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by Mirja Meyborg

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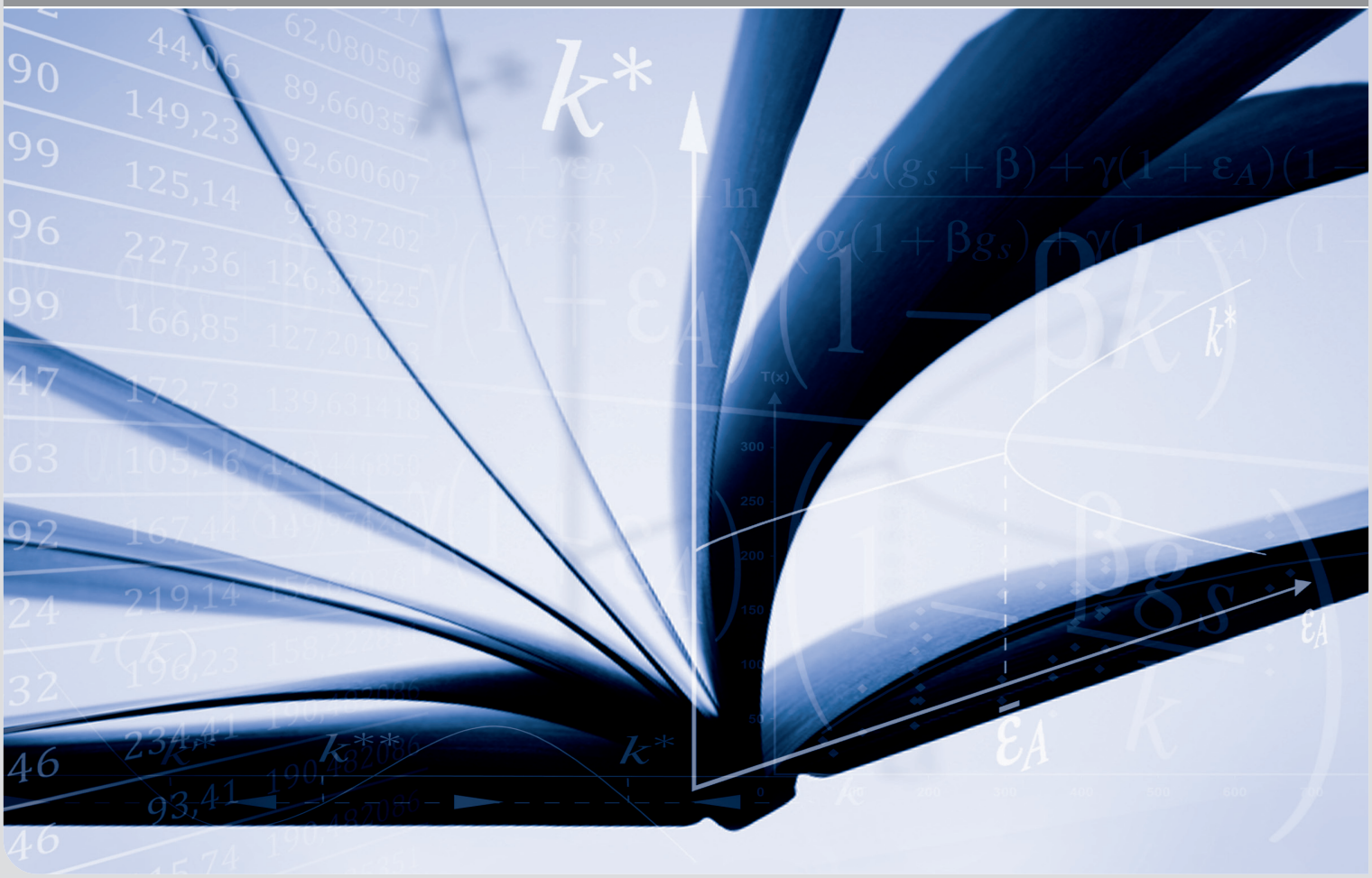

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The Impact of West-German Universities on Regional Innovation Activities – A Social Network Analysis

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Abstract:

In recent years, it has widely been accepted that the ability to create, access and use knowledge and technology is becoming a fundamental determinant of long-term development and competitiveness. Thus, it is not surprising that universities have increasingly become involved in economic development and are often believed to play a key role in regional economic development. This paper firstly examines how far all West-German universities are already involved in close network collaborations. Second, it demonstrates how many distinct linkages 45 chosen West-German universities already possess within the innovation network, and third, to what extent they are already needed as a link in the chains of contacts. Thereby, special attention is given to the eight West-German elite-universities. We basically found out that university interactions, especially university-enterprise networks, become much more important over the last 20 years, as their cooperation activity strongly increased over time. Besides, their distinct linkages to other actors as well as their importance as an intermediary within the innovation network highly increased over the last decade, too; this especially holds for the eight West-German elite universities.

