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ID 1656 | BRAIN TRAIN OR BRAIN DRAIN? EFFECTS OF HIGH SPEED RAIL ON THE SPATIAL STRUCTURE IN THE AGE OF THE KNOWLEDGE ECONOMY

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ABSTRACT: Transport infrastructures facilitate access to people, knowledge, and markets, thus increase the “potential of opportunities for interaction” (Van Geenhuizen et al., 2007: 7) of a place and stimulating economic activity, leading to urban development. Particularly in Europe, High Speed Rail (HSR) has been of growing importance in providing passenger mobility on medium distances. During the last three decades, HSR has connected more and more cores of metropolitan regions, airports, and sometimes also previously unserved peripheral places nationally and later internationally. Its spread occasionally also led to a reduction in rail accessibility when conventional rail services were subsequently reduced. At the same time, globalisation means that the ‘knowledge economy’ (KE) is becoming a key driver of development especially in highly developed countries. The performance of firms depends more and more on knowledge as production factor, and the input of highly skilled workers. Locational factors of knowledge-intensive firms differ from those of ‘conventional’ firms. They seek a combination of ‘global pipelines’ and ‘local buzz’ (Bathelt et al., 2004), i.e. global connectivity together with a stimulating local environment of face-to-face contacts. Under these conditions, HSR stations come into focus as potential new nodes for future economic development, since the immediate surroundings of HSR stations profit most from a gain in accessibility and provide ‘spaces for dialogue’, which are of particular relevance for KE firms. There have been several studies on the structural effects of HSR lines, especially in the cases of the French TGV and Spanish AVE networks. Despite the strong growth of ridership, hopes of a dispersion of economic development away from the metropolitan centres did not always materialise. Instead, some cases suggest that HSR access leads to ‘brain drain’ effects, upscaling on Mega-Regional levels, and residential ‘super-suburbanisation’ instead. Other studies argue that positive economic effects exist, but are merely of a redistributive nature. In each instance, the influencing factors augmenting economic development in the individual case, such as integration with the conventional network, and local absorptive capacity, must be more thoroughly discerned in research on transport effects. In this study, we present the results of a gravitational accessibility analysis of the German rail network in 1990, before the opening of the first HSR line, and its comparison with the 2017 values to quantify gains and losses in accessibility generated by HSR. The German case differs somewhat from most other European cases due to its federal, more dispersed spatial structure and the lack of a clear dominant centre. Furthermore we project accessibility changes by two ongoing HSR projects such as the new Berlin-Munich mainline via Erfurt and Nuremberg. We find that, besides obviously boosting accessibility in previously poorly connected areas, even stations which lose access to the intercity train network profit from HSR through greater overall network effects. However, the upgrading of the conventional rail network in East Germany after 1990 improved accessibility levels more than HSR projects. The results of the accessibility analysis can then be used for a range of 'quasi-experiments' for difference-in-difference analyses (cf. Ahlfeldt and Feddersen, 2010) of firm locations, especially in situations of high accessibility differentials, e.g. 'external shock' conditions in peripheral areas. As an outlook, we propose such a methodology to test the effects of accessibility changes on the development of knowledge-intensive firms, both in the immediate surroundings of new or upgraded HSR stations, as well as their regions.

KEYWORDS: High Speed Rail, Knowledge Economy, Accessibility, Urban Economics, Transport Planning, Spatial Planning

1 OVERVIEW

The last decades have seen the rise of High-Speed Rail (HSR) as a new type of transport infrastructure. Within and between many developed countries, especially in Europe, HSR has seen strong growth and has reduced rail travel times between metropolitan core cities in some cases drastically, while new lines continue to be developed. It has also occasionally improved the connection of previously peripheral areas if these were not just crossed by new lines but also received a station, while on the other hand, some regions have lost their connection to the higher order train network when they were bypassed by new HSR lines. Altogether HSR has greatly influenced the 'accessibility landscape' in Europe.

Due to their function as multi-scalar gateways, HSR stations gathered the interest of urban economists, planners, and economic development professionals as potential locations for new poles of development. This particularly applies in the context of knowledge intensive firms, which are of growing relevance, and which particularly value accessibility (Thierstein et al., 2008), i.e. the possibility to reach a high number of other people and firms quickly. Also, rail based public transport is among the more sustainable transport modes with growing importance for future planning strategies (UN Habitat, 2009). In planning, this nexus is known as transit-oriented development (Bertolini, 1999).

In this paper, we want to briefly review the rationale behind the premise that HSR access leads to economic development through the resettling of knowledge intensive firms, before we present the methodology and empirical results of an accessibility analysis of the German HSR network between 1991, the year of the opening of the first HSR line in Germany, and 2017. We also project further accessibility changes induced by two currently planned HSR lines. Based on this, we propose a methodology to explore the effects that HSR access has on locational decisions of knowledge intensive firms.

1.1 THE ROLE OF ACCESSIBILITY FOR REGIONAL DEVELOPMENT

Cities can be conceived as systems emerging from individual decisions by firms and households regarding their business or residential location and their mode of travel, among others (Parr, 2015). These decisions are mutually interdependent, resulting in a complex 'landscape' of push and pull-factors, path dependencies, and interlockings, between demand and supply of locations, reflected by land markets (Alonso, 1964). Usually, such urban systems develop only gradually over time, depending for example on demographic or social changes, or altered preferences. Only few events are strong enough to induce an 'exogenous shock' to the system, potentially resulting in sudden and sometimes dramatic shifts of demand, value, and ultimately use of land. Large public infrastructure investments can represent such shocks, since the sudden compression of time and space based on distances in (Euclidian-geometric) space (Plassard 1990 in Garmendia et al., 2012) simplifies access to people, knowledge, and markets

(Tierney, 2012) and thus leads to the redistribution of accessibility, i.e. “the potential of opportunities for interaction“ (Rietveld and Bruinsma, 1998). Accessibility improvements hence form a potential tool to foster urban and regional development, and better a knowledge base could help urban and regional planning professionals in assessing and harnessing the potentials of accessibility improvements for their constituencies. Even though it is recognised that accessibility plays a major role in shaping urban development, it is important to note here that it is of course not the only influencing factor. ‘Soft’ locational factors, such as the image of a city or its landscape and cultural amenities have been of growing importance as cities increasingly become ‘consumer cities’ (Glaeser et al., 2001).

