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The train has left the station: Do markets value intra-city access to inter-city rail connections?

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Abstract: This paper analyzes the impact of access to inter-city rail connections on property prices using hedonic, difference-in-difference and time-difference estimation strategies. We investigate the reorganization of the rail system in post-unification Berlin, Germany, which provides much variation in accessibility. Evidence does not support the existence of localized effects. Neither in proximity to stations nor at city-level are there significant price adjustments. No significant price effect is revealed on distance to stations, even when allowing for a complementary relationship. An increase in the attractiveness of central locations coinciding with the final announcement of the train schedule is not attributable to the intervention.

Keywords: *Property prices, transport innovation, inter-city connection, railroad, Berlin*
JEL classification: *R21, R40, R53*

1 Introduction

In recent decades, accessibility has increasingly been investigated in its role as a determinant of the spatial distribution of economic activity. Firms, employees and customers benefit from good access to other regions' markets due to the reduced cost of commuting, a supply of customers and raised availability of goods. In the interaction with agglomeration economies that arise from physical proximity, positive transport costs can explain the concentration of economic activity in regional agglomerations (Fujita, Krugman, & Venables, 1999; Krugman, 1991).[1] Similarly, transport costs on intra-urban level has received much attention since the early period of urban economics (Alonso, 1964).[2] While the early models focused on a tra-

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[1] See for empirical evidence on the role of agglomeration economies for location productivity, Ciccone & Hall (1996), Ciccone (2002), Henderson (2003). Hanson (2005) and Mion (2004) show that regional market access is positively correlated with regional economic wealth. Redding & Sturm (2008) even prove a causality runnig from market access to economic performance of regions.

[2] The usual citations also refer to Mills (1972) and Muth (1969). Important works sharing the same spirit, among others, include Beckmann (1969) and Solow (1973). The respective history of thought dates at least back to Von Thünen (1826).

deoff between price of land and access to the city center in order to explain intra-city location choice of households and firms, recent models have added the idea of production externalities that arise from the spatial interaction of nearby firms and drive them into economic cores (Lucas, 2001).[3] Hence, by bringing employees, firms and customers closer together, an improvement in transport infrastructure not only has a direct impact on commuting and shipping cost, but also has an impact on productivity, wage and income levels and, not least, on real estate prices. Empirical research in this context investigates the impact of highways (Chandra & Thompson, 2000; Isserman & Rephann, 1995; Michaels, 2008) and inter-city rail connections (Coffman & Gregson, 1998) on a regional scale. More closely related to the present analysis, a large number of studies analyzes the impact of intra-urban rail systems. These studies typically make use of data on real estate prices, which mirror an increase in demand for location due to improved accessibility (Bajic, 1983; Baum-Snow & Kahn, 2000; Bowes & Ihlanfeldt, 2001; Damm, Lerner-Lam, & Young, 1980; Dewees, 1976; Gatzlaff & Smith, 1993; Gibbons & Machin, 2005; McDonald & Osuji, 1995; McMillen & McDonald, 2004; Voith, 1993). Debrezion, Pels, & Rietveld (2007) provide a recent meta-analysis on this strand of research.

This study is, to our knowledge, the first to investigate the impact of access to inter-city rail lines on an intra-city scale, using detailed transaction data for an entire metropolitan area. 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. Similar to the case of intensively investigated intra-city transport stations, the potential reduction in transport costs should be reflected in an increasing demand for accessible locations, capitalizing in higher equilibrium real estate prices. Some of the aforementioned studies have explored the effects of transport innovations rather than employing purely cross-sectional approaches (Bajic, 1983; Dewees, 1976; Gibbons & Machin, 2005; McDonald & Osuji, 1995; McMillen & McDonald, 2004; Voith, 1993). The reorganization of a city´s inter-city rail network, however, is a rare occasion compared to the extension of metrorail net-

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[3] Similar formal models include Borukhov & Hochman (1977), Fujita & Ogawa (1982), Lucas (2001), Lucas & Rossi-Hansberg (2002), and Ten Raa (1984).

