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# Accessibility of German agglomerations – An approach with non-physical connectivity

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*Abstract:*

*The knowledge economy plays a key role in the spatial development of cities and towns. Options of flexible spatial organization of company locations have influenced business strategies and decision-making in choosing locations. This process establishes complex network economies in which knowledge-intensive firms are linked together in both physical and non-physical ways. Many international knowledge-intensive enterprises have already recognized the advantage of being located around airports and within the corridors between the airport and the city. The shift to the emerging network economy puts a special focus on large polycentric urban agglomerations as centres for efficient face-to-face information exchange. This paper argues that there is a strong theoretical interplay between network economies and agglomeration economies. On empirical grounds we bring together the location behaviour of knowledge-intensive firms with an accessibility analysis based on road, rail and air data. Strong correlations between the global connectivity of intra-firm networks and the accessibility pattern of the German space economy are assumed. We therefore first look at how multi-branch multi-location firms in the knowledge economy develop their intra-firm networks, calculating connectivity values on various spatial scales. Second, we compare these interlocking firm networks with the accessibility patterns of the German space economy. The analytical building blocks are 338 Functional Urban Areas in Germany, including adjacent agglomerations in Germany's neighbouring countries. It is shown that non-physical connection depends on air-access when interaction with international locations is intensive. For interaction within Germany road and rail seem to be the most important modes of access.*

**Keywords:** knowledge economy, Germany, interlocking firm networks, connectivity, accessibility

# 1 Introduction

Although information and communication technology (ICT) has the potential to spread information wherever an access to these technologies can be used, knowledge and knowledge economy tends to concentrate in global centres like global cities (Castells 2000; Florida 2005). Furthermore, the exchange of tacit knowledge requires a physical infrastructure through which interaction is enabled. Besides information and communication technologies in global city research airports are accepted as one of the key driver of globalization and provide access to global networks (Schaafsma 2003: 31).

Thierstein, Goebel and Lüthi (2007) have stated that airport access effects economic performance and leads in order to attract knowledge intensive firms to a spatial configuration which is called the airport region. Moving on, airport corridors as binding element between cities and airports have emerged because knowledge intensive firms demand diverse pools of labour which are to be found in agglomeration, on one hand and high access to global markets provides by airports (Button und Taylor 2000; Haas und Wallisch 2008; Kramar und Suitner 2008; Schaafsma 2009; Schaafsma, Amkreutz und Güller 2008).

Global cities or world cities are linked-up into global networks by ICT and airports. Friedmann (1986) pointed out his hypothesis on world cities and used volume of air traffic to define a hierarchy within those cities. Derudder and Witlox (2005) explored recent data of air traffic and detected the volume of international passengers of these cities' airports is still consistent to hierarchy of world cities or global cities defined by (Sassen 2001; Taylor 2004). Thus, the interplay between physical infrastructure and the position of a City within a linked-up worldwide network seems to be evident.

While Friedmann (1986) analysed physical interaction between cities, Taylor (2004) explored networks of non-physical interactions and used intra-firm networks of advanced producer services as an indicator of linking-up to global networks. The exchange of knowledge affects the strength of both modes of interaction. On the one hand codified knowledge can be transmitted through ICT networks more easily, tacit knowledge, on the other hand, requires the interaction of human capital (Polanyi 1967). Schamp (2003) argues that both tacit and codified knowledge is used simultaneously within innovation processes which in turn lead over to the assumption that physical and non-physical interactions have strong interdependency. Therefore, a spatial entity needs to offer dense infrastructure to get connected to networks of knowledge exchange.

Therefore we analyse correlations between locational behaviour of firms, their intra-firm networks, and the role of physical accessibility. Accessibility is understood as foundation to enter and establish networks of knowledge exchange. Although, these effects are assumed to be relevant for the economic growth and indeed for the locational behaviour of knowledge intensive companies, empirical evidence on how strong they are has not been done, yet (Behnen 2004: 284).

In this article we show that decision-making in choosing locations of firms in advanced producer sector (APS) and High-Tech sector (HT) correlates quite strong the accessibility of spatial entities. As well, we explore differences between both sectors. Although we classify High Tech and APS into knowledge economy, they tend to operate differently by accessing and exchanging knowledge. We assume firstly, that air access keeps important when non-physical connectivity to international location is strong and secondly, that rail and road access has got stronger influence on the regional and national scale of connectivity.

Due to this research question we elaborated the following structure. In section two we give some theoretical insights into the interplay between knowledge economy and accessibility of regions. Chapter three describes the data basis. Followed by chapter four, where the analytical results are shown and finally chapter five comes up with a concluding discussion.

## **2 Knowledge economy and accessibility**

Knowledge is a key driver for the competitiveness of firms and regions. For firms, knowledge is an important resource for innovation, which, in turn, is one of the major drivers of economic growth. According to Polanyi (1967), knowledge can be divided into two major categories: codified and tacit knowledge. Codified knowledge can be applied, expressed and standardized. Hence, it is a marketable good that can easily be distributed over time and space. New information and communication technologies offer the opportunity of increasingly codifying and commodifying knowledge and making it tradable across long distances, which means that codified knowledge becomes more and more de-territorialized. This enables companies to source activities and inputs globally and to benefit from relational proximity and international knowledge spillovers. Tacit knowledge, in contrast, refers to knowledge, that cannot be easily transferred. It comprises skills based on interactions and experiences. Tacit knowledge and personal experience are necessary in order to make use of codified knowledge in creative and innovative processes (Schamp 2003:181).

