Abstract: This article resumes and complements recent quantitative research on the impact of the Berlin railway system on the urban economy. Evidence suggests that access to intra-city rail lines has exhibited considerable impact on the value of urban land since at least as early as the late 19th century. Since then, access to the intra-city rail network has remained a significant determinant of urban land value, although the marginal impact has decreased over time. In contrast, the post-unification realignment of Berlin’s inter-city rail system has had, if any, only a weak impact on real estate markets. Micro-level simulations indicate that the new central station’s connection to the urban railway network is likely to have more pronounced, although relatively localized impacts, raising the question on how to balance the cost for infrastructure among landlords and society.

Keywords: Rail mega-projects, accessibility, land value, Berlin

JEL classification: R21, R40, R53

Version: September 2009

1 Introduction

The recent decades, both in the U.S. as well as in Europe, have brought forth a range of urban (re)development and revitalization initiatives for urban areas in need of external stimuli. International urban regeneration policies such as those stated in the UK Urban Task Force "Towards an urban renaissance" or the U.S. Department of Housing and Urban Development "The state of the cities" reports (DETR, 1999; HUD, 1999) usually put issues like the provision of attractive pub-
lic spaces, sophisticated architecture and urban design as well as the integration of arts and culture on the planning agenda. These policies, often targeted at downtown, waterfront or brown field developments caught in a downward spiral, frequently encompass public facilities as anchor structures that should illuminate their surroundings and serve as a catalyst for urban regeneration. Prominent examples are cultural or sport facilities with an “iconic” architecture, such as the famous Guggenheim Museum in Bilbao or Durban’s Kings Park Stadium built for the 2010 FIFA World Cup, among many others.¹ Some of the most striking and ambitious urban (re)development policies, however, have been implemented in the course of rail mega-projects with new, extended or renewed railway stations as focal nodes. Recent mega-projects like King’s Cross & St. Pancras in London, the new Vienna main station or Stuttgart 21 are hybrids of urban planning strategies and transport infrastructure policies. Unlike other (public) facilities, rail stations potentially exhibit a strong direct influence on the local urban economy in their function as central nodes of inter- and intra-city transport.

The impact of such large-scale rail projects therefore attracts the attention of various scientific disciplines, including economics which has recently rediscovered the dimension of space. The New Economic Geography (NEG) provides a conceptual and theoretical framework for modeling how spatial equilibrium distributions of economic activity emerge from the interaction of transport costs and agglomeration economies.² In a longer tradition, Urban Economics models the tradeoff between accessibility and transport costs from which the desirability of (abstract) urban space emerges. New Urban Economics (NUE) supplements traditional rent theory with a conceptual framework that accounts for real world settings such as the heterogeneity of space and urban polycentricity. Borrowing geoprocessing techniques from geodisciplines, empirical Urban Economic and

¹ For a background on “iconic” anchor structures and urban re-development strategies see Ahlfeldt & Maennig (in press).
NEG research over the recent decade has made considerable advances in providing empirical evidence for the validity of the theoretical frameworks. Empirical tests have exploited rail transport innovations as local shocks to intra-city accessibility (Ahlfeldt & Wendland, 2009; Gibbons & Machin, 2005), inter-city accessibility (Ahlfeldt & Feddersen, 2009; Coffman & Gregson, 1998) or intra-city access to inter-city rail lines (Ahlfeldt, 2009). Local economic stimuli, thereby, are not only expected from a pure welfare effect of a reduction in physical transport costs, but – more importantly – from bringing economic agents closer together and intensifying spatial interactions that give rise to productivity gains. Naturally, results of empirical analyses on the impact of transport innovations not only serve as a basis for the evaluation of theoretical frameworks, but also as a benchmark for expectations on the economic impact of rail mega-projects more generally. By providing direct access to other cities’ and regions’ economies, central rail stations – theoretically – qualify as the natural centers of gravity of cities. On the other hand, facilities and track beds occupy much of a city’s most productive space where economic density usually reaches the highest densities. The economic rationale for either extensive land consumption or expensive construction work for tunnels in order to shift facilities and lines below ground level therefore depends on the existence of sizable accessibility effects. If there are localized effects, in turn, the natural question arises on how to balance the respective costs between benefiting landlords and society. Not least, empirically calibrated models serve as a basis for the development of counterfactual scenarios that facilitate an evaluation of the impact of transport innovations from an ex-ante perspective.

Using this background, this article condenses and complements recent empirical evidence on the (urban) economic impact of large-scale rail projects in Berlin, Germany. It covers two core periods of railway reorganization. First, the late era of industrial revolution where Berlin became the capital of the German Reich and was one of the most dynamic cities in Europe, an equal to the leading metropolises in terms of population, economic and cultural prosperity and technological innovations that also comprised new rapid transit systems. The emerging underground- and suburban railway network represented a major
shock to the spatial equilibrium of the city and promoted development alongside lines and hub-stations, first of all within the area that is known today as the “City West”. The second focus is on the period after the unification of Berlin, when the city once again underwent major political, economical and cultural changes. The early 90s, when Berlin was chosen to become the capital of unified Germany and economic prospects were regarded very positively, was a time for extraordinary urban development projects like the new Government district or the office and shopping areas at Potsdamer Platz and Friedrichstrasse, among others. Due to the adverse economic performance within the Soviet zone of occupation and the remote isolated location of West Berlin during the period of division, Berlin’s rail infrastructure was found to be in need of modernization after Germany’s unification. A new mainline concept was implemented to connect Berlin to the German railway network encompassing the construction of a new north-south track, including a tunnel for the downtown section, a new central station as well as construction or extension and modernization of three additional mainline stations. The new mainline concept has been in operation since 2006 and has completely reshaped the pattern of intra-city access to inter-city rail connections. However, the new central station has yet to be fully connected to the underground rail network, which is expected to have an additional impact on the city structure.

2 The Early Days

By the end of the 19th century, Prussia in general and Berlin in particular had entered the second phase of industrialization, a period of rapid technological progress and economic growth. The organically-grown central business district (CBD) had been the center of economic activity for many centuries and was characterized by a dense structure and strict quarter-like functional segregation (Leyden, 1933). After the French-Prussian war and the subsequent foundation of the German Reich in 1871, Berlin held the status as the capital for both. This required the building of new administrative entities which were incorporated into the CBD. The growing administrative sector further contributed to the perceived
attractiveness of the area. Berlin, by the end of the century, represented a relatively typical so-called monocentric urban economy featuring an urban core with concentrated economic activity, surrounded by residential areas. In line with traditional rent theory developed in the 1960s (Alonso, 1964; Mills, 1967; Muth, 1969), land values continuously declined with distance and transport cost to the city center (Ahlfeldt & Wendland, 2008b).