Research has been inconclusive, however, whether improvements in accessibility can really benefit peripheral regions. Uncertainty persists on three questions. First, whether increased economic activities can be observed in general, or whether they are dependent on additional local, case-specific factors or thresholds, and if so, which (Feitelson and Rotem-Mindali, 2015: 297-298). Second, whether increased economic activities – should they exist – are generative, or only of a redistributive kind (Holvad and Leleur, 2015). And thirdly and most importantly, whether a redistribution of economic activity is directed away from the cores to the newly connected peripheral areas, representing a potential for regional and transport planning to induce local growth, or, fuelled by the transformation to the knowledge economy, to the opposite, i.e. a ‘brain drain’ effect and even stronger concentration in the cores (Vickerman, 1997). What is assumed here also depends on the theoretical framework used.

1.2 SPILLOVERS OR CONCENTRATION?

On the one hand, neoclassical economic theory assumes automatic convergence between regions. Inequalities regarding wages, rents, and interest rates are expected to dissolve as labour and capital is redistributed among the regions according to the greatest profit. Persistent inequalities are, in this view, the result of differences in productivity or barriers to the free movement of production factors (Barro and Sala-i-Martin, 1992; Solow, 1956). Location theory, which incorporates transport costs, also describes quasi-automatic sorting of activities in space under equilibrium conditions according to accessibility (Alonso, 1964). Different land user groups showed varying willingness to pay for proximity to economic centres, with commercial users bidding highest, followed by residential users, leading to a bid-rent gradient in a monocentric environment. Weber (1909) developed a locational theory for industrial firms, describing their locational choice based on minimal transport costs, which depend on distance and weight of the transported good.

Under the neoclassical framework, reductions of travel times must lead to increased economic activity through the exploitation of reduced (time) costs, increased economies of scale and competition.

On the other hand, since 1990, a body of theories under the label “new economic geography” (NEG) (Krugman, 1998) has emerged. NEG theories encompass path dependencies, transaction costs, and localised agglomeration economies, which can result in persistent regional differences and further agglomeration of firms and workers in successful regions.

Despite shortcomings (Storper, 2010), both approaches provide useful theoretical underpinnings for the analyses of accessibility change effects, since the predictions they allow are fundamentally different, requiring varying strategies for regional and transport planning. On the one hand, in neoclassical models, improvements in accessibility in a certain area will in turn lead to a re-sorting of land uses and a redistribution of optimal equilibrium locations, particularly when considering isolated but interlinked nodes like railway stations. In this case, areas close to stations can be better connected with each other than with their respective hinterland. The lower land prices in the newly connected areas, together with now sufficient proximity to other actors – mediated via transport links – , will lead some firms and individuals to relocate, especially start-ups in their initial phase when cost sensitivity is high. On the other hand, improved accessibility might destroy ‘niches’ of firms when barriers to stronger cores are removed under a self-reinforcing NEG framework.

1.3 THE KNOWLEDGE ECONOMY

Agglomeration economies become particularly important in light of the shift of European economies away from traditional industrial production towards ‘knowledge economies’ (OECD, 1996). Knowledge as a production factor is constantly becoming more important in developed economies, both as input and output in the production process (Kiese, 2013), and consequently attracting a focus of research (Lüthi et al., 2011). Industrial production is subject to technologisation, and demands a highly skilled labour force, or is shifted to locations with lower labour costs as part of a globalisation of value chains (Sassen, 1994). Under these conditions, cities and regions are successful when they manage not only to attract innovative, ‘knowledge-intensive firms’, but also highly skilled ‘knowledge workers’ as part of the ‘creative class’ (Florida, 2003).

Knowledge-intensive firms depend more than enterprises in other sectors on spatial proximity to customers, (potential) employees, and even competitors from the same field, since knowledge, especially symbolic and analytic knowledge, is often ‘tacit’, i.e. related to a certain local or personal context and cannot easily be codified or transferred across space (Asheim and Hansen, 2009). Since innovation is nonlinear and usually interpersonal, it makes frequent, even random, face-to-face contacts of actors necessary to create ‘spillovers’. This gives rise to substantial agglomeration economies on behalf of the firms. But also employees tend to concentrate in cities with a high number of knowledge-intensive firms, since the larger labour market gives them a greater variety in employment opportunities. This particularly applies to cultural and creative industries, which are a partial subgroup of knowledge-intensive industries. They are assumed to have the highest propensity to settle in a diverse urban surrounding, profiting from ‚urbanisation economies‘.

However, literature on spatial aspects of innovation also points to the fact that in order to avoid a „lock-in“ of actors within their local knowledge context, interregional or even global contacts alongside the local milieu are indispensable (Bathelt et al., 2004). Despite the progress in IT and communications technology (Castells, 1996), at least temporal proximity of actors in this context is still necessary as well. Hence, network economies must complement agglomeration economies for knowledge intensive firms.

The knowledge economy is however relevant to this research for another reason. Knowledge workers usually have an above-average propensity to use public transport for medium and long distances as it allows using travel time for work, which becomes more important with increasing valuation of time.

1.4 THE DEVELOPMENT OF HIGH-SPEED RAIL

Besides airports and highway infrastructure, in recent years especially High-Speed Rail (HSR) construction has attracted the attention of planning researchers and economic geographers.