Since the transfer of tacit knowledge requires direct face-to-face interactions, the findings of Polanyi are not only important for firms but also for regions. Innovative activities have been shown to be highly concentrated in a minority of urban regions (Simmie 2003). The main reason why these regions play an important role in the supply of knowledge is that firm networks benefit from geographical proximity and local knowledge spillovers. Malecki (2000) describes this aspect as the “local nature of knowledge” and highlights the necessity to accept knowledge as a spatial factor of competition:

“If knowledge is not found everywhere, then where it is located becomes a particularly significant issue. While codified knowledge is easily replicated, assembled and aggregated (...), other knowledge is dependent on the context and is difficult to communicate to others. Tacit knowledge is localised in particular places and contexts (...)” (Malecki 2000: 110).

The distribution and transfer of codified and tacit knowledge as well as the interplay between geographical and relational proximity forms a key basis for the development of regions. On the one hand, the concentration of knowledge resources in particular regions influences the roles that they may play in the global economy. On the other hand, the dynamics of knowledge exchange within and between regions contribute to either the maintenance or change in those roles within the functional urban hierarchy. This raises questions over the relative importance of regional versus international knowledge spillovers. Simmie (2003) shows that knowledge intensive firms combine a strong local knowledge capital base with high levels of connectivity to similar regions in the international economy. On this way they are able to combine and decode both codified and tacit knowledge originating from multiple regional, national and international sources (Simmie 2003).

### **3 Infrastructure, accessibility and non-physical connectivity**

#### **3.1 Physical infrastructure and accessibility**

To introduce the physical infrastructure of Germany figure 1 illustrates motorways, main railway lines and airports according to the volume of passengers. Solely, Frankfurt and Munich have airports available which operate as hubs in international networks. So, they reach volumes of passengers over 35 Mio. People a year. The role of Berlin as the capital of Germany turns out to be surprising. Two airports belong to the city but none of them has an international outreach which might be expected from a capital with about 3.5 Mio inhabitants. Both airports will be merged into one called Berlin-Brandenburg-International (BBI). It is expected that it will also be run as a hub-airport by several airlines. Contrastingly, Schaafsma (2003) argues that Lufthansa already decided to use Frankfurt which is located in the centre of Germany as the main hub and Munich as a sub-hub.

Moving on to motorways, the German network seems to be dense in all parts of the country, except the area between Hamburg, Berlin and Hannover. Demand within this region is identified and so, according to BMVBS (2010), two new north-south connections are planned. Since the unification of Germany much effort has been done to connect the eastern and western part of Germany. Especially, between Nurnberg, Erfurt and Leipzig the situation of motorway supply was improved. Metropolitan regions like Rhine-Ruhr, around Munich, Hamburg, Frankfurt, and Stuttgart are equipped very well, in any case.

Finally, the high-speed railway system is consistent to the network of motorways. As well, regions like the area between Hannover, Erfurt, and Leipzig are lacking quick access to this mode. Again, metropolitan areas are equipped best. But worth mentioning, the Airport of Munich has no high speed train access. Only, a light rail train connects city and the airport by a 45 minutes ride.