As is typical for industrializing regions, the revolutionary changes in production technologies generated enormous demand for a labor force, drawing peasants and villagers into the fast-growing cities. During this period, Berlin evolved from a relatively small area with only 913,984 inhabitants in 1871 to a metropolis with 4,338,756 within an area of 87,810 ha in 1939 (Statistisches Amt der Stadt Berlin, 1970, 1988). The rapidly increasing demand for space triggered far-reaching processes of decentralization affecting big manufacturers and households simultaneously. The accompanied social, economic, and spatial dynamics sustainably changed the city’s inherent structure.

2.1 Citywide Effects

The evolution of the public railway network decisively stimulated the reorganization of spatial patterns. The 1870s marked the starting point of the emergence of Berlin’s intra-urban railway system, when the circular line (1877) was built to connect the termini of former regional lines, thereby transforming regional connection networks into systems of inner-city mass transportation. In 1882, the east-west connection joined several inner-city stations with the circular line and up to 1890 a huge area of Berlin and its surroundings was served (Borchert, Starck, Götz, & Müller, 1987). It was, however, not until the subsequent decades that gradually added stations created a highly developed and very dense network that fundamentally changed the pattern of urban accessibility. The suburban railway network was complemented by the inauguration and further development of the underground railway, which started in 1905 and was to come
to a total length of about 80 km and 103 stations by 1939.\textsuperscript{3} By that time, the combined rapid transit network had reached a size close to that of present-day Berlin. As shown by Ahlfeldt & Wendland (2008b), the newly developed rapid transport network led to an asymmetric evolution of travel time to the city center (see Figure 1) breaking up the previous almost concentric accessibility pattern.

**Fig. 1 Travel Time to the CBD in 1890 and 1936**

![Image](image_url)

Source: Ahlfeldt & Wendland (2008b)

It is evident that in terms of CBD accessibility, areas along the emerging network benefited, in relative terms, at the expense of those that remained unconnected. If traditional rent theory holds, the decline in opportunity cost of travel time should have led to an attraction of residents and firms and a demand-driven increase in land value until, in equilibrium, the rise in land value fully compensated for the travel time savings. More generally, the decline in effective commuting cost should promote urban decentralization as the cost of remoteness is considerably reduced along the new network.

Ahlfeldt & Wendland (2008b) show that these theoretical expectations were met by reality. Over a study period ranging from 1890 to 1936 they find that the marginal price effect of a 1 km reduction in distance to the city center declined from as much as 78\% to about 40\%, reflecting that peripheral locations gained considerably in valuation relative to the city’s core area. No clear trend, instead,

\textsuperscript{3} The combined length of the metro and suburban railway network added up to more 410 km, including 222 stations in 1939.
was found if accessibility to the city centers was considered in terms of travel time and the evolution of the railway network was accounted for. The average decline in land value per 1 minute reduction in travel time scattered around 15% (see Table 1). This pattern can be interpreted in a way that the opportunity cost of traveling remained roughly unchanged over time, but as the average velocity increased due to transport innovations, residents and firms were willing to bid higher prices for properties with larger distances to the center. On the basis of a counterfactual scenario for 1936 Berlin that corrects for the price effects of transport network improvements, Ahlfeldt & Wendland (2008b) show that at least 50% of the 1890-1936 decentralization movement was attributable to the rapid transit network. The counterfactual scenario further suggests that without the evolution of the network, decentralization would have hardly exceeded the 1896/1900 level. This finding is in line with the estimates on the marginal effect of travel time reduction displayed in Table 1, which show a notable decline from 1890 to 1896, but no systematic decrease subsequently.

Notably, the decentralization movement is not explained entirely by travel time reductions. Besides the improvements in the network of buses and streetcars and a gradual increase in availability of individual transport, decentralization was certainly promoted by increasing demand for large industrial areas that could not be satisfied within downtown areas and a range of urban development policies. As noted above, Berlin during the first half of the 19th century had already experienced enormous economic growth accompanied by huge population gains. In anticipation of further development, planning authorities decided to widen and completely restructure large parts of the city, even including surrounding communities and towns. The so-called Hobrecht-Plan was implemented in 1862 and led to far-reaching building and reorganization processes (Hegemann, 1930). It combined the intensification of residential density surrounding the CBD with a concept of mixed-use development. Relatively large proportions were dedicated to commercial use, especially along the representative boulevards, which in many cases led radially away from, or in circles around, the old CBD. These efforts facilitated residential decentralization and a redistribution of market opportunities for businesses.
### Tab. 1  Marginal Land Price Effect of CBD Accessibility 1890-1936

<table>
<thead>
<tr>
<th></th>
<th>1890</th>
<th>1896</th>
<th>1900</th>
<th>1904</th>
<th>1910</th>
<th>1929</th>
<th>1936</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 km Reduction in</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td>77.5%</td>
<td>58.3%</td>
<td>52.0%</td>
<td>50.9%</td>
<td>45.3%</td>
<td>40.5%</td>
<td>39.7%</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(0.75)</td>
<td>(0.67)</td>
<td>(0.66)</td>
<td>(0.58)</td>
<td>(0.52)</td>
<td>(0.51)</td>
</tr>
<tr>
<td><strong>1 min Reduction in</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Travel Time</td>
<td>17.5%</td>
<td>15.0%</td>
<td>12.8%</td>
<td>14.0%</td>
<td>12.4%</td>
<td>15.6%</td>
<td>15.3%</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(0.86)</td>
<td>(0.73)</td>
<td>(0.80)</td>
<td>(0.71)</td>
<td>(0.89)</td>
<td>(0.87)</td>
</tr>
</tbody>
</table>

Notes: Own calculations. Estimates obtained from OLS regressions of log of land value in RM/sqm on distance or travel time to the CBD. All estimates satisfy significance criteria at the 1% level. See for data description and CBD definition Ahlfeldt & Wendland (2008b).

### 2.2 Localized Effects

The new transport network not only impacted on the city structure in terms of raising the attractiveness of the urban periphery relative to the core, but also had a significant local impact in proximity to the newly inaugurated rail stations. It is important to note that the traditional rent theory builds on the overly restrictive assumption of homogenous, featureless space. However, as discussed by Cheshire & Sheppard (1995), among others, real world prices for urban land depend on a battery of location (dis)amenities, public services and neighborhood attributes. Most importantly, accessibility, the fundamental determinant of a city structure, according to the rent theory, directly depends on the availability of transport infrastructure. Residents and firms trade the price of land not only against the distance to the city center, but also against distance to nearby railway stations whose value consequently capitalize into prices. Ahlfeldt & Wendland (2009), controlling for the overall decentralization process, show that over the period 1890-1936 land values significantly increased when the distance to the nearest rail station was reduced as the network became denser. They find that the value of land increased by up to 2.5% for a 100 m reduction in distance to a railway station.