works. The case of post-unification Berlin, being subject to this analysis, represents a particularly strong innovation in these terms. In the course of the modernizations required after the period of division, the two main stations of the formerly separated parts of the city were either disconnected from inter-city lines or reduced substantially in significance. A completely new central station was developed instead at a new location and three additional main stations were either inaugurated or considerably extended. As an additional feature the finally communicated train schedule differed considerably from the original transport plan, introducing an additional moment of surprise shortly before the implementation. The impact of this variation in accessibility on property prices is investigated over an 8-year study period, taking into account potential announcement effects (McDonald & Osuji, 1995; McMillen & McDonald, 2004). We focus both on price adjustments within the immediate impact areas of the stations as well as on city-wide effects, given that the stations' sphere of influence potentially covers the entire metropolitan area. Similar to Gibbons & Machin (2005), we exploit changes in the distances to stations in order to reveal the marginal value of rail access. In addition, we allow for a complementary relationship between mainline stations that does not represent perfect substitutes.

Our results potentially shed light on an interesting question arising from a planner perspective, given that inter-city railway stations are public facilities. Do these stations represent facilities with a local or global character? The optimum location choice critically depends on the answer to this question.[4] Although main-line stations do not belong to the classical NIMBY (not-in-my-backyard) facilities, which generate localized negative externalities, the opportunity cost of provision in space can be quite high.[5] Particularly in historically grown cities central stations are typically located within the urban core, where economic activity reaches the highest density. Hence, the large facilities and huge track beds occupy much of a city's most productive space while construction work for tunnels in order to shift facilities and lines below ground level is extremely expensive. If there are no spatially uneven benefits at city level, then a relocation to a somewhat less central location could be efficient, at least as long

[4] A public good or facility is considered to be local in the case of generating differentiated benefits at different distances. See Bellettini & Kempf (2008) on the spatial provision of local public good facilities and Koide (1987), among others.

[5] Political opposition to the location of NIMBY facilities has become a much-discussed issue in the political economy literature (Bellettini & Kempf, 2008; Frey, Oberholzer-Gee, & Eichenberger, 1996; Kuhn & Ballard, 1998; Wolsink, 1994).

as the new location is well-connected to the intra-urban transport network. A significant real estate price effect of access to inter-city rail connections, however, would support the spatially uneven benefits notion. A more local characteristic would in turn provide some justification for bearing either the occupation of highly productive space by open track beds or the expenses for tunnel construction.

2 Background

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. At the beginning of the 1990s, it was decided to implement a completely new concept for connecting Berlin to Germany's rail network. The key element of this 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 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 centrality and 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 surprising, 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. 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). In the course of the empirical analyses we will provide evidence supporting the notion that the new transport plan has left the majority of employees and residents worse off, making the decision difficult to understand from a pure transport economics perspective. 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.

3 Empirical Analysis

3.1 Hedonic Analysis

The record of property transactions considered in this analysis includes 32,763 transactions of developed properties that took place between January 1, 2000, and December 31, 2007, within the boundaries of the Federal State of Berlin, Germany. The transaction data provided by the Committee of Valuation Experts in Berlin (2007) includes the usual parameters such as age, floor space, plot area and storeys as well as information on land use, condition, plot shape, building type and contract details including information on buyer, seller, type of agreement and tax privileges, among other things. Since different buyers are likely to buy different types of properties, these variables potentially pick up some effects of otherwise unobservable characteristics.

In the first step of our analysis we track the evolution of sales prices in proximity to the considered mainline stations over time. We employ a quite flexible hedonic specification that also allows the central business district (CBD) gradient to adjust to gradual changes in the city structure.

$$\log(P_{it}) = X_i\, a + \beta_1\, DistCBD_i + \sum_u \beta_u\, DistCBD_i \times quarter_u$$
$$+ \gamma_1\, Station_{ij} + \sum_u \gamma_u\, Station_{ij} \times quarter_u + \vartheta_i + \varphi_t + \varepsilon_{it}, \text{with } u \neq 1, \quad (1)$$