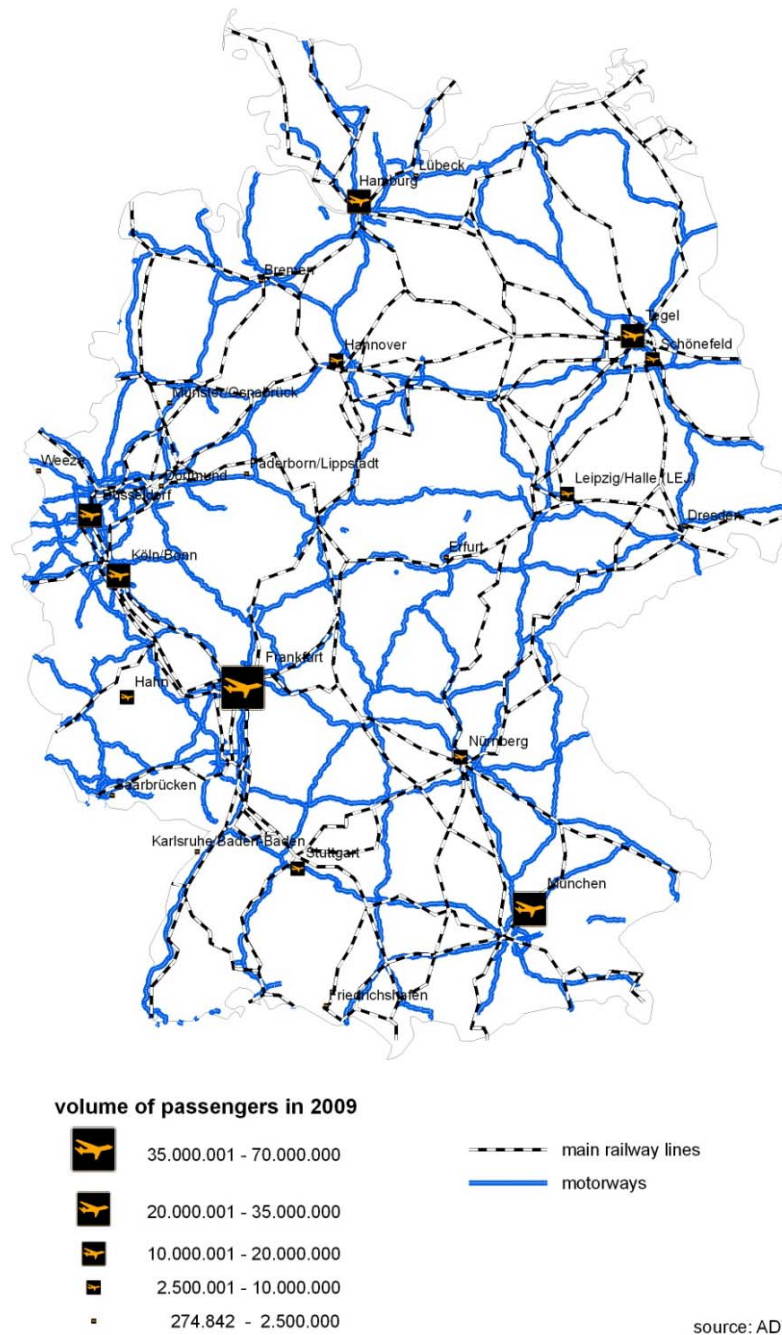


Fig. 1: railways, motorways and airports in Germany

Data of accessibility was originally calculated for NUTS 3 level. The values used here are indexes calculated for 27 members of the European Union. A value below 100 indicates an accessibility which is lower than the European average. Vice versa, values above 100 represent accessibility above the European average.

These data were transferred to the spatial units of Functional Urban Areas (FUA) by us to combine them with data of intra-firm networks. FUAs are agglomerations which are defined by an average commuting time of 60 min around an defined centre ESPON (2004).

Figure 2 shows a comparison of multimodal accessibility of NUTS 3 entities on left hand side and FUA on right hand side. Multimodal accessibility contains the potential accessibility by road, rail and air

traffic. While transferring data from NUTS 3 entities to FUA the importance of Munich airport becomes underestimated due to the facts that, firstly, the FUA of Munich includes districts like Starnberg in the south-west which are far away from the international airport located north-east of Munich and, secondly, the airport of Munich is located in the neighbouring FUA of Freising which is 40 kilometres away from the city of Munich. In contrast, the FUAs Nurnberg, Fürth and Erlangen reach values which are similar to Munich although the airport is not an international one like the one in Munich. It will be explained by the different spatial structure of these FUAs. The FUAs Nurnberg, Fürth, and Erlangen are small compared to the FUA of Munich and they are gathered directly around the airport. That means the structure of an FUA has strong influences on the calculation of accessibility data as has to be taken into account.

The regions with highest accessibility are gathered around metropolitan areas and reach values of 150 and more. Regions with bad accessibility can be found in the area between Berlin, Hamburg, and Hannover, as well as next to the national border in the east and north. Although, these regions still obtain values that are just slightly below the European average.