Of the localized changes occurring around new rail stations, the area that is known today as the “City West” certainly underwent the most striking development. This area represents an early example for how a considered urban development strategy embedded into a large-scale infrastructure project may promote the rapid transformation from an almost undeveloped area into a dense cluster of economic and cultural activity. The roots of the emergence of this sub-
center lie in the 1870s when it was Bismarck’s explicit wish and plan to transform Kurfürstendamm, a corduroy road connecting the historic center with the Grunewald hunting lodge, into a representative boulevard. By 1886 road works were finished and the development of representative villas began. By 1910 almost all properties along the new boulevard had been developed, however, they were still mainly used for residential purposes. The following years brought a gradual intensification of land use and an attraction of cultural and economic activity. In particular, the area emerged as the leading center for luxury retailing. Finally, during the 1920s, anecdotal evidence suggests that Kurfürstendamm had become the symbol of the roaring 1920s in Berlin (Metzger & Dunker, 1986).

Indeed, these notions are supported by the evolution of land values within the area. Figure 2 provides a non-parametric locally weighted regression estimate of the unknown non-linear relationship between normalized land value (to the median) and the distance to Breitscheidplatz within a 2,000 m impact area.

**Fig. 2 “City West” Gradients**

![Graph showing land value gradients](image)

Notes: Own calculations. Results obtained from locally weighted regression of normalized (to median) land value on distance to Breitscheidplatz (m). See for data description Ahlfeldt & Wendland (2008b).

It is evident that an enormous increase in area valuation occurred between 1910 and 1929 and that by 1929 the area had emerged as a strong sub-center with proximity effects capitalizing into property prices at least as far as within
1,000 m. Due to missing records on historical land values it is not possible to isolate the take-off period more precisely. The sub-center over the considered period not only gained in attractiveness relative to its immediate surroundings, but also in comparison to the historic center. Table 2 compares peak land values at Breitscheidplatz with those at Friedrichstrasse along the road stretch from Unter den Linden (U.d.L.) to Leipziger Strasse, which exhibited the highest land values during the observations period. While peak values at Friedrichstrasse increased by about one half, the respective increase at Breitscheidplatz amounted to as much as a factor of 10, with the largest gains occurring between 1910 and 1929.

Tab. 2 Peak Land Values at Friedrichstrasse and Kurfürstendamm

<table>
<thead>
<tr>
<th></th>
<th>Peak Land Value (Relative to Initial Period in Parentheses)</th>
<th>1890</th>
<th>1896</th>
<th>1900</th>
<th>1904</th>
<th>1910</th>
<th>1929</th>
<th>1936</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friedrichstrasse</td>
<td></td>
<td>1700</td>
<td>1825</td>
<td>1895</td>
<td>1920</td>
<td>2235</td>
<td>2000</td>
<td>2500</td>
</tr>
<tr>
<td>(U.d.L. – Leipziger Str.)</td>
<td></td>
<td>(1)</td>
<td>(1.1)</td>
<td>(1.1)</td>
<td>(1.3)</td>
<td>(1.3)</td>
<td>(1.2)</td>
<td>(1.5)</td>
</tr>
<tr>
<td>Kurfürstendamm</td>
<td></td>
<td>120</td>
<td>192.5</td>
<td>302.5</td>
<td>372</td>
<td>475</td>
<td>1200</td>
<td>1250</td>
</tr>
<tr>
<td>(Breitscheidplatz)</td>
<td></td>
<td>(1)</td>
<td>(1.6)</td>
<td>(2.5)</td>
<td>(3.1)</td>
<td>(4.0)</td>
<td>(10.0)</td>
<td>(10.4)</td>
</tr>
</tbody>
</table>

Notes: Own calculations. Land values given in nominal RM/sqm. See for data description Ahlfeldt & Wendland (2008b).

The impressive evolution of the Kurfürstendamm area has to be considered alongside the background of the evolution of the rail network architecture discussed above. Even before road works along Kurfürstendamm were finished, Bahnhof Zoo, which lies adjacent to Breitscheidplatz and later became the central station of the city during the period of division, was connected to the major east-west rail line in 1882. Ten years later, Bahnhof Zoo was being served by 7 streetcar lines, although the development of residential buildings had just begun. Another 10 years later, in 1902, the first underground railway line connected the area to the city center and even the second railway line, inaugurated in 1905, ran through the area. Although the area still exhibited a residential character, it evolved to the by far most important transport node outside the city’s core region.

There is a long tradition in economic geography that dates back to at least Harris (1954) in modeling the relative centrality of a location as the distance
weighted sum of e.g. population. Building on this tradition, Ahlfeldt & Wendland (2008a) employ a refined multi-level market potential indicator in order to assess the centrality of each of Berlin’s 15,937 housing blocks with respect to the population of all other housing blocks in account of the rail network architecture (see A1 in the appendix for a formal expression). As a key-innovation, this accessibility indicator facilitates distinct transport costs for walks to and from stations and rides on the rail network. Figure 3 visualizes centrality as represented by this accessibility indicator for 1875 and 1910. It shows that, by 1910, in terms of network centrality, the area around Breitscheidplatz had become one of the leading city regions, years before the attraction of economic and cultural activity began.

**Fig. 3 Rail Market Potential 1875 and 1910**

Table 3 shows how the network-based access to city markets at Breitscheidplatz evolved in relation to the crossroads of Friedrichstrasse and Unter den Linden during the period 1875-1935. Most interestingly, besides a long-term catching-up process, it turns out that from 1910 to 1920 the area, in these terms, even outperformed the traditional center. Notably, this was precisely the decade that preceded the “golden era” of Kurfürstendamm during the 1920s. As expected, the largest improvements to accessibility occurred after 1882 when the east-west rail line opened and after 1902 and in 1905 when the first two underground rail lines of the city were inaugurated. The decline in relative
accessibility after 1920 mainly reflects the inauguration of two new north-south underground lines crossing the historic center.