The European Union Directive 96/48 (European Council, 1996) defines in Art. 5 (3c) as HSR “specially built high-speed lines equipped for speeds generally equal to or greater than 250 km/h, specially upgraded high-speed lines equipped for speeds of the order of 200 km/h” and, in exceptional cases, upgraded lines with lower speeds in the case of “topographical, relief or town-planning constraints”. For this paper, we focus on specially-built high speed lines only, since these create stronger disruptions to the economic framework and are thus better suited for significant pre-post comparisons.

HSR lines started to complement and replace ‘conventional’ rail starting in the 1960s with the Shinkansen in Japan (Tokyo-Osaka), and from the 1970s on in several European countries, such as Italy (1977, Rome-Ponticelli), France (1981, Lyon-Paris), Germany (1991, Hannover-Würzburg), and Spain (1992, Madrid-Seville). After decades of losing shares in the passenger market to individual motorised transport and airlines, HSR was seen by railway administrations as a chance to regain competitiveness on medium distances up to 800km. The number of HSR lines and stations as well as passenger figures in Europe have been growing constantly since (UIC, 2009), also as part of the Trans-European Networks (TEN) initiative of the European Union. HSR has taken foothold in other countries outside of Europe as well, while the relation to air transport has shifted from competition to a more mixed form that recognises the need for symbiosis for longer distances (Lijesen and Terpstra, 2011).

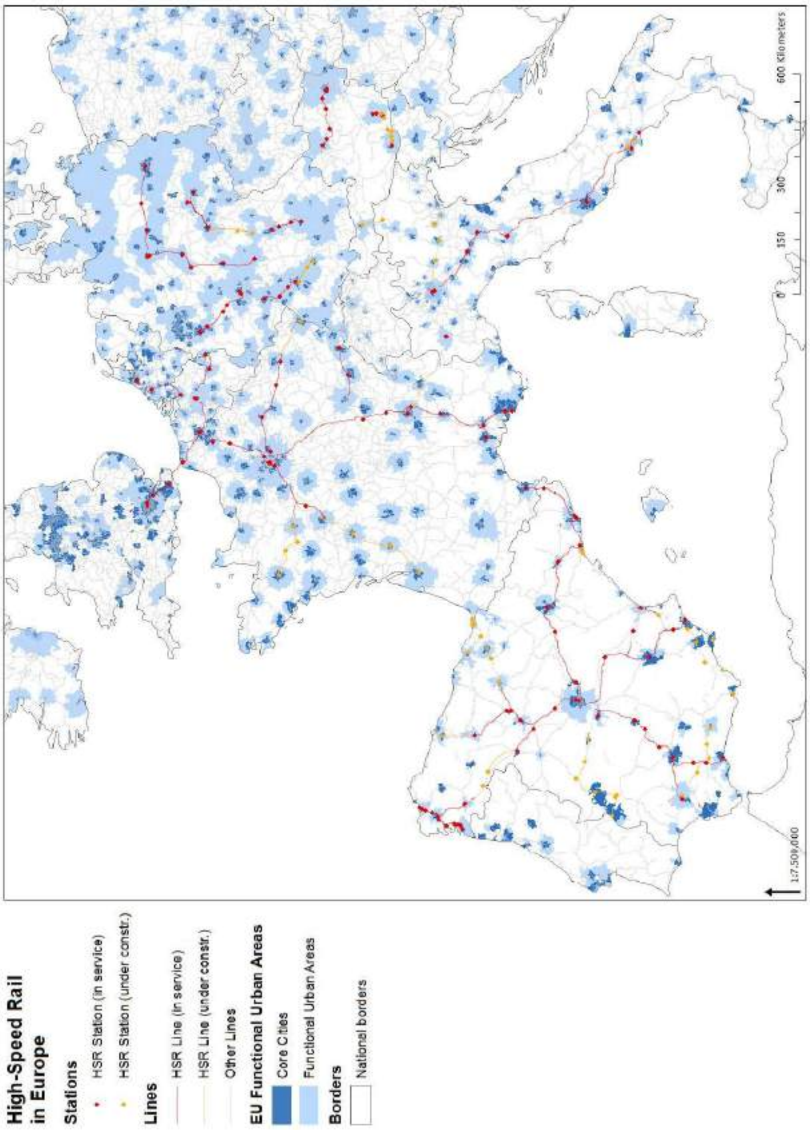

Figure 1: High Speed Rail in Europe. Source: own illustration using Eurostat, 2014; OpenStreetMap, 2016

Figure 1 shows that HSR strategies differ between countries: Networks in unitary countries and countries with a strong national capital city feature more direct links between the capital and secondary cities, while those of federal countries, often with a more balanced settlement structure, show more tangential links. While most networks were initially developed nationally, the European dimension of the network was strengthened during the last decade with the planning and opening of several international links such as the Paris-Brussels-Cologne/Amsterdam corridor. While network operators in Italy have almost completely refrained from constructing stations outside of larger cities, the Spanish network operator strongly invested in new stations on the countryside. Germany takes a middle position here, while France saw a strategy change from 'gares de betteraves' to more centrally located stations. Despite three decades of HSR research, the effects of these differences remain under-investigated in ex-post analyses (Preston, 2012). Regarding Germany there is no comprehensive review of scientific literature yet.

1.5 REGIONAL ECONOMIC EFFECTS OF HIGH SPEED RAIL

Three main approaches to specifying the regional economic effects of HSR are used in literature: Aggregate measures, e.g. the comparison of overall regional transport investment with unemployment measures or GDP growth (Aschauer, 1989), more detailed spatial computable general equilibrium (SCGE) models, and project-specific calculations such as CBA and hedonic price approaches (Iacono and Levinson, 2015: 244). While most of the approaches are suitable to arrive at approximate cost-benefit ratios for planned HSR projects based on the utility for current users, they have difficulties in capturing catalytic effects and induced urban development, which is especially relevant to planners. We will concentrate on the latter for this paper, since we propose a methodology based on this method that potentially takes into account catalytic effects using firm location data.