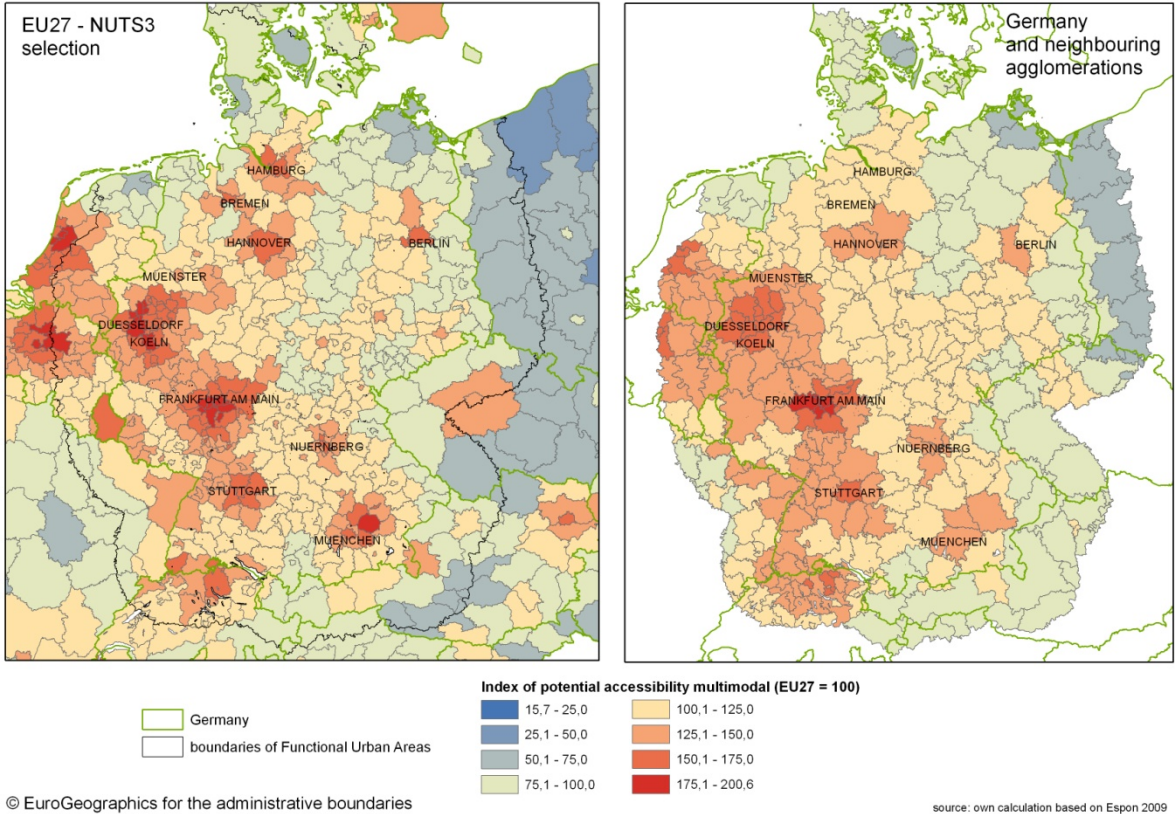


Fig. 2: Calculation of accessibility for Functional Urban Areas

It can be assumed that Germany due to its dense population distribution is well equipped with physical infrastructure on one hand and provides quite good access to several modes of traffic on the other hand. Whereas road and rail offer a ubiquitous supply and tend to improve accessibility on the regional scale, airports and their accessibility lead over to a spatial concentration in metropolitan areas in the western part of Germany. Furthermore, the range of airports affects the national and international scale.

## 3.2 Defining non-physical interaction

The analysis of intra-firm networks is based on the methodology of the Globalisation and World Cities Study Group (GaWC) at Loughborough University. This approach estimates city connectivities from the office networks of multi-city enterprises. Intra-firm networks are spatially distributed branches of one individual corporation. The basic premise of this method is that the more important the office, the greater its flow of information to other office locations. The empirical work comprises three steps.

In the first stage of the empirical work, we had to create a reliable company database. In identifying APS- and High-Tech firms and collected information about their local and regional authorities from the websites. The result of this process was a basic set of 270 APS firms and 210 High-Tech enterprises.

In a second step we developed a so called 'service activity matrix'. This matrix is defined by FUAs in the lines, structured along the regional, national, European and global scale, and knowledge-intensive firms in the columns. Each cell in the matrix shows a service value ( $v_{ij}$ ) that indicates the importance of a FUA (i) to a firm (j). The importance is defined by the size of an office location and its function. By analysing the firms' websites, all office locations are rated at a scale of 0 to 5. The standard value for a cell in the matrix is 0 (no presence) or 2 (presence). If there is a clear indication that a location has a special relevance within the firm network (e.g. regional headquarter, supra-office functions) its value is upgraded to 3 or in case of even higher importance to 4. The enterprise headquarter was valued with 5. If the overall importance of a location in the firm-network is very low (e.g. small agency in a small town) the value is downgraded to 1.

In the third step, we used the interlocking network model by Taylor (2004) to estimate connectivities of FUAs (Taylor 2004). Network connectivities are the primary output from the interlocking network analysis. The measure is an estimation of how well connected a city is within the overall intra-firm network. There are different kinds of connectivity values. The connectivity between two FUAs (a, b) of a certain firm (j) is analysed by multiplying their service values (v) representing the so called elemental interlock ( $r_{abj}$ ) between two FUAs for one firm:

$$r_{abj} = v_{aj} * v_{bj} \quad (1)$$

To calculate the total connectivity between two FUAs, one has to summarise the elemental interlock for all firms located in these two FUAs. This leads to the city interlock ( $r_{ab}$ ):

$$r_{ib} = \sum r_{abj} \quad (2)$$

Aggregating the city interlocks for a single FUA produces the interlock connectivity ( $N_a$ ). This describes the importance of a FUA within the overall intra-firm network.

$$N_a = \sum r_{ai} \quad (a \neq i) \quad (3)$$

If we relate the interlock connectivity for a given FUA to the FUA with the highest interlock connectivity ( $N_h$ ), we gain an idea of its relative importance in respect to the other FUAs that have been considered. The resulting values of relative connectivity score somewhere between 0 and 1.

$$P_a = (N_a/N_h) \quad (4)$$



From this calculation we obtain an indicator of integration into several networks. Figure 3 shows the connection to surrounding neighbours on the one hand and to global locations on the other hand to realize the oppositional orientation into global or regional networks. Surrounding neighbours are defined by the rook contiguity<sup>1</sup> of first and second order. The values shown here are sums of the city interlocks to either the surrounding neighbours or locations outside of Europe for the global scale.

Some Functional Urban Areas like Berlin, Leipzig, and Cologne combine in High-Tech as well as in APS a high connectivity to both scales. The rural parts in Eastern Germany hold high values in APS only on the regional scale and are not linked-up into global networks. Furthermore APS evokes an area-wide distribution on the regional scale. But, in turn, global activities are concentrated in a small number of centres.

Moving on to High-Tech, such opposition is not evident. Regions which have intensive interaction with neighbouring agglomerations also show strong connections to global locations. Some exceptions can be detected in the southern parts of Germany. Especially, regions between Stuttgart, Nurnberg, and Munich hold high values on the regional but not on the global scale.