**Tab. 3 Relative Rail Market Potential 1875 – 1935**

<table>
<thead>
<tr>
<th>Year</th>
<th>1875</th>
<th>1880</th>
<th>1885</th>
<th>1890</th>
<th>1895</th>
<th>1900</th>
<th>1905</th>
<th>1910</th>
<th>1920</th>
<th>1925</th>
<th>1930</th>
<th>1935</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>0.1%</td>
<td>0.5%</td>
<td>23%</td>
<td>28%</td>
<td>36%</td>
<td>48%</td>
<td>99%</td>
<td>126%</td>
<td>119%</td>
<td>68%</td>
<td>61%</td>
<td>60%</td>
</tr>
</tbody>
</table>

Notes: Own calculation. See for data description and generation of rail market potential Ahlfeldet & Wendland (2008a)

Clearly, the early investments into the connectivity of the Kurfürstendamm area are hardly explainable by passenger demand only. Intuitively, one would expect the focal node of a transport network to be within the existing core of economic activity. From the historical center, the other major sub-centers, Hermannplatz and Bernauer Strasse, could also have been connected more easily. However, despite their shorter distance from the historical center, these centers were not connected until the end of the 1920s, almost 30 years after Kurfürstendamm, although underground lines would have run through very densely populated areas. Even the obvious underground line below the traditionally most important retail and commercial boulevard, Friedrichstrasse, was not developed until the mid-1920s. The selection of the first underground rail paths was clearly determined exogenously to the distribution of urban economic activity and was a result of a mixture of political interest in urban development and private economic interests like real estate speculation (Erbe, 1987). The declared intention of planners and property developers was to promote further investments and building (Bohm, 1980).

After all, the historic evidence demonstrates the potential of a combined urban development and a large-scale transport infrastructure policy to promote demand for land and attraction of economic activity. The widely acknowledged duo-centric structure of present-day Berlin, to some degree reflects the tangible long-term effects of these policies, although further strengthening of the Kurfürstendamm area was certainly promoted during the period of the city’s division.
3 The Present Day

The post-WWII period of city separation had a significant impact on the city’s transport geography, in particular within West-Berlin. Even before Berlin’s division the largest part of the underground network was within the western part of the city, not least as a result of the integrated transport and urban development policies described above. After separation this imbalance increased. Since the eastern Municipal Transport Services managed the suburban railway network, the western authorities naturally focused on the improvement of underground infrastructure. One ambition of the authorities was to meet the need of the reorganization of the transport network with respect to the Kurfürstendamm area that emerged as the predominant city centre of West-Berlin (Merritt, 1973). The reorganization and extension of the underground network in West-Berlin involved relatively large investments, which were facilitated by monetary transfers from the FRG to ensure comparable living standards in the exclave. In contrast, the suburban railway system run by eastern transport authorities experienced a continuous decline in significance. Mainline rail infrastructure and facilities suffered considerably from the city’s isolation and the loss of access to the hinterlands during the period of division. At the same time, rail infrastructure within East-Berlin suffered from the adverse economic performance within the Soviet zone of occupation so that after unification Berlin’s rail infrastructure was found to be in considerable need of modernization. Urban rail networks needed to be re-integrated and, in particular the suburban rail network had to be renovated to meet modern standards. At the same time, the unified city required a major modernization of its mainline infrastructure in order to face the natural passenger flows between the capital and the rest of the unified country.

3.1 Localized Effects

The re-integration of the city’s urban transport networks occurred in two stages. First, shortly after unification, network links and temporary improvements facilitated the first joint transport line map since 40 years. Second, rail links between West-Berlin and the hinterland had to be fully recovered, which after 30 years out of traffic effectively meant the construction of new tracks, electric plants and
stations (Book, 1995). This stage was virtually completed in 2002 when the suburban ring line was back in full operation. Mainly due to the improvements made to the underground network in West-Berlin during the post-war period, the network with 275 stations and 475 km of overall network length had considerably grown compared to pre-war Berlin.\(^4\) This relative increase in the network size potentially induced an increase in network externalities and, hence, a raise in the value of having a station in close proximity. On the other hand, the broad availability of individual transport as an alternative transport mode should have reduced the relative importance of the rapid transport network. Comparing the estimates of Ahlfeldt (2008a) to Ahlfeldt & Wendland (2009), the latter effect seems to be clearly dominating. Accordingly, the marginal price effect of a 100 m reduction in the distance to the nearest urban rail station fell from as much as 2.5% to about 0.4%. This effect, however, is still highly statistically significant and relatively large compared to the impact of other location attributes, e.g. natural amenities like green and water spaces or public facilities like schools.

While the modernization of the intra-urban rail system was mainly a task of reintegration and renovation, at the beginning of the 1990s it was decided that the mainline rail system had to be reorganized entirely. The key element of the new concept was the development of a new north-south railway track, including a tunnel for the downtown section. The intersection of the new north-south with the old east-west track was chosen to be the location of Berlin’s new central station, which was timely inaugurated for the football world championship in 2006. The station was designed by the prominent architecture firm GMP and involved investments that amounted to approximately €1 billion for facilities and feeder lines. In total, the modernization of Berlin’s railway tracks cost over €4 billion (Hops & Kurpjuweit, 2007). The new central station “Hauptbahnhof” – representing one of Europe’s largest and most modern interchange stations – and the huge investment amounts stand exemplarily for the post-unification euphoria at the beginning of the Nineties when Berlin’s economic perspectives

\(^4\) The combined length of the metro and suburban railway network added up to more 410 km, including 222 stations in 1939.
were still very positively regarded. Two more mainline stations were developed along the new railway track at the intersections with the inner ring line: “Gesundbrunnen” in the north and “Südkreuz” in the south. Moreover, at the western periphery of Berlin, “Bahnhof Berlin-Spandau” was considerably extended and modernized. The new stations along the north-south track were to provide additional transport capacities in order to disburden the existing mainline stations “Bahnhof Zoo” and “Ostbahnhof”, which had served as central stations within the formerly separated parts of the city. In particular Bahnhof Zoo, which after unification became Berlin’s most frequented station due to its proximity to the West-Berlin core area around Kurfürstendamm and its good connections to the urban railway network, was considered to be undersized in light of only three platforms and a total of 150,000 passengers served per day. Due to the characteristic configuration formed by the north-south, east-west and the northern ring track, the new transport plan was named the “mushroom” concept.