Keywords: Human Capital, Economic Growth, Social Network Analysis, Patent Analysis, Patent Collaboration, Network Interaction, West-German University, Elite-University

1 Introduction

In recent years, macroeconomic theory has lain renewed attention on university research in driving economic growth (see Romer 1990), hence, universities have increasingly become involved in economic development and are often believed to be one of the conditions for successful regional economic development (see Miner et al. 2001 and Etzkowitz 1989, 2000). Universities are also believed to play a more active role within knowledge production and transfer, as Godin and Gingras (2000) discovered an increasing trend of cooperation activity between universities and other institutions over time. Besides, Jaffe (1989) discovered that businesses located in close proximity to university research generate a greater number of patents.

The aim of this paper is now to explore and demonstrate the role of West-German universities within innovation networks. The innovation network itself is constructed through patent data provided by the EPO[1] Worldwide Patent Statistical Database Version October 2010 (PATSTAT) and is illustrated through a Social Network Analysis (SNA) (see chapter three). Thereby, the overall activity and structure of university networks is examined, as well as the amount of linkages they possess within the innovation network, and to what extent they are already needed as a link in the chains of contacts.

In order to achieve the objective drawn above, the paper is structured as follows. Section two deals with the theoretical background, illustrating the relevance of technology and knowledge advance regarding sustainable regional economic growth rates, highlighting the importance of human capital originating from universities. Section three provides the methodology and the data set of the analysis. Here, the SNA is illustrated. By means of this analysis, the degree to which the West-German universities are integrated into the innovation network is presented. Thereby, the paper is divided into three parts. First, the overall activity and structure of all West-German university networks are explored over a time period from 1990 until 2010. For the second and third step of analysis, we chose 45 West-German universities, all of them which have more than 10.000 students, are public funded and which have the right to award doctorates. Here, all distinct linkages of the 45

[1] European Patent Organisation

chosen West-German universities within the innovation network are illustrated and their importance as an intermediary within the innovation network. Thereby, special attention is given to the eight West-German Elite-Universities[2]. Both analyses are carried out for a time period from 1999 until 2010. Section four is based upon the empirical results of the conducted analyses, while section five presents the conclusion of this paper.

2. Theoretical Background

It is not a new phenomenon that economists appreciate the importance of technological progress in order to retain sustainable economic growth rates. Adam Smith (1776) already referred in his book 'An Inquiry into the Nature and Causes of the Wealth of Nations' to the advantages of technical advance through his famous description of productivity improvement in the making of pins. Later on, it was Schumpeter (1911) who pointed out that sustainable economic growth rates can be achieved through new technology and innovation. But, due to the limited mathematical capabilities applied on economies at this time, his work has not been displayed in a formalised way. Even though his work has not been considered for further developments of innovation theories for a long time, he has later on strongly influenced all further innovations theories. Elaborating upon the question of the relationship between knowledge generation and economic growth, it is not surprising to go back to Solow's neoclassical growth model. Solow (1956), for example, was able to approximate the relevance of technical advance for economic growth by illustrating that the two factors, namely labour and capital, of the classical Cobb-Douglas production function do not fully explain economic growth in the USA. For him, a third factor, namely the input of technology, was essential for sustainable economic growth. Of course, also his traditional theory of economic growth does not yet clearly measure the role of human capital. Augmented theorizing on economic growth went beyond the limits of exogenous technological innovation and highlighted the importance of the accumulation of human capital as a determinant of economic growth (see Romer 1986, Lucas 1988 and Grossman

[2] The eight West-German Elite-Universities were announced in 2006 and 2007 as a result of a German initiative to enhance higher education and research with special aid programmes. The aim of this initiative is to enhance the scientific landscape in Germany in the long run and to remain competitive worldwide. For further information see http://www.bmbf.de/de/1321.php, 2011/03/02.

and Helpman 1991), thereby, Lucas (1988) was one of the first researchers who considered human capital as an alternative to technological process to improve economic growth. Traditionally, education and learning by doing were considered as main sources of human capital, and, for that reason, many growth models have introduced these factors in their models. Regarding Romer (1996), countries need to understand the importance of technical advance, therefore, building up a knowledge-based economy to retain stable economic growth rates. Thus, it has widely been accepted that the ability to create, access and use knowledge and technology is becoming a fundamental determinant of long-term development and competitiveness. So, it is not surprising that in times of globalization universities have increasingly become involved in economic development and are often believed to play a key role in regional economic development (see Miner et al. 2001 and Etzkowitz 1989, 2000). Besides, Etzkowitz (1989, 2000) argues that the traditional university whose primary objective is research and teaching has been displaced by increasingly "entrepreneurial university" which generates revenue and enhances its political viability through technology transfer, the commercial transfer of innovation, the generation of spinoff companies, and direct engagement in regional development. Recent work on local economic development has further focused on network building due to the fact that networks facilitate economic growth. Thus, networks are seen as a kind of construction through which productive resources, social values and economic interests can freely circulate (see Glückler (2007)). Also Breschi and Lissoni (2003) remarked that networks that include members from more than one company spread knowledge freely among the various countries. Hence, as knowledge diffusion between social actors and firms is critical for innovation and growth, it is not surprising that the literature on collaborative research networks and their impact on knowledge diffusion and innovation have increased greatly, too.