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<sup>1</sup> Rook contiguity: this method defines spatial entities as neighbored by sharing a common border. In contrast to queen contiguity this also accepts neighbourhood when spatial entities share a common single point.

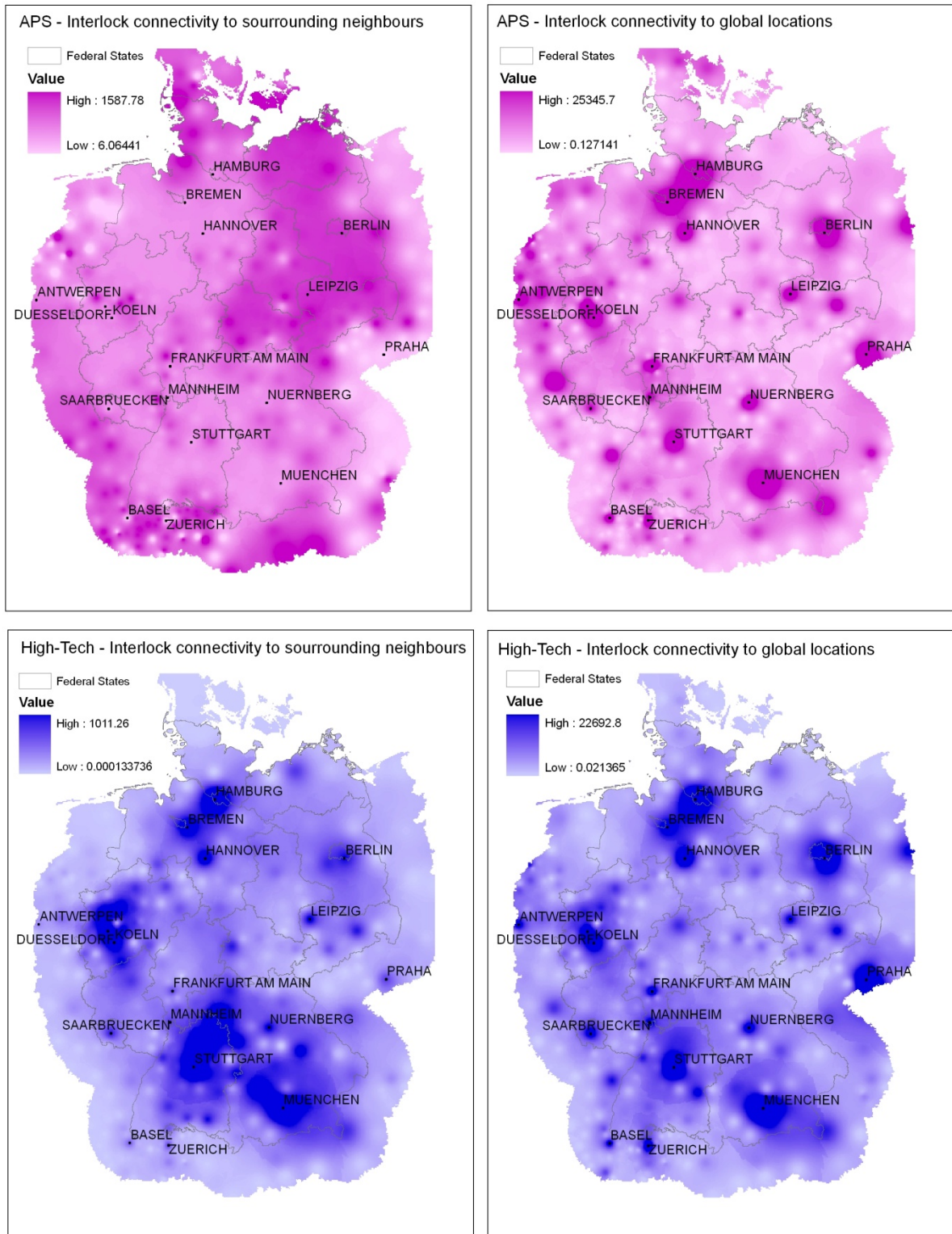


Fig. 3: Interlock connectivity of APS and HT on the regional and global scale

## 4 Effects of accessibility on Non-physical interaction

### 4.1 Connectivity

As shown above the defined modes of accessibility leads to a certain spatial structure. Whereas, rail and road tend to be ubiquitous, airports are concentrated in metropolitan regions. The question arises which mode of access affects the non-physical interaction in which way.

There is a strong interdependence between critical mass and integration in networks. After all, the bigger a region the more companies it hosts. Therefore the following figure 4 shows a comparison of correlations between interlock connectivity, accessibility, and population as well as employment that are used as indicators for approximating critical mass. Only to calculate the correlations to the latter variables we excluded all FUAs which are not in Germany because data for population and employment is not ready to use. Correlation between non-physical interaction and accessibility data are calculated for the whole of Germany and neighbouring agglomerations. Above all, correlations are listed when they are at least significant to likelihood level of 95 %.

As mentioned before, strongest correlations are detected to population and employment. This gives a reference to guess which impact accessibility has. Let us have a look on listed spatial scales and their dependency. Firstly, the higher accessibility via rail and road the stronger connections to surrounding neighbours are. This result is caused by the high values of interlock connectivity within metropolitan regions. We have seen that the Rhine-Ruhr possesses a dense network of rail and road. Above all, especially in High-Tech, this area all shows dense non-physical interaction.