where P_{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[6] (in km) and $Station_{ij}$ is a dummy denoting whether a property i lies within the immediate catchment area of a station j. We rely on the definition by Gibbons & Machin (2005) who found 2 km to be a feasible walking distance and an appropriate impact area for urban railway stations. Similarly, $quarter_u$ denotes the quarter in which the transaction took place. Betas, Gammas and a represent the set of coefficients to be estimated. The estimator facilitates a composite error term, including traffic cell (Verkehrszelle) effects ν_i controlling for unobserved time-invariant location characteristics, quarterly effects φ_t controlling for the overall macroeconomic conditions and a random component ε_{it}.[7] Standard errors are clustered on traffic cells, allowing for variance-shifting across space. Coefficients β_u and γ_u test for a significant change in the CBD gradient and the price level within the station neighborhood relative to the beginning of the observation period. In the sense that we test for a significant change in price differentials between treatment (station neighborhood) and control group (rest of the city) relative to the base quarter, γ_u coefficients yield difference-in-difference (DD) estimates without the need for defining a treatment period a priori.

Figure 1 illustrates estimated β_u coefficients when no particular station is considered in the analysis. While until 2005 there is hardly any significant change in the CBD gradient observ-

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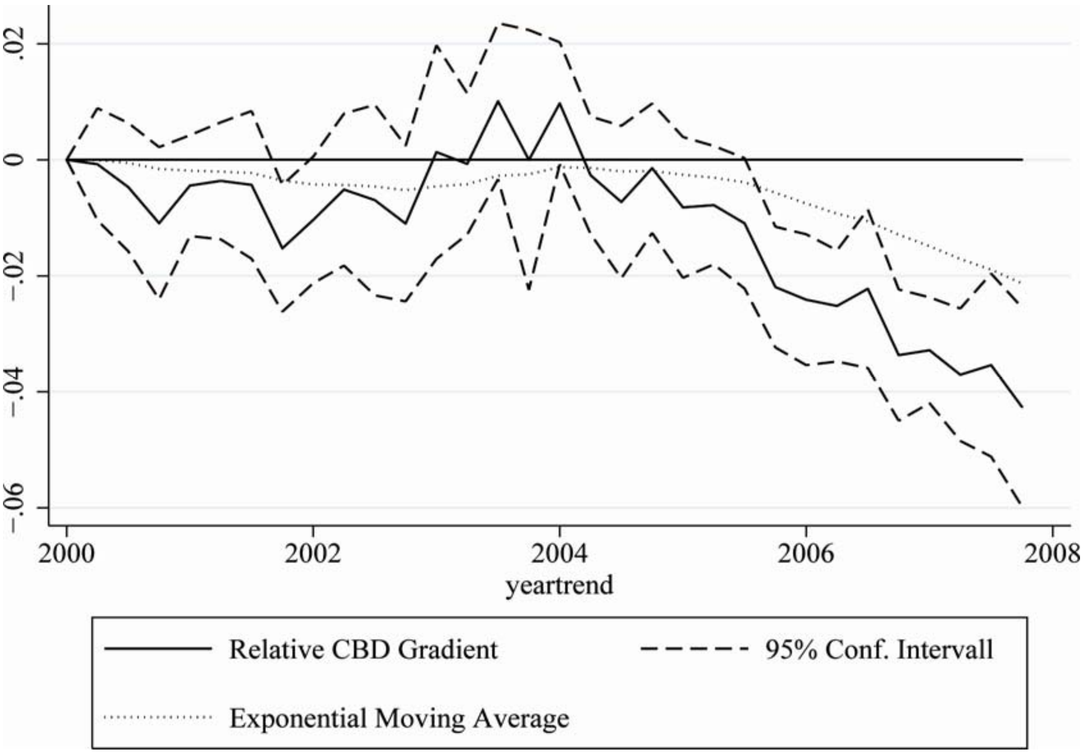
6 The CBD is defined as the crossroads of Friedrichstrasse and Leipziger Strasse. Centrality of this point is highlighted by the nearby metro-station called Downtown (Stadtmitte).

7 The study area covers 338 officially defined traffic cells.

able, afterwards there is a remarkable increase in magnitude. The estimated differentials become statistically significant by mid-2005, which notably coincides with the announcement of the new train schedule. From then on, evidently, the marginal price effect of locating closer to the CBD has steadily increased. A list of hedonic transaction characteristics, including estimation results, is presented in Table A1 (1) in the appendix. The exponentially weighted average supports the notion of a significant and sustainable adjustment of the CBD gradient after 2005.