Firstly, difference-in-differences analyses of pre- and post-intervention land values in both a treatment and control area have been used to estimate the economic benefit for a location that received an accessibility increase by disentangling the influencing factors (Ahlfeldt, 2011). The difference-in-differences analysis establishes a clear link between accessibility changes – positive and negative – and land prices. However, it is important to realise the limitations of this approach, based on the imperfections of land markets and value estimation methods. Studies using the difference-in-difference approach on house prices found only minor effects of HSR access so far, for example in the case of Taiwan (Andersson et al., 2010). Rather, several authors point to the fact that HSR stations also come with negative externalities that impact land values, such as noise and crime (Gargiulo and de Ciutiis, 2010; Armstrong and Rodriguez, 2006; Bowes and Ihlanfeldt, 2001), accidents and impacts on landscape appearance (Chang et al., 2014).

Using land values in a difference-in-differences approach also makes it possible to analyse the assumptions of market participants regarding future effects, since land values are determined by expected future earnings. However, they cannot inform us about the long-term, catalytic effects of improved accessibility, since an increase in land values is not automatically followed by urban development. Hence, a difference-in-differences approach using firm location data seems to be a promising method.

On the regional scale, the role of the size of newly connected municipalities on the actual effects of HSR is often highlighted (Ureña et al., 2009). If two cities or airports are connected by HSR, a number of studies found that the line will work in favour of the already stronger one of the two, and to the detriment of the weaker counterpart, as well as the countryside (Terpstra and Lijesen, 2015; Plassard, 1992 in Garmendia et al., 2012). Accordingly, HSR has been found to support upscaling on Mega-City level in Europe (Morris et al., 2003) and in the case of the Pearl River Delta area in China (Hou and Li, 2011). There is a danger of increased peripheralisation of unconnected smaller localities within the region and rising spatial imbalance (Monzón et al., 2013), which requires “careful planning and policy intervention to effect necessary ancillary investment” (Vickerman, 1997: 36). When following cohesion and regional development goals with mega transport infrastructures such as HSR, integration with conventional and regional rail is also important to maintain a polycentric structure (González-González and Nogués, 2016). Some authors doubt the usefulness of HSR for regional dispersion of economic activity altogether, as in the case of the Japanese Shinkansen network (Sasaki et al., 1997).

On the other hand, Mohino et al. (2014) find significant growth effects in Spain, depending on “the context, the physical, economic, and locational circumstances, and the HSR network/services characteristics” among them distance from other centres, land availability, intermodality, station location, plans, and other station assets. A polycentric and well-integrated Mega City Region, helped by HSR connections, is a strong catalyst for economic development in the age of the knowledge economy: “A flourishing knowledge economy hinges on more intense social interactions, which means a more intelligent allocation of resources across the landscape” (Tierney, 2012). However, in the case of rural stations close to strong metropolitan centres, HSR stations can contribute to unwanted suburbanisation (Demuth, 2004).

Finally, HSR research has also focussed on the stations themselves and their immediate surroundings: How can cities turn the accessibility gain into concrete advantages, manifest in urban design (Bertolini and Spit, 1998; Trip, 2008; Thierstein, 2014)? Researchers have studied the ‘Bilbao effect’ of star architecture on its surroundings creating spillover effects for the entire city (Alaily-Mattar et al., 2017, forthcoming) which is also employed for HSR station buildings, especially in Belgium and Italy. Even if the station itself is not redeveloped, an increase in accessibility can lead to an induced form of ‘gentrification’, when landowners are incentivised to refurbish or sell their real estate due to rising land values, sometimes not unintended. Municipal planning administrations often try to support such developments by financing the reconstruction of public spaces and disused rail land around the station. How this process occurs in practice needs contextual review in each single case.

To sum up, most studies indeed find evidence for increased economic activity around nodes of improved accessibility, but assess that it is redistributive in nature, and depending on further influencing factors (de

Rus, 2008). However, no studies looked at firm locations in particular, and ex-post studies over longer timespans remain rare.

2 RESEARCH QUESTION AND HYPOTHESES

Following from the previous paragraphs, the research question behind this paper is how the introduction of HSR in Germany between 1991 and 2017 has changed the public transport accessibility landscape. The premise is that an induced change in public transport accessibility through High-Speed Rail can spread knowledge-intensive firms from metropolitan cores to smaller centres in the region and so help to promote regional economic development.

- Our hypotheses are that
- Accessibility improvements at HSR stations have been significant
- Some regions have significantly lost accessibility due to new, bypassing HSR lines
- Due to its federal, more dispersed spatial structure, HSR effects in Germany differ to some extent from those of more centralised countries such as France and the UK

After presenting our empirical results for this first step of research, we propose a way forward how to apply the gathered data on firm location choices.

Figure 2 shows these hypotheses, together with some implicit assumptions of our research.