Secondly, as expected, the impact of road and rail declines from the regional to the global scale in both High-Tech and APS. Especially, APS correlations loose importance the wider intra-firm networks reach. Similarly, High-Tech confirms this trend, but still shows significant interrelations between to rail and road access on the global scale. This phenomenon is caused by the concentration of non-physical global connections in the centres of metropolitan areas that provide good access to all modes in any way. Therefore the assumption has to be modified somehow because High-Tech results are influenced by a certain concentration of global activities on dense FUAs with a huge number of population and employment. Indeed, the influence of both population and employment increases from the regional to global scale.

Thirdly, correlations to air access do not differ between several scales. Undoubtedly, they are significant but do not confirm the expected assumptions of a growing impact of air access on the European and global scale.

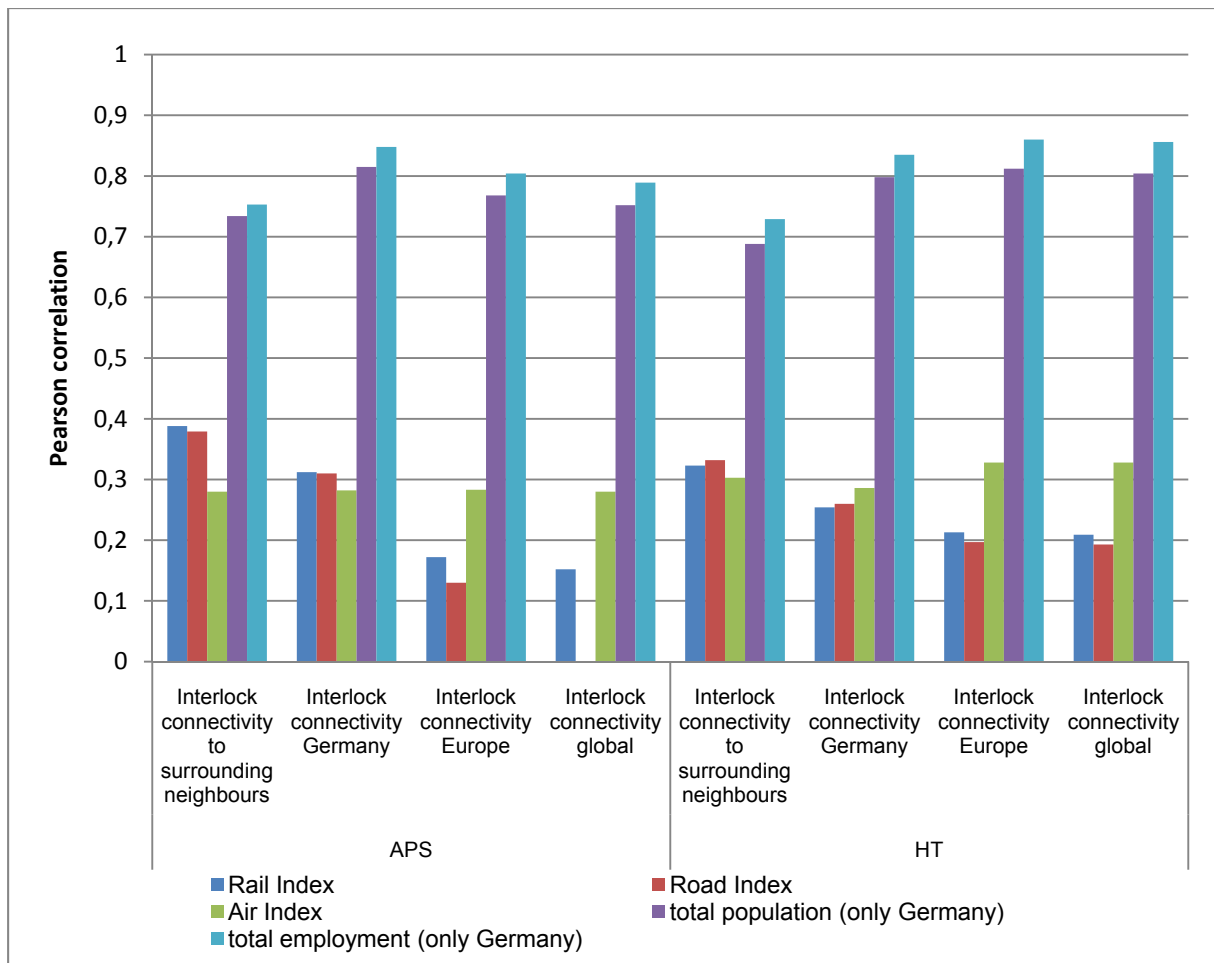


Fig. 4: Correlation between interlock connectivity on different scales, accessibility by different modes, population, and employment

Summing up, the initially stated hypothesis that air access keeps the most important one and that air access is a more relevant factor for interactions outwards Germany has to be clarified. In the case of APS its influence on connectivity does not change at all. Contrastingly, correlations to road and rail declines steadily. Also critical mass becomes slightly less important. Therefore the relative impact of air access might get stronger which will be demonstrated in the next chapter.