At the beginning of July 2005, however, the rail carrier Deutsche Bahn AG quite unexpectedly announced that instead of allocating transport capacities more or less equally among the two mainlines the vast majority of long-distance trains would cross Berlin on the newly developed north-south line after the implementation of the new transport plan on March 28, 2006. Even more surprisingly, it was decided that the remaining trains approaching and leaving the new central station via the east-west track would no longer stop at Bahnhof Zoo, thereby reducing its significance to a regional dimension (Hasselmann, 2005). This decision raised strenuous protests from various business and passenger lobbies, which is in line with the theoretical predictions of NEG models that access to other regions’ markets is a significant determinant of local economic performance (Fujita et al., 1999). If accessibility to other regions’ markets significantly impacts on the economic performance of regions and cities, then city areas close to transportation links like highways, airports or train stations should particularly benefit from regional integration. Eventually, the spatial interactions between economic agents that involve inter-city trips also require journeys to and from transport nodes within the cities, which can account for quite a considerable proportion of travel time.
Given the unexpected loss in accessibility to regional markets, which at least to the effective degree were unexpected, and the strong opposition of business lobbies, one would expect a considerable impact on location desirability within the catchment area of Bahnhof Zoo, which, in turn, should lead to a significant downward adjustment in real estate prices. Similar adjustments should have taken place in the vicinity of Ostbahnhof, which was also affected adversely by the new transport plan, and – in the opposite direction – within the catchment area of stations benefiting from the reorganization.

Our identification strategy for potential adjustments, builds on Ahlfeldt (2009). The evolution of property prices is therefore tracked within the catchment area of stations defined as a 2 km distance ring (Gibbons & Machin, 2005), in relation to the rest of Berlin (control area). The empirical strategy, which is described in more detail in the appendix (see A2), makes use of the full set of all developed properties sold between January 1, 2000, and December 31, 2008, and controls for a broad range of property characteristics as well as unobserved time-invariant location attributes while facilitating general adjustments in the core-periphery structure. Figure 4 visualizes how price differentials (log differences) in adjusted land prices per square meter of land between the catchment areas of Bahnhof Zoo (Hauptbahnhof) and the control area changed over time. Notably, there is a continuous downward trend within the catchment area of Bahnhof Zoo. However, no particular adjustment in the trend is evident around the crucial period between the announcement and implementation of the new transport plan (July 2005 to March 2006). To the contrary, evidence suggests a recovery of the area after 2007, indicating that any adverse real estate price effects of the closure of Bahnhof Zoo, if existent, were dominated by alternative forces. Similarly, Figure 4 shows no upward adjustments in price trends around 2006 within the catchment area of Hauptbahnhof, either indicating that price effects of the new transport plan were negligible or that the effects had been anticipated and capitalized into prices before the observation period began. Figure 5 shows smoothed (relative) trends for all mainline stations affected by the new transport plan on the background of the time of announcement and implementation (see A3). Again, the pattern is not very persuasive with regard to
price adjustments. While around Bahnhof Südkreuz there is hardly any impact on the relative area valuation observable, the neighborhood of Ostbahnhof experiences a continuous demand-driven increase in property prices despite the reduction in significance of the mainline station. Within the neighborhood of Bahnhof Gesundbrunnen, which clearly benefited from the new transport plan, there is also a continuous increase in relative prices observable. However, no considerable adjustments take place where expected and there is even a downward adjustment in the trend starting during the post-implementation period. It should be noted, however, that the impact of the announcement of the new transport plan should clearly be expected to be more pronounced for the stations that were adversely affected compared to those benefiting from the realignment. While a rise in significance for the latter could long be anticipated – despite an uncertainty about the final extent – the moment of surprise of the new plan effectively lied in the extent to which Ostbahnhof and in particular Bahnhof Zoo were disconnected from the mainline network. The positive trend around Bahnhof Gesundbrunnen as well Bahnhof Spandau (2002) could therefore be interpreted as the result of a long-run adjustment process. The additional information from the announcement and implementation of the plan would then have simply been too small to yield significant impacts.

From the identification strategy discussed above it is not possible to reject a significant impact of the mainline reorganization on property prices. It is virtually not possible in practice to perfectly separate property price effects arising from the realignment from all other (unobservable) changes occurring in the neighborhood of stations. E.g. the downtown areas around Bahnhof Zoo might have suffered anyway from the (re)emergence of new office and shopping areas within the historical center in Mitte. Similarly, our findings for the neighborhood of Ostbahnhof are net-effects of the change in mainline accessibility and ongoing urban (re)development. It is, however, possible to conclude that the localized impact on property prices arising from the pure change in mainline accessibility seems to be relatively small in relation to the overall neighborhood changes occurring around stations.
3.2 Citywide Effects

In contrast to metrorail stations, mainline stations provide services for a much larger sphere of influence, potentially covering the whole city. An impact of mainline accessibility may therefore not only be detected on the basis of
comparison between the immediate station neighborhoods and the rest of the city. The reorganization of the Berlin mainline network potentially affects the relative attractiveness of locations that experience a rise or fall in accessibility at the level of the whole city. If real estate markets traded the value of urban land against mainline accessibility, we would expect a significant increase in land value within areas that were positively affected compared to those that were hit adversely. Identifying positively and negatively affected areas, however, is not straightforward due to the relatively complex reorganization of the network architecture. As proposed by Ahlfeldt (2009) we deal with the complementary relationship between mainline stations by assuming that residents use the nearest mainline station for all connections served by that station and the city’s major rail hub for the remaining connections. Note that both Bahnhof Zoo and Ostbahnhof are treated as central rail hubs during the period prior to the network reorganization, while during the post-period only Hauptbahnhof holds this status. Building on this rationale the average distance to a mainline connection can be calculated by weighting the distance to the nearest station with the fraction at total connections and distance to the (nearest) rail hub with the remaining fraction. A formal expression of this definition is in the appendix (A4).

Figure 6 shows the location of all stations considered in the study on the background of spatially interpolated changes in average distance to mainline connections. As expected, the areas that experienced the strongest decline in access to mainlines are around the formerly most important stations Bahnhof Zoo and Ostbahnhof, particularly extending to the west and east (light shaded). Central areas and areas to the north, south and north-west benefit from the new stations Hauptbahnhof, Gesundbrunnen and Südkreuz and the extension of Spandau, which at least partially compensates western areas for the closure of Bahnhof Zoo.
Having identified the positively and negatively affected areas, the relative change in area valuation that came with the implementation of the new plan can be identified by a simple difference-in-difference strategy, in which we differentiate over time (before/after) and area (positive/negative). As an indicator of land value we use property transaction prices per square meter of land, adjusted for structural characteristics and aggregated to the level of traffic cells (Verkehrszellen). Separation of structural characteristics from the residual price paid for the value of land is done by standard hedonic regression as described in the appendix and in more detail in Ahlfeldt (2009). Aggregation of adjusted land prices to traffic cells is done for the periods from October 1, 2002, to June 30, 2005, (before) and April 1, 2006, to December 31, 2008, (after). This definition ensures that we compare the spatial structure of land prices before the final announcement of the transport plan to the situation after the implementation, thereby avoiding anticipation effects of the announcement entering the before pe-
period. Furthermore, periods are chosen in a way that the number of transactions that occurred between both periods is comparable. Again, a full record of all property transactions of developed properties is used for the statistical analysis. Table 4 compares the situation before announcement and after implementation of the new transport plan on the basis of 293 out of 338 traffic cells (Verkehrszellen) in which transactions occurred in both periods.