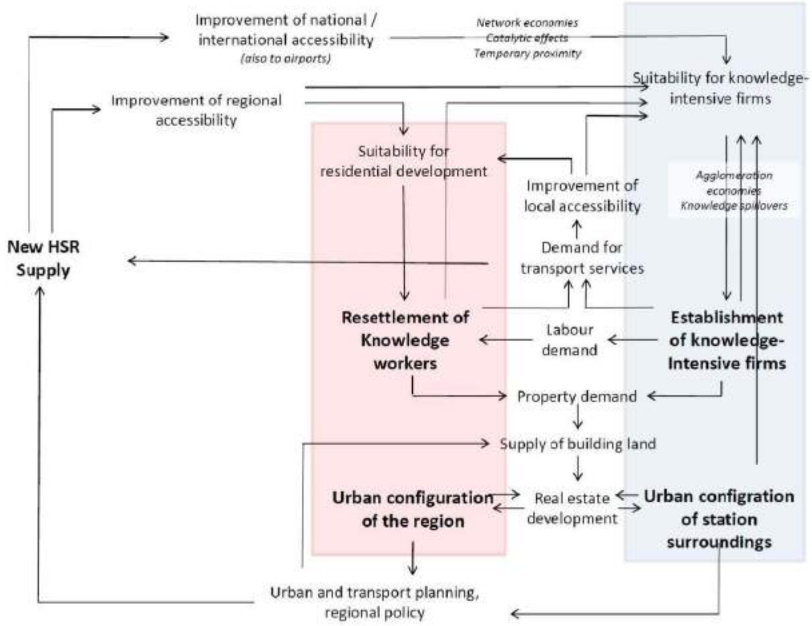

Figure 2: Impact model showing implicit and explicit hypotheses. Source: own illustration

3 METHODOLOGY FOR ACCESSIBILITY ANALYSIS

Accessibility can be measured in different ways. There are simple supply indicators (e.g. length of road network per spatial unit) or more complex indicators, such as gravitation models (Neumeier, 2016), which describe the number of opportunities (e.g. people or firms) that can be reached from a point in a network, weighted by distance. The farther away other opportunities are in the network, the lower the attached weight, until it becomes zero after a certain threshold. We employ a model of the latter type, weighted by population, for our analysis of accessibility levels and changes induced by HSR in Germany.

The model firstly contains a list of the timetable travel times of all regular long-distance train connections in Germany in spring 1991 (DB, 1990; DR, 1990) and spring 2017 (DB, 2017) between any stations served. These connections form the core network. Regular in this case means that there had to be at least one train connection in each 2-hour timespan over a period of eight consecutive hours on a working day. In case of differing travel times for these connections, the slowest available time was chosen. We selected 1991 as reference year since 1990/1991 was the last timetable year before the inauguration of the first HSR line, Hannover-Würzburg, and the first after reunification between West and East Germany.

To assign weights to the stations, we used the population of functional travel-to-work regions ("Stadt-Land-Regionen" developed by the BBSR (2014)). The 266 travel-to-work regions in Germany are comprehensive, non-overlapping and contingent spatial units based on commuter flows representing functional spatial relationships. The weighing factor of a station was defined as the population of the containing travel-to-work region in the applicable year, divided by the numbers of long-distance-train stations in that region, excluding airport stations.

Not all regions are served by regular long-distance trains. However, accessibility changes through HSR introduction may also affect these regions indirectly through regional train connections to the HSR nodes. Hence for all travel-to-work regions not served by long-distance rail (1991: 132; 2017: 154), a 'central station' was defined, based on its importance in the regional context. In most cases, this was the main station of the dominant municipality within the region. In case the chief city did not have any railway connection (1991: 9; 2017: 8), the most central station within the rail network in that region was chosen as 'central station' instead (e.g. Bad Bentheim instead of Nordhorn, Gerolstein instead of Daun). There was no travel-to-work region without railway access in either 1991 or 2017. The 'central stations' receive the full weighing factor of the containing region. This avoids a 'disconnection bias' (regions no longer served do not feature in the calculation anymore, hence overall accessibility might be increased even though less regions are connected).

Additionally, 64 interchange stations were considered that provide links between 'central stations', but are not in regional centres themselves. These stations receive no weighing factor. Subsequently all regular regional train connections between these regional centres, the interchange stations and those of the core network were added to the list of connections. In a few number of cases this meant that also connections with a lower frequency than 2-hourly had to be considered. These form the supplementary network.

A potential accessibility underestimation bias in gravitational analyses can arise in border areas, when metropolitan centres just across the border are not counted in. Hence we added a buffer around the country of 90 minutes rail travel time. As spatial base units in this zone we used 64 NUTS3 regions and their most important urban centres, which are spatially comparable to the functional travel-to-work regions used within Germany. All train connections to and within these regions were also added to the list.

This resulted in a list of 444 stations with 1300 connections in 1991 and 501 stations with 1353 connections in 2017, respectively.

Based on this connection dataset, we calculated gravitational accessibility measures for all included stations, using the formula in Figure 3. Each main station j was assigned a weighing factor W. The gravitational accessibility of a municipality i is then defined as the number of people that can be reached, applying a distance decay factor β on travel time. This way, nearby municipalities are weighted more than municipalities far away. We applied a decay factor of β = 0.015, which translates into a 'half-life' of approximately 45 minutes, meaning that a person in a municipality 45 minutes away is weighted half as much as a local inhabitant. This reflects the assumed strong agglomeration effects for knowledge-intensive firms, but also takes into account that we're looking at day-long business trips and not commuting relations, for which a higher decay factor would be applicable.

$$Gravity[i]^r = \sum_{j \in G-\{i\}, d[i,j] \leq r} \frac{W[j]}{e^{\beta \cdot d[i,j]}}$$

Figure 3: Formula to calculate gravitational accessibility. Source: Sevtsuk and Mekonnen (2011)

For interchanges at stations, a changing time of two minutes was assumed. If the change was between travel modes (e.g. train and bus), the assumed changing time was 10 minutes. No hierarchy of train service levels was applied – for each station-pair connection, the fastest route was chosen. We used a cutoff threshold at 270 minutes travel time, since we assumed passengers to prefer air transport for longer journeys, but distance decay for these travel times is already very high anyways.

To model the changes in accessibility induced by the two planned HSR lines between Nuremberg and Erfurt, which is due to open in late 2017, and Stuttgart to Ulm, which is planned to be completed in 2022, the analysis was repeated with a manually adapted timetable dataset with the expected future travel times.