Interrelations of High-Tech interlock connectivity and air accessibility intensify from the regional to the global scale. Therefore air access is expected to become even stronger while isolating it from the covariances to the other modes.

## 4.2 Isolated access to airports from access to rail and road

Regions with an airport often provide dense road and railway systems with access to high-speed travelling as well. For example Frankfurt Airport has its own railway station where some of the fastest connections within Germany are passing through. From here it takes about 50 minutes to reach Cologne, which is 200 kilometres away. On the other hand, it takes the same time from Munich Airport, the second biggest one in Germany, to Munich central station. To isolate the impact of an airport on a region, we employed partial correlation and tested the influence of air accessibility as such by excluding covariances with all other modes of access.

Similar to the previous analysis the impact of accessibility by air increases when the connectivity to abroad also increases. At least, all correlations are significant to likelihood level of 95 % and are considered to be reliable. High-Tech values sit slightly above those of APS. Moving from the national to the global scale this difference decreases, but on all levels shown in this figure 5 accessibility by air seems to be more important for High-Tech firms than for APS firms which, again, might be influenced by a certain concentration of global High-Tech activities.

Thus the question arises why High-Tech firms show continuously higher values. One reason might be given by the fact that the ratio of interlock connectivity within Germany of High-Tech sector is 0.5; the same ratio of APS reaches 1.5. That means the majority of all interactions within High-Tech are carried out predominantly outside Germany, whereas APS interactions are localized within the German boundaries.

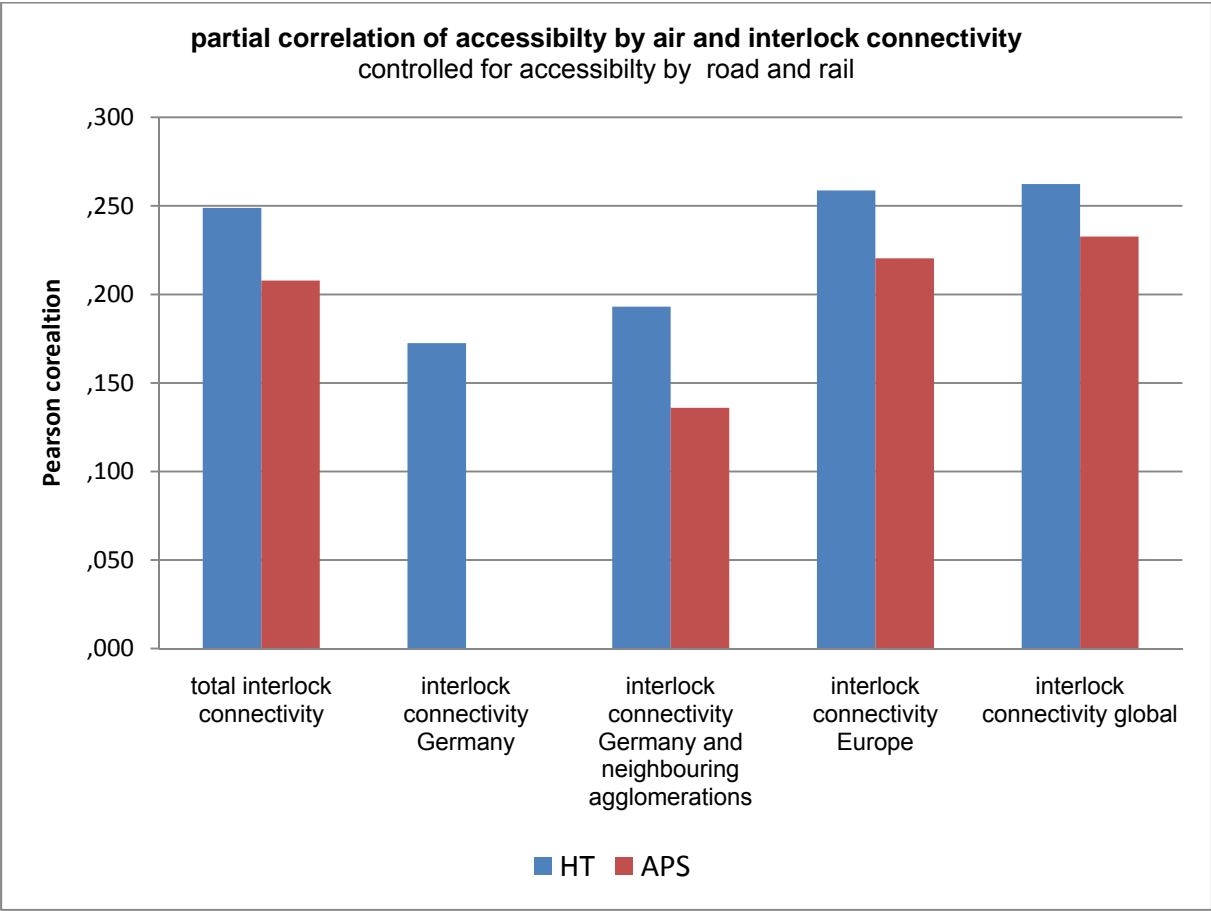


Fig. 5: Partial correlation between interlock connectivity on different scales and accessibility by air

To sum up these findings, APS firms on the whole tend to concentrate on the national market. Especially banks are distributed area-wide to supply their services. Although, there are a lot of APS Firms which interact only abroad and use airports as a hub to access affiliates around the globe quickly. Airport cities emerge as a functional spatial configuration from this development (Schaafsma, Amkreutz und Güller 2008).