**Tab. 4 Average Distances and Land Prices**

<table>
<thead>
<tr>
<th></th>
<th>Full sample</th>
<th>Positive</th>
<th>Negative</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before (1)</td>
<td>After (2)</td>
<td>Before (3)</td>
<td>After (4)</td>
</tr>
<tr>
<td>Mean distance</td>
<td>7.00</td>
<td>7.41</td>
<td>7.69</td>
<td>6.30</td>
</tr>
<tr>
<td></td>
<td>(5.9%)</td>
<td>(-18.1%)</td>
<td>(25.3%)</td>
<td></td>
</tr>
<tr>
<td>Mean land price ($/m²)</td>
<td>430.84</td>
<td>420.17</td>
<td>403.50</td>
<td>401.50</td>
</tr>
<tr>
<td></td>
<td>(-2.5%)</td>
<td>(-0.5%)</td>
<td>(-3.7%)</td>
<td></td>
</tr>
<tr>
<td>Sample</td>
<td>293</td>
<td>293</td>
<td>118</td>
<td>118</td>
</tr>
</tbody>
</table>

Notes: Own calculation. Percentage changes between periods in parentheses. Distance and land price and are aggregated to traffic cells as described in Ahlfeldt (2009). Positive (negative) is the group of traffic cells that experiences a reduction (increase) in distance between the periods before and after the intervention. The periods before (after) range from October 1, 2002 (April 1, 2006), to June 30, 2005 (December 31, 2008).

A first natural question to ask in quasi-experimental work of this kind is whether the innovation did what we expected it to do, namely reduce the mean distance to stations within areas that were positively affected and to increase distance in areas that were positively affected. Based on the figures presented in Table 4 this notion can be affirmed. Mean distance to a mainline connection decreased from 7.69 km to 6.30 km within a sample of 118 traffic cells that were positively affected. In percentage terms this corresponds to a reduction of about 18.1% (3 and 4). In contrast, as much as 175 traffic cells were worse-off with the new network structure, experiencing an increase in mean distance from 6.52 km to 8.17 km, which corresponds to a relative increase of 25.3% (5 and 6). The difference in mean distances between the two groups increases by as much as 3.05 km (7). A regression based t-test clearly points to high statistical significance. In terms of average mainline accessibility it is further notable that the “positive” sample switches from being relatively disadvantaged to being advantaged compared to the “negative” sample, and the other way round. At the city level the new transport plan has led to an overall decline in average accessibili-
ty as suggested by the relatively large number of traffic cells in the “negative” group and the increase in mean distance from 7.0 to 7.41 km, which correspond to an increase of 5.9%, for the whole sample (1 and 2).

The Second row of Table 4 shows changes in mean prices in both groups that are also in line with expectations. There is a modest reduction in mean price for the “positive” group of about 2€ per square meter or 0.5% (3 and 4). Although the “negative” group continues to be – on average – higher valued than the “positive” group, the decline in mean price of about 17€ per square meter or 3.7% is relatively large compared to the “positive” group (5 and 6). Relative to the “negative” group, the “positive” group experiences a rise in land price per square meter of about 15€ (7), which appears quite substantial in relation to an average land price of around 400€ per square meter. It has to be noted, however, that a regression-based t-test does not reject this effect to be statistically significant different from zero at conventional levels. Evidence for an impact of mainline accessibility on land prices, hence, is very weak at best. A similar result is obtained if the relationship between changes in land prices and changes in average distances are investigated (Ahlfeldt (2009).

On the basis of the evidence presented so far it has to be concluded that either mainline accessibility exhibits a relatively limited impact attractiveness of location, or the effects of the network organization had already been anticipated before the beginning of the observation period. While on the one hand, plans date back to the early 90s, it is on the other hand unlikely that effects had been fully anticipated within the entire city area prior to the final announcement. This announcement, as discussed, held a considerable amount of surprise, which was expressed in strenuous protests from business and passenger lobbies. It was argued that the degree of reallocation, and in particular the complete disconnection of Bahnhof Zoo, was not reasonable from a transport economics perspective. Accordingly, the heavy decline in access to the inter-city lines within the Bahnhof Zoo catchment area, including hundreds of thousands of residents, could hardly be justified by a 4-minute reduction in travel time for passengers departing from the eastern parts of the city in a western direction (Ataman,
2005). Since one would expect a major rail carrier to act rationally from a transport economics perspective, evidence in support of the “irrationality” argument of opponents would also support the notion that the final transport plan could hardly be foreseen and anticipated.

As discussed, Table 4 suggests an overall decline in mainline accessibility in terms of affected traffic cells. Since population and employment are not necessarily distributed evenly across traffic cells, this by no means implies an effective reduction in accessibility from the perspective of residents and employees. In Table 5, therefore, the groups of positively and negatively affected areas are expressed in terms of population (2005) and employment at workplace (2003).\(^5\) The figures, however, again support the fact that the vast majority of the population and employees were worse-off by the network reorganization. As shown in the first row, there are almost 800,000 inhabitants (3) and almost 200,000 employees (6) more within the “negative” group than in the “positive” group, which means that approximately 60% of residents and employees now have larger average distances to mainline connections. This figure even increases to about 64% if mainline accessibility is expressed in terms of travel time along the rapid transit network (U- and S-Bahn) and corresponding walks to stations.

**Tab. 5 Affected Population and Employment**

<table>
<thead>
<tr>
<th>Change in average</th>
<th>Population</th>
<th>Employment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive (1)</td>
<td>Negative (2)</td>
</tr>
<tr>
<td>distance (km)</td>
<td>1,269,680 (38.1%)</td>
<td>2,065,432 (61.9%)</td>
</tr>
<tr>
<td>travel time (min)</td>
<td>1,188,177 (35.6%)</td>
<td>2,146,935 (64.4%)</td>
</tr>
</tbody>
</table>

Notes: Own Calculation. Percentages of total population and employment are in parenthesis. Travel time refers to combined walks to nearest rapid transit station and shortest train ride along the network. See for a more detailed description Ahlfeldt (2009).