Our chosen approach necessarily entails a number of shortcomings due to reasons of simplicity. Firstly, the dataset is timetable-based, i.e. does not take into account delays but assumes an ideal traffic situation. Secondly, we used the travel-to-work regions as spatial units for both 1991 and 2017 even though real functional spatial relations shortly after reunification differed significantly from the potential, especially in border areas. Thirdly, it was assumed that the entire population of the regions can reach the central stations with no further spatial drag, though this potentially introduces a slight bias in favour of larger metropolitan regions.

4 RESULTS

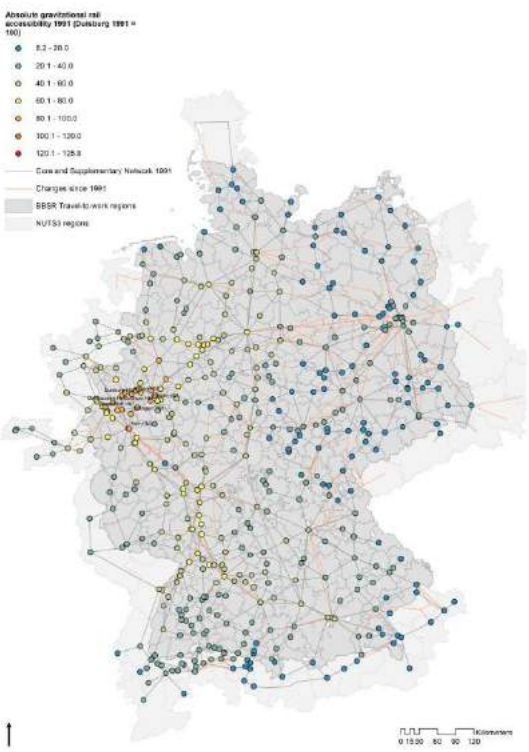

Figure 4: Absolute gravitational rail accessibility 1991 (Duisburg 1991 = 100).
Source: own illustration using BBSR (2014)

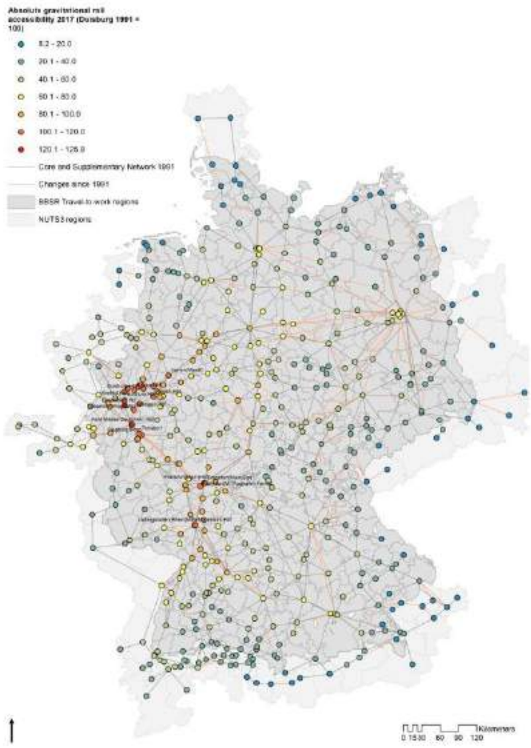

Figure 5: Absolute gravitational rail accessibility 2017 (Dusiburg 1991 = 100)
Source: own illustration using BBSR (2014)

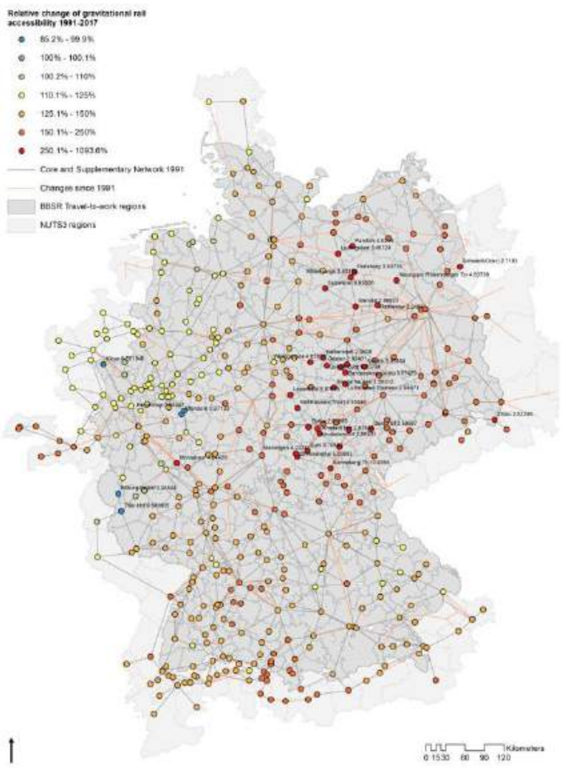

Figure 6: Relative change of gravitational accessibility 1991-2017 Source: own illustration using BBSR (2014)

Figure 4 shows the absolute accessibility of population by rail for 1991, using a 45 minutes half-life threshold. The values are normalised on the highest value, which is Duisburg Hbf (cf. Table 1). This result may be surprising given Duisburg's status today as a post-industrial city with below-average economic performance, compared to its neighbours in the south, but this has not always been the case, and can be explained by its central location in the largest urban agglomeration in Germany. The ten stations with the highest accessibility in 1991 are all located in the Rhine-Ruhr region.