Both APS and High-Tech firms operate on global scale as well, High-tech firms on the whole are not fixed to the national markets to offer daily supplies in the way APS firms do. They organize value

chains which have a high shares in production worldwide. Often, this is carried out in locations with lower wages and high qualification of employment like India or South-East Asia.

Including time as a dimension, high-tech firms evoke strong global relationships by requiring fixed capital. The result of these worldwide operations is “footloose” industries. Standardised elements of value chains which are equates codified knowledge are carried out. So, for example production plants are built wherever machinery and real estate is low on costs.

### 5 Conclusion

According to mentioned differences between High-Tech and APS much more effort has to be done by analysing their certain structure of networking and especially, strategic decisions of choosing locations have to be taken into account.

Finally, after excluding intertwining effects of air, road, and rail access as well population and employment by partial correlation we obtain the solely impact of air access on non-physical interaction (fig. 6). Indeed, air access seems to be import only for interaction to locations in Europe and worldwide. Correlations on other scales are less important or not significant to likelihood level of 95%. The Hypothesis that airports are one of the key factors in globalization is confirmed. After all, accessibility by air involves non-physical interaction and catalyses global networks of knowledge exchange.

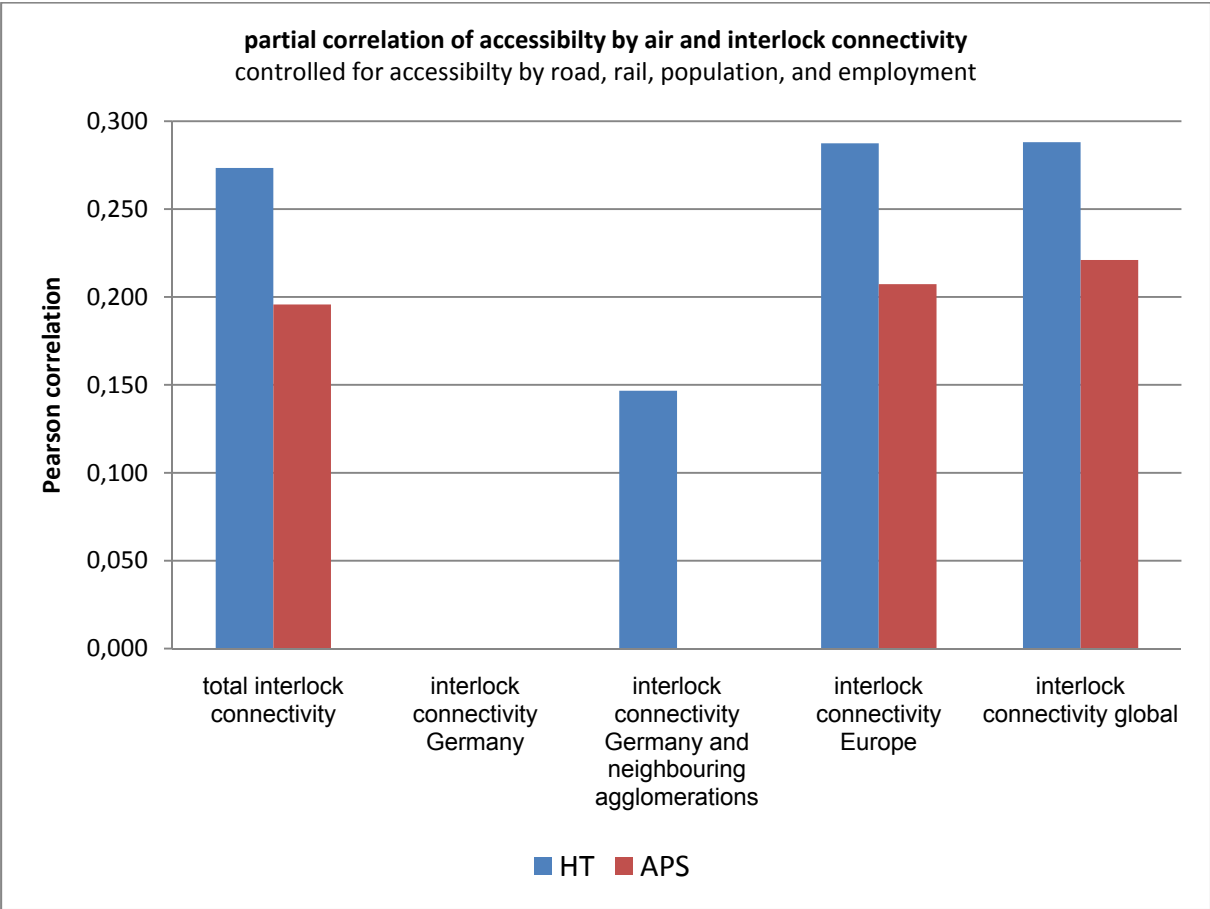


Fig. 6: Partial correlation between interlock connectivity on different scales and accessibility by air

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