant values regarding the spatial distribution of their cooperation partners depending on where they are coming from. However, the elite universities have been more likely linked to partners coming from North America and EU14 than from BRIC. In contrast, the technical and non-technical as well as the medical and non-medical universities have frequently occurring significant values in this regard. The technical universities have cooperated more often with partners coming BRIC and JANZ than from North America and EU14 compared their counterparts, while the medical universities have had more likely linkages to partners from North America and EU14 than from BRIC and JANZ compared to the non-medical universities.

These important findings will be further discussed within the last chapter regarding the final conclusion, reflection and policy recommendations.