	Station	Accessibility (Duisburg Hbf 1991 = 100)
1	Duisburg Hbf	100
2	Essen Hbf	98,71
3	Düsseldorf Hbf	98,34
4	Dortmund Hbf	96,73
5	Bochum Hbf	95,60
6	Köln Hbf	94,20
7	Wuppertal Hbf	92,66
8	Hagen Hbf	92,14
9	Oberhausen Hbf	90,57
10	Solingen Hbf	90,42

Table 1: The ten most accessible rail stations in Germany 1991

If we compare the absolute values with those of 2017 in Figure 5 and Table 2, we can see that the centre of gravity has somewhat shifted to the south. The most accessible station is now Cologne, and several stations from the Rhein-Main area, such as Frankfurt Main Station and Frankfurt Airport have made it to the list. With Mannheim a city even further south is on 7th position. Smaller towns of the Ruhr area do not feature anymore in the top 10, even though it must be noted that total accessibility improved for all stations in the area. This coincides with the economic stagnation the Ruhr has experienced in the analysed timeframe, compared to the economically more successful south.

This effect is clearly due to the opening of a new high speed rail link between Cologne and Frankfurt in 2002, which reduced the travel time between the two cities from 2.5 hours to one hour. The line has been well used since and led to further economic integration of the two metropolitan regions (Ahlfeldt and Feddersen, 2010).

	Station	Accessibility (Duisburg Hbf 1991 = 100)
1	Köln Hbf	125,78
2	Köln Messe/Deutz	122,54
3	Düsseldorf Hbf	121,8
4	Frankfurt(M) Flughafen Fernbf	119,72
5	Duisburg Hbf	118,21
6	Frankfurt(Main)Hbf	113,78
7	Mannheim Hbf	113,09
8	Wuppertal Hbf	112,85
9	Düsseldorf Flughafen	112,75
10	Essen Hbf	112,67

Table 2: The ten most accessible rail stations in Germany 2017

A look at the relative gains and losses in accessibility between 1991 and 2017 in Figure 6 and Table 3 shows a completely different picture, however. It becomes clear that the strongest gains in relative terms did mainly not occur in regions with high speed rail investment, but in East Germany, which saw substantial and comprehensive improvement of its dilapidated rail infrastructure in the two decades after German reunification. An almost tenfold relative increase of accessibility was estimated for the small town of Sonneberg in Thuringia, which had a peripheral boundary location within the former GDR rail network, adding to the longer travel times. Only one station among the ten stations with the strongest positive relative changes is not located in East Germany: Montabaur, an intermediate stop on the Frankfurt-Cologne HSR line that was added due to regional political pressure. While this shows that HSR can induce substantial accessibility improvements, the upgrading of conventional rail in East Germany has proven to be more effective in rising accessibility levels, though from a low initial state.

The comparison of timetables for West Germany has revealed that on many conventional rail lines, travel times have not changed at all between 1991 and 2017, and in some cases even increased by a few minutes. While this may be due to increased margins to offset delays, some stations show a substantial relative reduction in accessibility, which is in some cases due to both a shrinking regional population as well as deteriorating supply of rail connections. This particularly affects the 'inner periphery' regions of Eifel and Sauerland. Kleve, with a reduction of 14.8% is a specific case since the former local transboundary railway connection to the Netherlands has been cut, despite EU initiatives to (re)connect transport infrastructures internationally.

	Station	Accessibility change
1	Sonneberg(Thür)	+993.6%
2	Salzwedel	+595.6%
3	Leinefelde	+487.7%
4	Grimmenthal	+410.0%
5	Montabaur	+384.4%
6	Neuruppin Rheinsberger Tor	+383.7%
7	Wernigerode	+383.6%
8	Mühlhausen(Thür)	+355.0%
9	Meiningen	+322.3%
10	Parchim	+302.1%
	...	
440	Trier Hbf	-1.9%
441	Attendorn	-2.9%
442	Finnentrop	-5.7%
443	Bitburg-Erdorf	-6.5%
444	Kleve	-14.8%

Table 3: Strongest relative changes in gravitational accessibility

	Station	Accessibility change (Duisburg Hbf 1991 = 100)
1	Limburg Süd	+106,06
2	Vaihingen(Enz)	+82,63
3	Montabaur	+75,95
4	Frankfurt(M) Flughafen Fernbf	+53,44
5	Limburg(Lahn)	+45,12
6	Leinefelde	+44,46
7	Salzwedel	+41,57
8	Wolfsburg Hbf	+41,48
9	Siegburg/Bonn	+40,18
10	Hanau Hbf	+39,44

Table 4: Strongest absolute changes in gravitational accessibility

Table 4 shows absolute changes in accessibility between 1991 and 2017. It also contains the completely new stations Limburg Süd on the Cologne-Frankfurt HSR line and Vaihingen(Enz) on the Mannheim-Stuttgart HSR line, of which there are relatively few in Germany compared to other European countries. These achieved extremely high accessibility levels from the start and should offer highly attractive location conditions for knowledge-intensive firms. In terms of absolute gains, also other new HSR lines feature prominently, e.g. Wolfsburg Hbf on the Berlin-Hannover line. Interestingly, the first and longest new HSR link opened since 1991 between Hannover and Würzburg seems to have had less influence.

	Station	Accessibility change
1	Coburg	+66.02%
2	Sonneberg(Thür)	+59.12%
3	Bamberg	+20.23%
4	Lichtenfels	+20.05%
5	Erfurt Hbf	+19.03%
6	Kulmbach	+17.98%
7	Weimar	+15.98%
8	Neudietendorf	+15.03%
9	Kronach	+14.62%
10	Arnstadt Hbf	+12.01%
	...	
498	Mehltheuer	-0.05%
499	Plauen(Vogtl) ob Bf	-0.04%
500	Jena Paradies	-1.35%
501	Saalfeld(Saale)	-7.40%

Table 5: Strongest relative changes in gravitational accessibility after the opening of the Nuremberg-Erfurt HSR line in December 2017

With the available data we next modelled probable future changes in accessibility after the opening of two HSR lines currently under construction, the lines between Nuremberg and Erfurt, which will be opened in 2017 and is expected to reduce travel times between Berlin and Munich to about 4 hours, and the line between Stuttgart and Ulm, which is part of the Trans-European corridor from Paris to Bratislava. We show in this paper the expected accessibility changes resulting from the Nuremberg-Erfurt line in Figure 7 and Table 5.