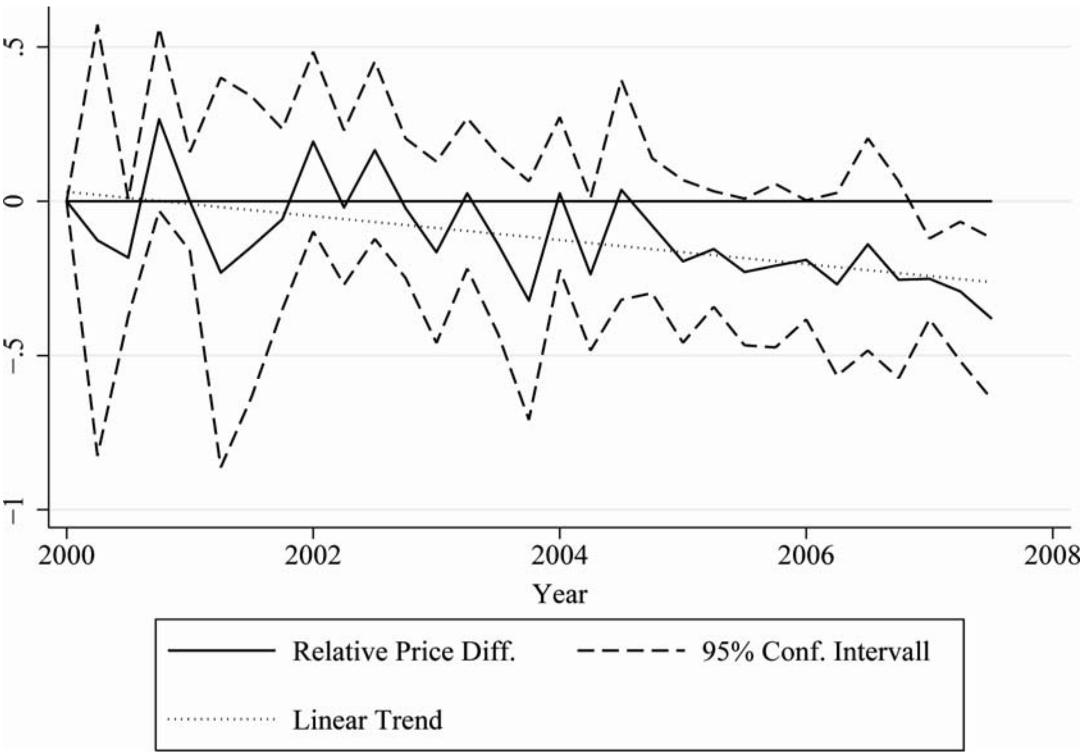
Fig. 1 Relative CBD Gradient



Notes: Figure presents changes in CBD gradient relative to the first quarter of 2001, estimated according to specification (1) while omitting station effects. Exponentially weighted moving average uses a 0.1 weight.

In Figure 2 we present results for the extended specification where we allow for varying price differentials within the neighborhood of Bahnhof Zoo. While there is an evident decline in price level over the course of our study period, there is no sign of a structural break after implementation or even after the final communication of the new transport plan. Instead, price differentials seem to increasingly follow a linear downward trend over the whole observation period. A similar picture is revealed by Figure A1 in the appendix, which presents the results of analogical analyses for all main stations affected by the new transport plan. If there are any significant changes in relative prices, then they follow a linear trend, showing no sign of tructural breaks within the period of announcement and implementation after 2005. The positive and negative trends in the neighborhoods of Ostbahnhof and Hauptbahnhof even run counter to intuition, indicating that evolution of relative attractiveness of those areas was dominated by other factors. Generally, there seems to be less volantility during the last years of the observation period, which could be interpreted as a sign of reduced uncertainty about the relative importance of stations within the network. However, at least partially, this effect is also attributable to an increasing frequency of transactions within the recent years.

Fig. 2 Relative Price Differential for the "Bahnhof Zoo" Impact Area



Notes: Figure presents relative price differentials between the 2 km impact area around "Bahnhof Zoo" and the rest of the city relative to the first quarter of 2000.