3 Methodology and Data of Analysis

In order to give insight into the assumption drawn above, we apply the Social Network Analysis (SNA). It can be generally illustrated how countries, regions, firms or individuals cooperate with each other, thus, demonstrating the development of the regional, national

or international connectivity. So, the SNA method is designed to "[…] discover patterns of interaction between social actors in social networks" (Xu and Chen 2005). It implements this by revealing the overall network structure, as well as that of subgroups within the network, then examining the patterns of interaction among these various groups. It is an interdisciplinary methodology developed mainly by sociologists and researchers in social psychology. Later on, the SNA has been further extended in collaboration with mathematics, statistics, and computing. Especially advances in computer technology, availability of computer databases and the emergence of several software packages like Ucinet[3], Pajek[4] or NetDraw[5] has allowed for the construction and analysis of scientific collaboration networks. All this made it attractive also to other disciplines like economics or industrial engineering as it now developed to a formal analyzing tool (see Cantner and Graf 2006). So, the SNA has quickly developed over the last two decades as the fruitful combination of theoretical concepts with the numerous application possibilities has attracted many other research disciplines (see Wassermann and Faust 1994).

The networks illustrated by the SNA are mostly described by a graph[6], consisting of nodes joined by lines, i.e. the SNA treats individuals as nodes and the relationship between individuals as linkages (see Wasserman and Faust 1994). In the following, it is illustrated how a network can be constituted:

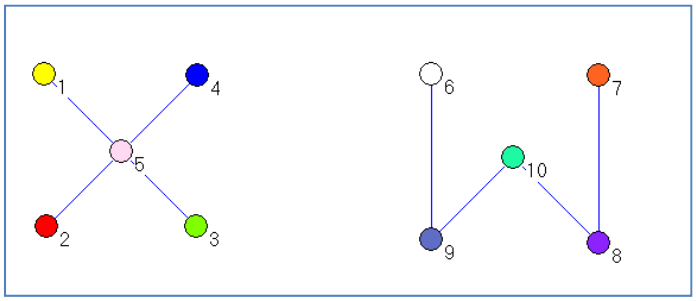

Figure 1: Star- and Line-Networks.
Source: Nooy et al., 2005, S. 125.

[3] See http://www.analytictech.com/ucinet/, 2010/10/21
[4] See http://pajek.imfm.si/doku.php?id=start, 2008/05/23
[5] See http://www.analytictech.com/netdraw/netdraw.htm, 2011/10/05
[6] See Wassermann and Faust (2008): Social Network Analysis; Cambridge University Press for further information on graph theory.

Figure 1 shows two possible forms of a network. On the left side, a so-called star network is pictured. Such a network is characterised by only one central node (node 5) which is linked to all other nodes (nodes 1 to 4). Thus, node 5 possesses four distinct linkages to other actors, whereas nodes 1, 2, 3 and 4 have just one distinct linkage to node 5. In this context, it is very feasible to determine which node the most centralised one is, namely node 5. On the right side, a so-called line-graph is illustrated. In this case, nodes 8, 9 and 10 have two distinct linkages each, whereas nodes 6 and 7 possess only one linkage each. Hence, it is now much more difficult to find out which node is the most centralised one. Therefore, network characteristics have to be used in order to find out which actor might be the most linked and centralised one within a network (see Nooy et al., 2005). Thereby, the degree of an actor is important as this measure implies the simplest possibility to determine the actors' centrality. Thereby, it is defined that central actors must be the most active in the sense that they have the most linkages to other actors in the network. Degree centrality is, thus, expressed through $C_d = d_i$, where C_d is degree-centrality and d_i the number of linkages (degree). The higher the degree-centrality the more active is the actor within the network (see Wassermann and Faust, 2008). Second, the value of betweenness-centrality measures the extent to which an actor is needed as a link in the chains of contacts, facilitating the spread of information through the network. Hence, this measure takes into account the connectivity of the node's neighbours, giving a higher value for nodes which bridge clusters (see Nooy et al., 2005). The value of betweenness-centrality is defined as:

$$C_b(n_i) = \sum_{j<k} g_{jk}(n_i) / g_{jk}$$

g - number of actors in the network

n_i - actor$_i$

C_b - betweenness-centralitiy

As aforementioned, we intend to firstly demonstrate how strong the West-German universities are generally linked to other actors within the innovation network. Thus, we filtered out all West-German patents which were filed at the EPO from 1990 until 2010 and classified them in either being a university, a research institute, an enterprise or a private person. So here, we get a first impression of the development path of the networking activity of all West-German Universities, and with whom exactly they are collaborating with. In order to formally analyse our networks of study, we use the concepts of degree- and betweenness-centrality. By means of both values, it is now demonstrated how far the West-German universities are integrated within the innovation network. On the one side, it is shown how many linkages to other actors exist, and on the other side, it is demonstrated to what extent the West-German universities already bridge clusters, i.e. how important they are as intermediary within the innovation network.