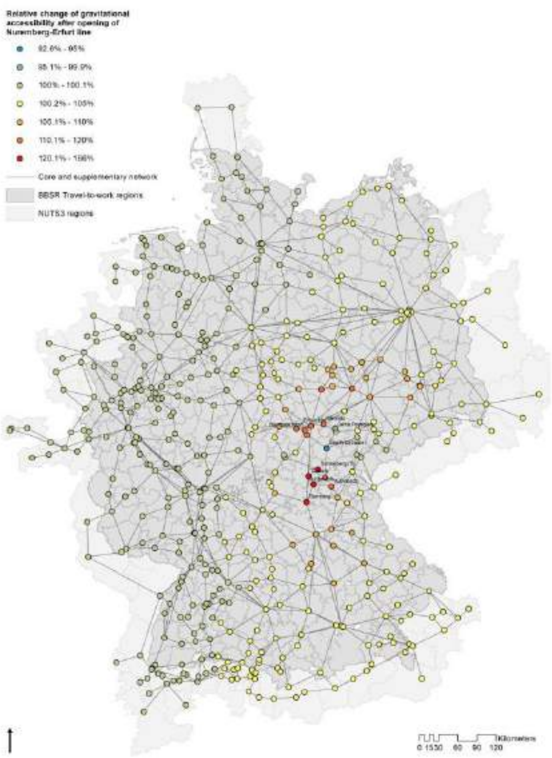

Figure 7: Relative change of gravitational accessibility after opening of Nuremberg-Erfurt line Source: own illustration using BBSR (2014)

The Nuremberg-Erfurt line will be the one of the first in the German context that leads to a substantial reduction of conventional long-distance rail on the existing main line between Nuremberg and Leipzig. Hence, the project creates winners and losers regarding accessibility. The towns of Jena, Saalfeld, and Lichtenfels, located on the existing line, will lose their frequent direct connections to Berlin and Munich, and will be relegated to regional trains to connect to the new HSR line in nearby Erfurt. However, the relative and absolute accessibility differences are small compared to the gains realised at other locations, among them once again the formerly peripheral Sonneberg and Coburg. In terms of rail accessibility, Sonneberg is clearly the region profiting most from German reunification. Lichtenfels even realises a relative gain, since the connection to the HSR with interchange in Coburg is still faster than the existing direct connections. However, the benefits for peripheral regions depend a lot on the stop frequency, which is still unclear in the case of Coburg but will likely be not more than a few stops a day.

To conclude, we can confirm our hypothesis that accessibility improvements of HSR stations have been significant, but with the major qualification that in relative terms, the upgrading of the East German rail network has had even stronger effects on gravitational accessibility. This is despite the replacement of long distance rail with regional trains in many parts of East Germany since 1991, which led to a reduction of the number of people living in travel-to-work regions directly served by long-distance rail (1991: 61.3 Mio.; 2017: 56.6 Mio.).

HSR effects in Germany have been more evenly spread, due to the more dispersed settlement structure and patchy implementation of HSR. This contrasts with the experiences of more spatially hierarchized countries like France and the UK, where effects are often directly dependent on realised travel time to the capital city (Chen and Hall, 2015).

5 INTERPRETATION AND OUTLOOK

What was treated as a premise for this paper we want to investigate in more depth in the future: The assumption that an induced change in public transport accessibility through High-Speed Rail can spread knowledge-intensive firms from metropolitan cores to smaller centres in the region and so help to promote regional economic development, and whether there are location-speific, temporal, or rail-service related factors that can influence this effect, particularly the local centrality of the station and the interconnectedness with other modes of transport. The accessibility analysis has revealed that there are a number of stations that received significant positive shocks in terms connectivity, such as Limburg Süd and Montabaur on the Cologne-Frankfurt line, Vaihingen(Enz) on the Mannheim-Stuttgart line, and Bamberg and Coburg on the future Nuremberg-Erfurt line, which should allow KI firms to settle.

In order to do this we propose a difference-in-differences approach, comparing the number of firms in knowledge-intensive branches, the number of their employees, and their revenues immediately around 'treated' stations as well as their city-regions with those in comparable regions that have not received HSR investment. Such firms datasets are readily available and present a rarely used source for regional economic analyses so far.

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ID 1675 | COORDINATION OF TERRITORIAL COHESION BY EUROPEAN TERRITORIAL COOPERATION AND TRANS-EUROPEAN TRANSPORT NETWORKS ‐ THE CASE OF CROSS-BORDER TRANSPORT

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1 INTRODUCTION

Territorial cohesion aims at fostering a more balanced and harmonious development of the European regions, making use of individual regional strengths for an overall EU benefit and linking them effectively to ensure a higher territorial integration of the Member States among others. Furthermore, cooperation across administrative borders is to be promoted actively (Commission of the European Communities 2008).

The two policies European Territorial Cooperation (ETC) and Trans-European Transport Networks (TEN-T) are intended to contribute to several aspects of territorial cohesion: the ETC Policy focuses on the support of European border regions, contributing to a European integrated territorial development and promoting the exchange of experiences across borders (European Union 2006). Therewith, the effects of the administrative borders shall be minimized and territorial cohesion shall be increased (European Commission 2005). The TEN-T Policy shall efficiently link the national transport networks of the Member States and make them interoperable in order to contribute to a borderless European territory. Additionally, remote regions are to be integrated to the residual territory (European Union 2012), bottlenecks in the European transport system are to be removed and missing-links to be constructed (European Parliament