While we can largely reject the idea that the realignment of inter-city connections had a significant impact within the immediate vicinity of stations, the general change in city structure is nonetheless remarkable, particularly given the coincidence with the final announcement. In contrast to metrorail stations, mainline stations are likely to have a much wider sphere of influence, potentially covering the whole city. It is therefore not necessarily surprising that there is no impact when comparing the immediate neighborhoods to the rest of the city. Instead, we should expect a broader impact of altered mainline accessibility, which could eventually reflect in a significant increase in attractiveness of central relative to more peripheral locations.

In order to disentangle the effects arising from a change in mainline accessability from other factors influencing marginal prices paid for relative centrality, we employ a transport innovations perspective that compares the situation before and after the intervention. Therefore transaction prices are first adjusted for property characteristics and time effects, which yields residual land prices (*RLP*). The residual land price represents a kind of shadow price paid for the square meter value of location. We use estimated attribute values obtained from the estimation of a specification similar to (1), where we omit the CBD-gradient and station components. Results are presented in Table A1 (2) in the appendix.

$$RLP_{it} = \exp(\log(P_{it}) - X_i \, \hat{a} - \widehat{\varphi_t}) \quad (2)$$

Aggregation of residual land prices to traffic cells for the periods before and after the intervention allows for a straightforward comparison between the two periods. The appropriate definition of “before” and “after” periods, however, is somewhat controversial. On the one hand, one may argue that rational real estate investors discount the future stream of rental incomes as a basis for their investment decisions. Given this rationale we would expect an adjustment of property prices right after the announcement of a change to train services (McDonald & Osuji, 1995; McMillen & McDonald, 2004). On the other hand, owner-occupiers that discount the future benefits of transport improvements largely due to availability of attractive alternatives in the present will have little incentive to move to places before the change in accessibility becomes effective (Gibbons & Machin, 2005). Hence, the definition of feasible “before” and “after” periods to some degree depends on the assumptions made on the behavior of real estate agents. If the change in city structure indicated by Figure 1 was attributable to the intervention under investigation, then this would support the first notion as the structural break apparently occurs right after the final communication in 2005. We experiment with different definitions of before and after periods and find that this question is of limited relevance for the implications of the present analysis, at least within the considered observation period. However, we believe that for the main strand of discussion it is good to avoid behavioral assumptions as much as possible. We will therefore compare the period starting right after the new concept was put into operation (April 1, 2006) to a period that ends with the communication of the final plan, closely coinciding with the relative increase in the attractiveness of central locations suggested by Figure 1 (June 30, 2005). Given that the after period covers 21 months, a before period of equal length would represent a straightforward definition. Since there is, however, a general increase in market activity in the later years, we extend the before period by one year, so that we have approximately 9,500 observations in both periods. In the end, we obtain a before period ranging from October 1, 2002 to June 30, 2005 and an after period covering the period from April 1, 2006 to December 31, 2007.

3.2 Before-After-Comparison

Before-and-after comparisons have frequently been applied to assess the impact of train transit on property prices, particularly in studies on U.S. cities (Bajic, 1983; Dewees, 1976; McDonald & Osuji, 1995; McMillen & McDonald, 2004). Gibbons & Machin (2005) extend this strand of literature contributing first evidence for the UK. The aforementioned studies have all investigated modifications of intra-urban railway systems. While specifications obviously vary from case to case, they share the basic idea of comparing what happens in areas affected by an innovation to the evolution within a control area unaffected by the shock, thereby isolating the treatment effect. In contrast, this paper investigates a variation in access to inter-city connections, which essentially affects the entire metropolitan area. Instead of distinguishing between treatment and control groups, we therefore refer to areas that are positively or negatively affected by the intervention, defined on the basis of whether they experience an increase or decrease in accessibility. Our natural intuition would be that, if at all, an increase in accessibility should lead to an upward adjustment in land price, and the other way round.