As aforementioned, for all analyses patent data are the basis. A patent is a temporary monopoly, issued by an authorized governmental agency. It grants the right to exclude anyone else from the commercial production or use of a specific new device, apparatus, or process. This right is given to the inventor of this innovative device or process after an examination that pays attention to the novelty of the claimed item and its potential utility. Of course, the inventor can assign the right to use the patent to somebody else, usually to its employer, a corporation, or sold to or licensed for use by somebody else (see Griliches, 1990). Patent statistics are a crucial tool for scientists, statisticians and policy makers interested in innovation and intellectual property rights (IPR), as they measure the successful output of R&D efforts (see Carpenter and Narin 1983, Griliches 1984, Schmoch et al. 1988, and Grupp 1998). As innovation-indicator, patents refer to technological innovations, mirroring a part of the existing technological knowledge stock of a sector, region, or economy (see Frietsch et al., 2008). This study concentrates on patents which are filed at the EPO or went through the Patent Cooperation Treaty (PCT) filing process at the World Intellectual Property Organisation (WIPO). In doing so, it is assured that we deal with patents with a high-expected economic value (see Frietsch et al., 2008). Moreover, we further concentrate on co-applicant networks, i.e. we only consider networks of applicants, not of inventors. A connection between two actors is existent, if two applicants are on the same patent. Besides, one challenge was to filter out all West-German university patents, as in Germany the so called ‘Hochschullehrerprivileg’ prevailed until February 2002. This means

that employees of universities (professors or scientific assistants) could freely dispose of their intellectual property rights, and thus appear as patents applicants (see Meyer-Krahmer and Schmoch 1998). In order to filter out all university patent applications, we had a look at the academic title, and check all patent applications with professors as applicants. Hence, we could determine whether the professor really works at universities, and to which university they are really affiliated to.[7]

4 Empirical Results

As this paper basically explores the role of West-German universities within innovation networks, we firstly present a general overview of social network interactions of all West-German universities compared to all other actors. All other actors imply enterprises, private persons or research institutes. The following table shows exactly this development from 1990 until 2010.

Social Network Interaction of West-German Universities compared to other Actors, 1990-2010 (absolute numbers)						
	Enterprise		Private Person	Research Institute	University	
1990-1992	2100		508	447	**41**	
1993-1995	2290		1140	74	**75**	
1996-1998	2108	**x2**	863	234	**90**	**x10**
1999-2001	2933		1247	329	**164**	
2002-2004	3439		1036	314	**196**	
2005-2007	4300		939	472	**387**	
2008-2010	*1311*		*370*	*153*	*193*	

Table 1: Social Network Interaction of West-German Universities compared to other Actors, 1990-2010 (absolute numbers), Source: Patstat.

Before coming to the interpretation of the results, we have to note that the last time period is a kind of special, as you can observe the incredible strong decrease of social network interactions within all groups. This is due to the incompletion of the patent-data within this last time period, as we work with the PATSTAT Version October 2010 and as a patent will be

[7] This proceeding is also done by Meyer-Krahmer and Schmoch 1998.

yet disclosed after 18 months. Nevertheless, this last time period still illustrates a good trend or prospect for all distinct analyses.

Coming now to the results, it is obvious that the university networks continuously increase over time. From the fifth to the sixth period, their network collaborations even rise by around 100%. Of course, the absolute number of networks of the enterprises is obviously much higher. But, their number of networks just doubled from the first to the sixth period, whereas the university networks even increase tenfold. The development of the networks of the research institutes and private persons is quite unsteady and not as eye-catching as the other two network developments. Private persons could at least increase their patent collaborations over time, whereas the research institutes do not even make it to increase their networks from the first to the last, respectively sixth, period. In all, university interactions seam to become a much more important weight. But with whom do the universities mainly collaborate with? The next table gives now the answer of this question.

Social Network Interaction of West-German Universities, 1990-2010 (absolute number)					
	University - Enterprise	University - University	University - Private Person	University - Research Institute	Aggregated Univesity Networks
1990-1992	13	4	22	2	41
1993-1995	56	0	19	0	75
1996-1998	29	4	43	14	90
1999-2001	65	15	56	28	164
2002-2004	104	28	31	33	196
2005-2007	182	52	30	123	387
2008-2010	*109*	*22*	*13*	*49*	*193*

Table 2: Social Network Interaction of West-German Universities, 1990-2010 (absolute number), Source: Patstat.