\(^5\) All employees who contributed to social insurances are considered.
These findings support the argumentation of numerous opposition groups that the access to mainlines has become inferior for the majority of residents as a result of the new transport plan and that the situation has been unnecessarily aggravated by the complete disconnection of Bahnhof Zoo. It also highlights that, in terms of maximizing access to customers, the new transport plan is not very efficient and that real estate markets were therefore unlikely to anticipate the final adjustment. One of the possible explanations frequently quoted by the opponents of the new transport plan was that the Deutsche Bahn AG aimed at concentrating passengers at the new central station Hauptbahnhof in order to promote its success as one of Berlin’s major shopping malls, with more than 15,000 square meters of shopping area. It should, however, be noted that the concerns of business lobbies about the Zoo area experiencing a major decline in attractiveness following the disconnection of the station were unjustified. After all, there is – despite the huge dimensions of the reorganization – remarkably little evidence for significant real estate price effects of mainline accessibility. As discussed, the absence of significant effects is unlikely to be explained entirely by anticipation effects. Apparently, the relatively low frequency of long-distance train rides leads to residents strongly discounting the value of mainline stations on distance/travel time. Mainline stations, accordingly, are public facilities with a rather global character, in economic terms justifying a relatively peripheral location where opportunity cost of space is relatively low. Regarding rail mega-projects and related ambitions of promoting urban development and providing economic stimuli in neglected areas, these findings imply that improvements in mainline accessibility by itself will hardly trigger considerable impacts. Instead, an integrated urban planning strategy that goes beyond the scope of a purely transport economic rationale is strongly recommended.

3.3 The Outlook

Having engaged with the impact of rail mega-projects in Berlin during two pioneering periods of rail network (re-)development, some words are due on future developments of rail infrastructure. The initial development of the intra-urban railway network in the late era of industrialization as well as the re-development
of the inter-city network after unification were brought forth under outstanding economic conditions when Berlin was catching up to the leading European metropolises or – as in the case of post-unification Berlin – was expected to do so. Meanwhile, this euphoria has made way for a considerable economic disillusion. Forecasts point to a stagnating population during the next decades at best. It is, therefore, not the time for new rail mega-projects. The probably most important extension to the existing networks, consequently, still emerges out of the need to connect the new central station Hauptbahnhof to the existing urban railway network. Placed on a strip of land close to where the Berlin Wall stood, the station, despite its geographic centrality, was built into a largely undeveloped area, only connected to the urban railway network through the suburban east-west railway track. Two major railway network extensions are currently being considered. First, a northern connection to the circular line of the suburban railway system of approx. 1.7 km length is scheduled. According to the current plans, this extension would not be accompanied by the inauguration of new stations. The second promising project is the eastern connection to the metro line 5 (U5) at Alexanderplatz via "Brandenburg Gate" and the Boulevard "Unter den Linden". The first section from Hauptbahnhof to "Brandenburg Gate" has recently been inaugurated, temporarily labelled U55. As a further extension, this line may continue westwards through the residential area of the Moabit district until connecting to the suburban circular line at the station "Jungfernheide". Following these plans, metro line 5 would be extended in total by approximately 9 km and 10 stations, of which 8 would be completely new.

The new central station Hauptbahnhof clearly serves as an anchor structure within surroundings that, to a large extent, still need to be (re)developed. Given the limited evidence on economic stimuli of mainline connectivity it is an inter-

---

6 The Federal Office for Building and Regional Planning projects a population of 3,316,600 in 2020 and 3,070,400 in 2050.

7 The structure plan also considers extension of the line to Tegel Airport and further northwards. However, due to the scheduled closure of Tegel Airport this extension has become quite unlikely and will not be further considered. Effectively, even the westward extension from central station is seriously being questioned.
esting question how the development of Hauptbahnhof to an intra-urban rail hub would impact on location attractiveness. Empirical evidence suggests that urban rail stations – in Berlin and elsewhere – exhibit a pronounced, although localized impact. As demonstrated by the case of Kurfürstendamm during the 1920s, intra-urban rail hubs may foster the agglomeration of urban economic activity.

This issue is addressed by Ahlfeldt (2008b), who develops an empirical NUE model that connects the 15,937 city blocks on the basis of the metro- and suburban railway network in order to predict the impact of network alterations on the value of urban land. In line with existing evidence, the model predicts a significant and localized impact around the newly developed rail stations. Furthermore, the model predicts the impact to considerably spread along the existing network, reflecting increasing demand for land where passengers save travel time by adjusting their routes to the newly available alternatives. Figure 7 shows the outcome of the micro-level simulation in terms of predicted changes in standard land value (Bodenrichtwert) in €/m² for a scenario with the north-, west- and eastbound extensions. Clearly, the model predicts the largest impact within the business areas in the historical city center, in particular along the Boulevard Unter den Linden. Selected properties may experience an increase in standard land value of up to 120 €/m². As expected, the model also predicts a considerable relative increase in land value around Hauptbahnhof of up to more than 10%. Since land values, however, are generally lower than in the core city areas, the increase in absolute terms is more moderate as presented by Figure 7.
From the model results presented above, it is possible to infer on the aggregated value added to landlords owning about 557,000 registered properties in Berlin (2007). Based on the area covered by these properties, the total value added in aggregate amounts to slightly more than 175 Mio €. More interestingly, it can be shown that this increase in wealth is distributed highly localized. Based on the predicted values of Ahlfeldt (2008b), we therefore calculate the Lorenz curve in order to visualize the percentage of total value added for a given percentage of developed land area (See Figure 8). The Lorenz curve (solid line) has a clearly convex shape, revealing the inequality in the distribution, which becomes particularly apparent in comparison to the line of equality.

---

8 Note that the model does not allow for a decline land value. While there is certainly a network externality raising net aggregated land value, some locations may suffer from less demand due to increased attractiveness of competing locations. Therefore this figure should be interpreted as an upper-bound estimate of aggregated impact.
(dashed line). For instance, one half of the total value added capitalizes into less than 16% of total property area. Similarly, a quarter of the total value added capitalizes into less than 4% of total property area. Owners of the respective properties clearly benefit disproportionally from the transport innovation. Since only a limited fraction of the affected areas is publically owned, a relatively small number of private landlords will benefit disproportionally from the largely publically financed improvement of rail infrastructure.

Put in other words, costs are equally distributed across the society while there is a striking imbalance in the benefits. This imbalance further increases if one considers that a large fraction of public expenditures is paid out of federal funds and that there is not only an inequality in the distribution between landlords, but also between landlords and renters. Increasing demand for living space following infrastructural improvements leads to an upward adjustment in rent level that – in equilibrium – compensates for the utility arising from travel time saving. While renters in the long run expect a constant net-utility, private landlords receive a positive externality from a public investment they have only marginally contributed to. From a welfare economic perspective, therefore, monetary compensations by the benefited landlords would be justified. Although the magnitude of compensations would be best assessed upon a statistical ex-post evaluation, model predictions as discussed above, potentially represent a useful tool for planning authorities to assess the potential contribution from an ex-ante perspective and to develop a viable finance concept in times of budget scarcity.
Fig. 8 Lorenz Curve

Notes: Own calculation and illustration on the basis of the results of Ahlfeldt (2008b). Solid line is the Lorenz curve. Dashed line is the line of equality.