The definition of the groups, however, is non-trivial in light of some stations appearing and disappearing from the map while others experience an increase or decrease in the frequency of train service. Two definitions of access to inter-city connections will be followed in the remainder of the analysis. First, we restrict our attention to proximity to the central rail-hubs, from which all inter-city connections can be accessed in the respective period, and which therefore represent perfect substitutes. Accordingly, the minimum distance from traffic cell z to the next inter-city rail hub in period z is defined as follows:

$$MinDist_{yz} = \begin{cases} \text{Min}\left(DistZoo_y, DistOst_y\right) \text{ if } z \text{ is before} \\ DistHbf_y \text{ if } z \text{ is after} \end{cases} \tag{3}$$

where $DistZoo_y$, $DistOst_y$ and $DistHbf_y$ stand for distance to Bahnhof Zoo, Ostbahnhof and Hauptbahnhof. We assign a traffic cell to the group of positively affected areas “positive” if $MinDist_{yafter} - MinDist_{ybefore} < 0$ and to “negative” when the opposite is true. Based on this definition, Table 1 presents descriptive statistics for distance to inter-city rail hubs and logs of property prices for the full sample (1-2), as well as for the groups of positively (3-4) and negatively (5-6) affected traffic cells in the periods before and after the intervention. We strictly restrict our attention to those traffic cells for which price data is available in both periods. Table 1 results suggest an overall decline in accessibility to inter-city connections at city level, with the expected differences between the positive and negative groups. A reduction in distance to mainlines only occurs to 59 out of 287 traffic cells, while mean distance increases from 7.25 to 9.16 km across all areas. At the same time, the positive group only experiences a mean reduction by 1.51 km while the mean distance for the negative group increases by 2.81 km. Comparison of mean log prices also yields a tendency pointing to the "right" direction. On average, the price level within the positive group rose by 2% and declined by 4% in the negative group.

Similar to Gibbons & Machin (2005) we employ a difference-in-difference (DD) estimation strategy in order to test for a significant change in mean distance and price level across groups and periods (7).[8] Results reveal a highly statistically significant reduction in distance to station for the positive group relative to the negative group by 4.31 km. The respective positive treatment effect on property price levels of about 6% is not statistically significant at conventional levels.[9]

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8 We estimate the following difference-in-difference: $(\bar{Y}^{positive}_{after} - \bar{Y}^{positive}_{before}) - (\bar{Y}^{negative}_{after} - \bar{Y}^{negative}_{before})$ where Y is either distance or the log of price. As residual land prices are adjusted for attribute characteristics there is less need for a matched estimate.

9 The exact percentage (PC) impact can be derived from the estimated coefficient (b) using a simple formula: $PC = [\exp(b) - 1] \times 100$.

Tab. 1 Before-After-Comparison: Bahnhof Zoo / Ostbahnhof vs. Central Station

	Full sample		Positive		Negative		Estimate
	Before (1)	After (2)	Before (3)	After (4)	Before (5)	After (6)	DD (7)
Distance	7.25	9.16	7.32	5.81	7.22	10.03	-4.31***
	(4.12)	(4.79)	(3.56)	(3.77)	(4.26)	(4.65)	(0.14)
Log price	6.04	6.01	5.99	6.01	6.05	6.01	0.06
	(0.36)	(0.40)	(0.29)	(0.33)	(0.37)	(0.41)	(0.04)
Sample	287	287	59	59	228	228	287

Notes: Log price refers to residual land prices as defined in (2), aggregated to traffic cells. Distance is defined as in (3). 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, 2007).

In our second approach to modeling the access to inter-city connections we allow for a complementary relationship between all mainline stations in operation in the respective periods.[10] We calculate an average distance measure ($AvDist_{yz}$), 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.[11] Absolute and relative numbers of daily inter-city connections provided by the DB Station & Service AG (2008) are presented in Table A2 in the appendix.