We now see how often the universities interact with the other three actors, namely enterprises, research institutes and private persons, and, of course, with universities themselves. As we can observe from the table, the universities most often interact with enterprises and research institutes, and to a lesser extent with other universities and private persons. University – enterprise interactions increase by around 300% from the fourth to the sixth period. As these linkages are also the most in absolute numbers, we can conclude that university – enterprise networks get much more important over the last decade. Also university – research institute and university - university interactions increase especially

from the fourth to the sixth period, but their absolute numbers regarding network interactions remain relative small. University – private person networks does not seem to play a major role at all. To sum up, a strongly growing importance of universities in innovation networks can be observed, especially regarding university – enterprise network interactions.

Now the degree-centrality of the West-German universities is illustrated. First, we show the amount of distinct linkages of the eight West-German elite-universities.

Degree-Centrality of the eight West-German Elite-Universities, 1999-2010

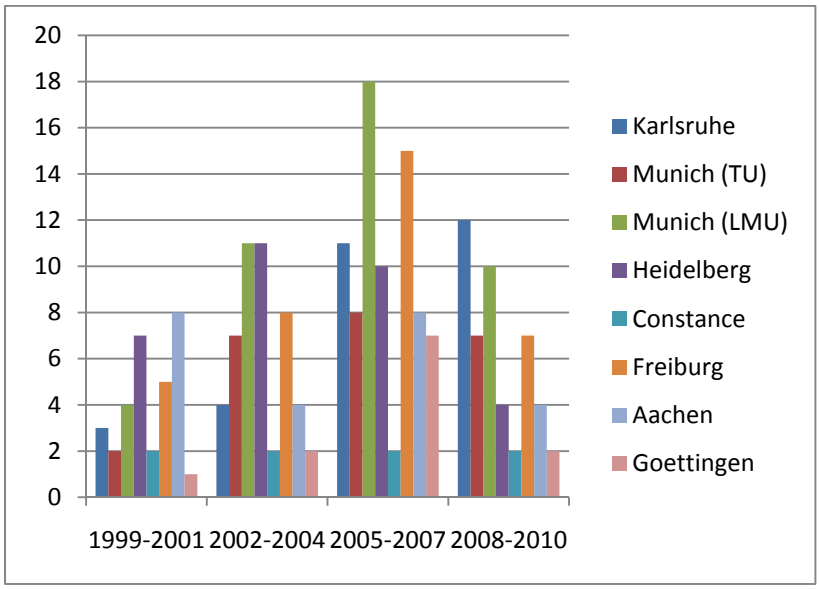

Figure 2: Degree-Centrality of the eight West-German Elite-Universities, 1999.2010 (absolute number) Source: PATSTAT.

Here, we have to note that all eight elite-universities have always been not only active in patent filing but also active in patent collaborations. Throughout all periods, most universities developed quite well, whereas Munich (LMU) and Freiburg saw the most increase of their linkages to other actors. Also Heidelberg, Munich (TU), Aachen and Karlsruhe are very strong. Goettingen gets better over time, but the linkages of Constance remain low. In the case of Constance, we have to note that it is the smallest university (only 10.081 students) compared to the other seven. However, within all periods, the average value of linkages has always been higher than the average one of all other universities. In the time period 2005-2007, the eight elite-universities had all in all around ten linkages per

university, and the others around five linkages per university[8]. To get a better impression of the networking activity of the eight elite-universities, the next figure demonstrates the degree-centrality of the top-five West-German Universities from 1999 until 2010.