4 Conclusion

This article condenses and complements the results of a series of empirical research on the impact of rail mega-projects on the urban economy of Berlin during the late era of industrial revolution and the period after unification. Evidence suggests that intra-urban rail stations exhibit a significant impact on demand for land, although the effect is relatively localized and diminishes slightly over time as the availability of individual transport increases. As demonstrated by the case of the Kufürstendamm area during the 1920s, intra-urban rail hubs – at least if embedded into an urban development strategy – exhibit a potential to foster urban economic development and to promote the agglomeration of urban economic activity. In comparison, the effects of large-scale inter-city rail projects are less striking. Even the fundamental reorganization of the inter-city rail network in post-unification Berlin has had, if any, only a weak impact on relative land values, both within the station neighborhoods as well as at the city level. This is remarkable given that the realignment has had an adverse effect on the majority of area, population and employment, was hardly foreseeable in its final form and was strongly opposed by various business and passenger lobbies.
Productivity gains arising from inter-city connectivity as suggested by NEG models apparently do not capitalize strongly into housing prices. Residents seem to discount the value of inter-city rail stations weakly on distance, most likely due to the relatively low frequency of usage. Given this rather global character of rail stations, two conclusions for planning authorities emerge. First, the limited direct impact on the urban economy may justify a relatively peripheral location of the station in order to make available the spaces occupied by facilities and feeder lines, which often cover much of a city’s most productive space. Relocation may be a feasible alternative if expensive tunnel constructions are not financially viable. Second, the availability of access to mainlines by itself is unlikely to induce considerable stimuli on a neighborhood. At least, effects are small compared to many other influencing factors. Authorities carrying out urban development policies in the course of rail mega-projects should therefore develop strategies that go beyond a purely transport economics perspective.

Regarding future developments of rail infrastructure, a considerable impact on the local economy is to be expected from the improvements in the connectivity of Berlin’s new central station to the metrorail network. In line with empirical evidence, NUE models predict significant, but localized effects. Monetary compensations by landlords who disproportionately benefit from the externalities related to the investment project are therefore justified in welfare economic terms. With empirical methods, among others those discussed in this article, the degree to which private landlords benefit from public investment can be identified. Micro-level simulations, as shown, facilitate the prediction of the expected impact, enabling authorities to define priorities and to develop viable financial concepts that also take into account potential compensations by private landlords.
Appendix

Rail market potential (RMP) as visualized in Figure 3 and compared in Table 3 is generated according to the following formula:

\[
RMP_i = \exp (-b \cdot d_{is}) \sum_m (\sum_j P_j \exp (-b \cdot d_{mj})) \exp(-a \cdot d_{sm}), \text{wobei } m \neq s \quad (A1)
\]

where \(a\) and \(b\) are transport cost parameters taking the values of 0.5 and 2, \(d_{is}\) is distance from location \(i\) to the closest station (origin) \(s\), \(d_{sm}\) is the shortest trip length along the network to station (destination) \(m\), \(d_{mj}\) is the distance from station \(m\) to location \(j\) whose population is \(P_j\). See for a more detailed description (Ahlfeldt & Wendland, 2008a).

The identification strategy for the evolution of relative land prices within station neighborhoods as presented in Figures 4 and 5 builds on the following hedonic regression equation:

\[
\log(Psqm_{it}) = X_i h + \beta_1 DistCBD_i + \sum_u \beta_u DistCBD_i \times quarter_u + \gamma_1 Station_{ij} + \sum_u \gamma_u Station_{ij} \times quarter_u + \delta_i + \phi_t + \varepsilon_{it}, \text{with } u \neq 1, \quad (A2)
\]

where \(Psqm_{it}\) is the sales price of property \(i\) at time \(t\), \(X_i\) is a vector of property attributes, \(DistCBD_i\) is the distance to the CBD\(^9\) (in km), \(Station_{ij}\) is a dummy denoting whether a property \(i\) lies within 2 km of a station and \(quarter_{ui}\) is a set of dummy variables denoting the quarter in which the transaction took place. Betas, Gammas and \(h\) represent the set of coefficients to be estimated. The estimator facilitates a composite error term, including traffic cell (Verkehrszelle) effects \(\nu_i\) controlling for unobserved time-invariant location characteristics, quarterly effects \(\phi_t\) controlling for the overall macroeconomic conditions and a random component \(\varepsilon_{it}\) (see Ahlfeldt, 2009).

---

\(^9\) The CBD is defined as the crossroads of Friedrichstrasse and Leipziger Strasse. Centrality of this point is highlighted by the nearby metro-station called Downtown (Stadtmitte).
Smoothed trends are the unknown non-linear relationship between the estimated $\gamma$ coefficients (from A2) and a quarterly trend obtained from locally weighted regressions (a bandwidth of 0.5 is used):

$$\hat{f}_u = f(trend_u) + \omega_u \quad (A3)$$

Average distances ($AD$) as used in Figure 6 and Table 4 are defined as follows:

$$AD_{yz} = \begin{cases} 
\frac{n_{jz}}{N_z} \text{NearDist}_{yjz} + \left(1 - \frac{n_{jz}}{N_z}\right) \text{Min} \left(\text{DistZoo}_y, \text{DistOst}_y\right) & \text{if } z \text{ is before} \\
\frac{n_{jz}}{N_z} \text{NearDist}_{yjz} + \left(1 - \frac{n_{jz}}{N_z}\right) \text{DistHbf}_y & \text{if } z \text{ is after} 
\end{cases} \quad (A4)$$

where distance from traffic cell $y$ to the next station $j$ (NearDist$_{yjz}$) in period $z$ is weighted by the station’s share of total daily inter-city connections ($n_{jz}/N_z$). The remaining share ($1-n_{jz}/N_z$) serves as a weight for the distance to the next inter-city rail hub, where the respective connections can be accessed (see Ahlfeldt, 2009).

Adjusted land prices analyzed in Table 4 are estimates $\tilde{p}_{yz}$ (see A2). Column (7) of Table 4 presents the following difference-in-difference (DD):

$$DD = (\tilde{p}_{\text{after}}^{\text{positive}} - \tilde{p}_{\text{before}}^{\text{positive}}) - (\tilde{p}_{\text{after}}^{\text{negative}} - \tilde{p}_{\text{before}}^{\text{negative}}) \quad (A5)$$

where $Y$ is either distance or the log of land price.
Literature