Degree-Centrality of the Top-Five West-German Universities, 1990-2010

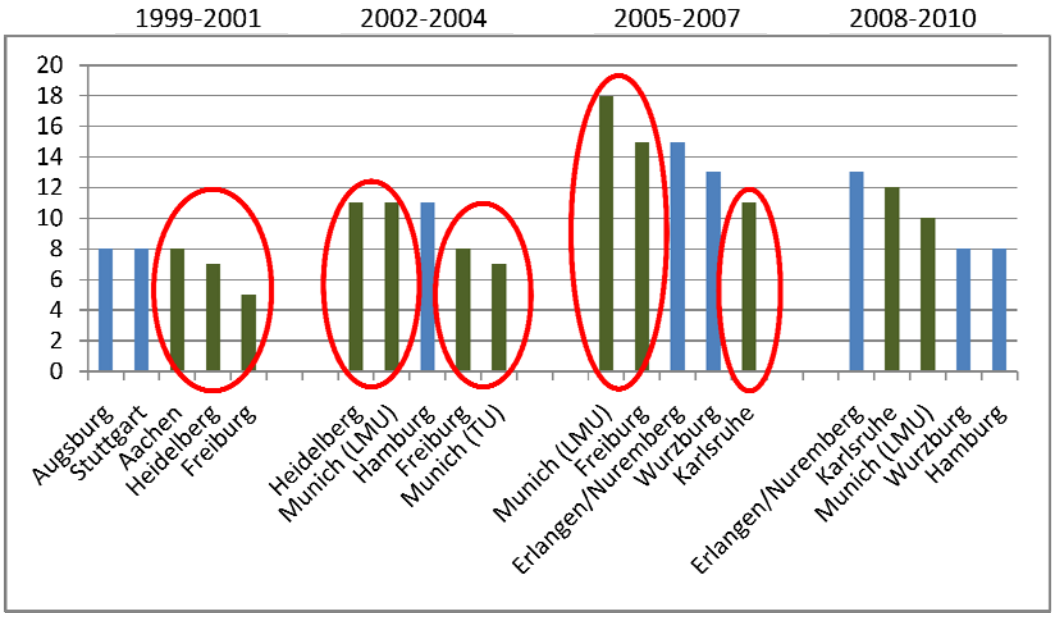

Figure 3: Degree-Centrality of the Top-Five West-German Universities, 1999.2010 (absolute numbers) Source: PATSTAT.

Here, all 45 West-German universities have been subject of study. Within the first period, it is Augsburg, Stuttgart and Aachen who occupy first place regarding their distinct linkages to other actors. Heidelberg and Freiburg did also well, occupying fourth and sixth place. Thus, four of our eight elite-universities are at the forefront regarding their network collaborations. However, Munich (LMU) and Karlsruhe (two further elite-universities) even occupy sixth and seventh place. It is only Munich (TU), Goettingen and Constance which only possess 2 linkages each. Within the second period, it is again Heidelberg (1st) and Freiburg (5th) which are under the top-five. Now, it is also Munich (LMU) which is at the forefront, together with Hamburg (1st). Whereas Munich (TU) just possess two linkages during the first period, it occupies now 5th place, possessing already seven distinct linkages to other actors. So, there are now even four elite- universities which are under the top-five, whereas Karlsruhe and Aachen occupy eights place. Constance and Goettingen have again only two linkages and are rather weak compared to the other West-German elite-universities. Within

[8] Own calculations, Source: PATSTAT

the third period, it is again Munich (LMU), Freiburg and Karslruhe which are under the top-five, followed by Heidelberg (7th) and Munich (TU) and Aachen (8th). The last period is to handle again with care but it is obvious that especially Erlangen/Nuremberg and Wurzburg are really catching up.

Before coming to the betweenness-centrality, the next figure shows the combined degree-centrality of the eight West-German elite-universities compared to the other 37 universities from 1999 until 2001 and from 2008 until 2010.

Combined Degree-Centrality of the eight West-German Elite-Universities compared to the other Universities, 1999-2001 and 2008-2010

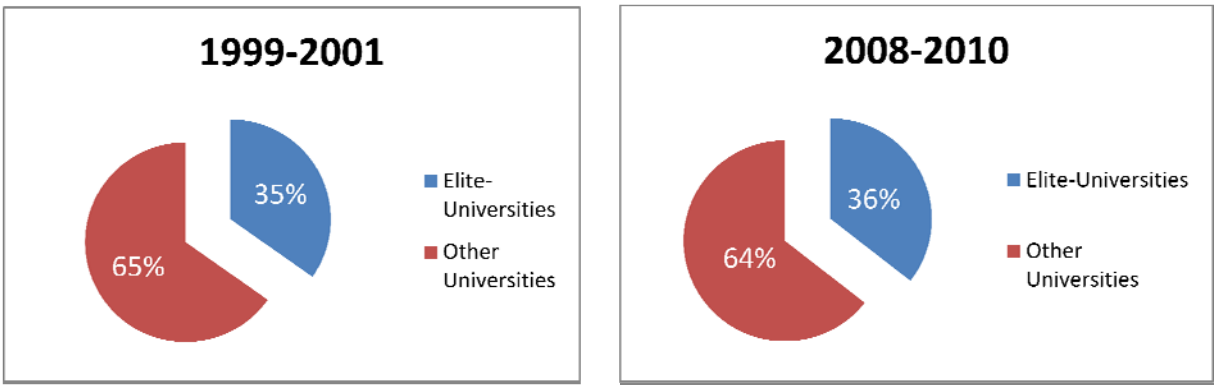

Figure 4: Combined Degree-Centrality of the eight West-German Elite-Universities compared to the other Universities, 1999-2001 and 2005-2007, measured in absolute Numbers of Linkages Source: PATSTAT.

Here, it is very eye-catching that between 1999 and 2001 the eight West-German elite-universities possess 35% of all possible distinct linkages, even though they just make up 17 % of all West-German universities considered. This also holds for the last time period 2008-2010.

Up to this point, we observe a strongly growing emergence of the West-German universities in innovation networks what especially holds for the eight West-German elite-universities. But to what extent are the West-German universities are already needed as a link in the chains of contacts. This is where we come to the value of betweenness-centrality. The following figure firstly shows the value of betweenness-centrality of the eight West-German elite-universities.

Betweenness-Centrality of the eight West-German Elite-Universities, 1999-2010

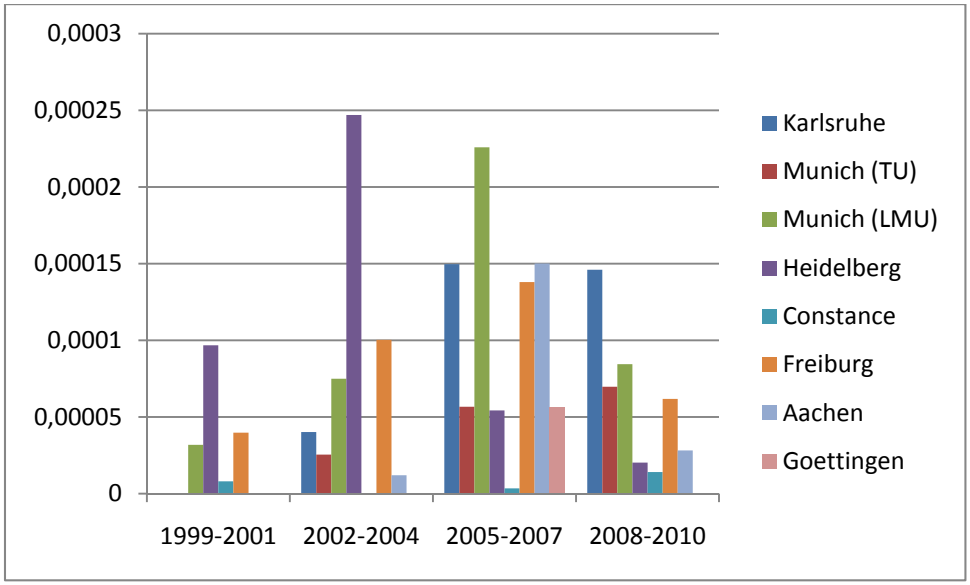

Figure 5: Betweenness-Centrality of the eight West-German Elite-Universities, 1999-2010. Source: PATSTAT.

Here, it is examined how often the eight elite-universities lie on the shortest way between two other actors. As we can see from the table, we still have a quite unsteady development regarding their importance within innovation networks. It is mainly Karlsruhe, Munich (LMU) and Freiburg which experienced a kind of stable development path. Heidelberg saw the most unsteady development, as its value of betweenness-centrality strongly decrease from the second to the third period. Aachen and Munich (TU) experience a quite similar development, even though they develop quite slowly. Goettingen and Constance rather play a minor role compared to the others. To sum up, all eight elite-universities lay at least once on the shortest way between two others, and it is to mention that within the first and second period only 11 (13) universities lay on the shortest way between two others at all.

The next figure now shows again the value of betweenness-centrality of the top-five West-German universities between 1999 and 2010.

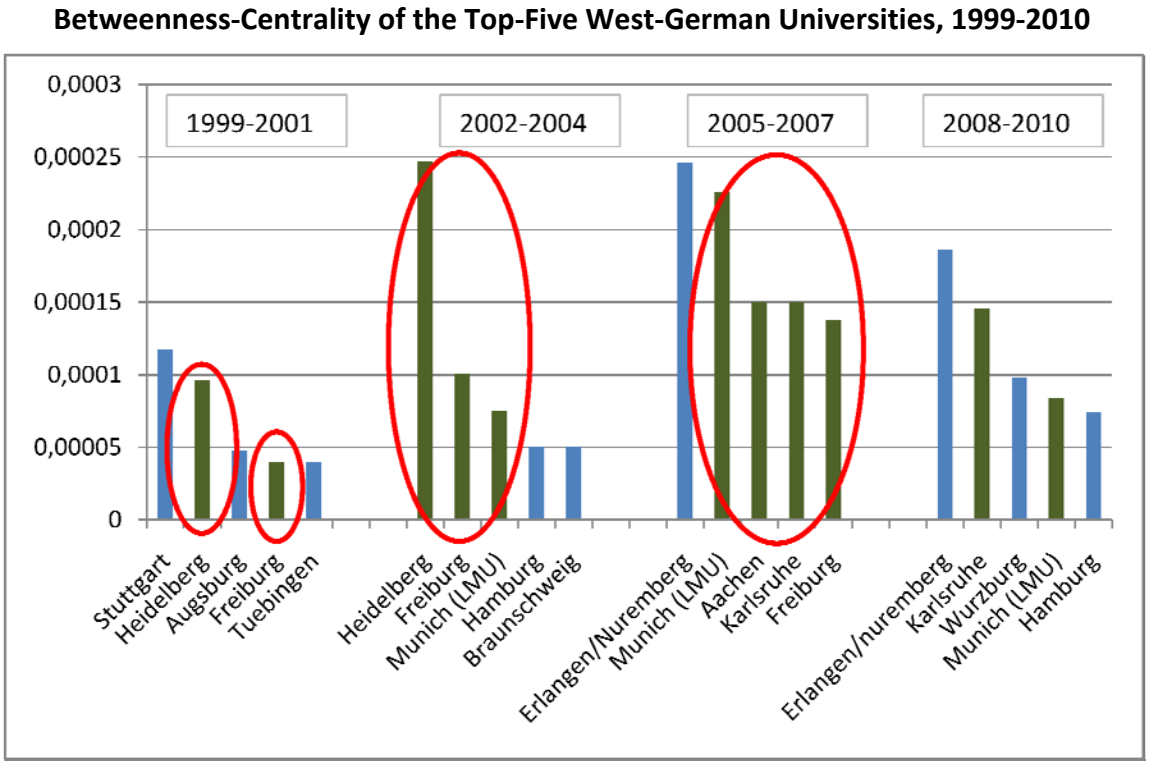

Figure 6: Betweenness-Centrality the Top-Five West-German Universities, 1999-2010. Source: PATSTAT.

As we have seen from the degree-centrality, it is again Stuttgart and Augsburg which are at the forefront within the first time period. However, two of the eight elite-universities are also under the top-five, whereas Munich (LMU) occupies sixth, Constance eighth and Aachen eleventh place. Karlsruhe, Munich (TU) and Goettingen have never lain on the shortest path within this first time period. Between 2002 and 2004, we have again Heidelberg and Freiburg under the top-five, whereas Heidelberg did especially well. Munich (LMU) could advance itself, being now below the top-five. Karlsruhe occupies sixth Munich (TU) seventh and Aachen tenth place. Here, it is also Hamburg and Braunschweig which seem to be very important in the transmission of information through the network. Within the third period, it is striking that we now even have four elite-universities below the top-five, whereas Munich (TU), Heidelberg, Goettingen and Constance can also be seen as an intermediary in the transmission of information. But it is also obvious that Erlangen/Nuremberg and Wurzburg get more and more important, as they are really catching up, especially within the last two periods.

5 Conclusion

The aim of this paper was to examine the role of West-German universities within innovation networks, as universities have increasingly become involved in economic development and are often believed to be one of the conditions for successful regional economic development. So, the importance of the ability to create, access and use knowledge and technology has become a fundamental determinant of long-term development and competitiveness.

Our special attention was given to 45 chosen West-German universities, respectively to the eight West-German elite-universities. First, we had a look at the overall activity and structure of all West-German universities compared to enterprises, research institutes and private persons. Here, we explored that university networks continuously increased over time. From the fifth to the sixth period, their network collaborations even rose by around 100%. Especially striking was the fact that their networks even increased tenfold from 1990 until 2007, whereas the networks of the enterprises just doubled during this time period. Moreover, coming to the networking partners, it is striking that university–enterprise interactions increased most. As these linkages are also the most in absolute numbers compared to the other possible networking partners, we can conclude that university–enterprise networks get much more important over the last decade. Nevertheless, also university-research institute and university-university interactions increased from 1990 until 2007, even though the absolute numbers remained relative small. This overall finding goes in line with Godin and Gingras (2000), as they also found an increasing trend of cooperation activity between universities and other institutions in recent years.

The second and third step of analysis also delivered interesting results regarding the networking activity of the 45 chosen West-German universities and their importance as an intermediary in the transmission of information trough the individual network; this especially holds for the eight West-German elite universities. Regarding their distinct linkages to other actors within the network, it is striking that all eight elite-universities have always been active in networking. Within all periods, the average value of linkages of the eight elite-universities has always been higher than the average one of all other universities. From 2005 until 2007, the eight elite-universities had around 10 linkages per university and

the others only around 5 linkages per university. In all, we observe a strongly growing occurrence of the West-German universities in innovation networks in general, but this finding especially holds for the eight West-German elite-universities. But to what extent are the West-German universities are already needed as a link in the chains of contacts? Here, we have to note that within the first and second period only 11, respectively 13, universities lie on the shortest way between two others at all. Off these universities, four, respectively six, elite-universities have already been important as an intermediary within the innovation network. Between 2005 and 2007, all eight elite-universities lie at least once on the shortest way between two others. Besides, it is striking that we now even have four elite-universities below the top-five, whereas Munich (TU), Heidelberg, Goettingen and Constance can also be seen as an intermediary in the transmission of information. But it is also obvious that Erlangen/Nuremberg and Wurzburg get more and more important, as they are really catching up, especially within the last two periods. The next step of this work is to explore the reasons why which university performs well and why particularly the elite-universities appear to be more engaged in networking activities than the other universities.

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