Formally expressed, the average distance to an inter-city connection reads as follows:

$$AvDist_{yz} = \begin{cases} \frac{n_{jz}}{N_z}\left(NearDist_{yjz}\right) + \left(1 - \frac{n_{jz}}{N_z}\right) \mathrm{Min}\left(DistZoo_y, DistOst_y\right) \text{ if } z \text{ is before} \\ \frac{n_{jz}}{N_z}\left(NearDist_{yjz}\right) + \left(1 - \frac{n_{jz}}{N_z}\right) DistHbf_y \text{ if } z \text{ is after} \end{cases} \quad (4)$$

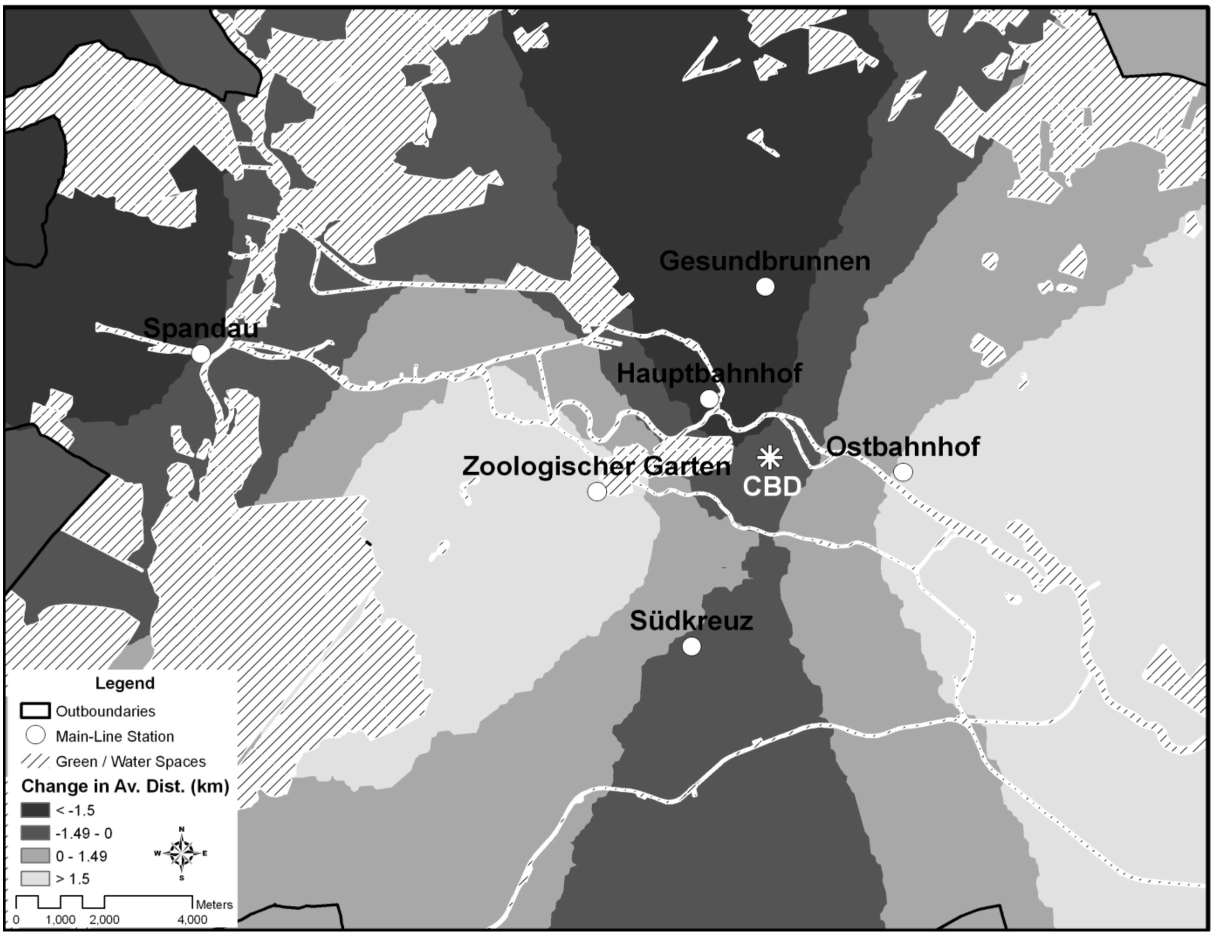
Figure 3 shows the location of all stations considered in the study on the background of spatially interpolated changes in average distance ($AvDist_{yafter} - AvDist_{ybefore}$). As expected, the areas that experienced the strongest decline in access to mainlines are around the formerly most important 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

[10] See Ahlfeldt & Maennig (in press) for a detailed discussion on how to capture complementarity in urban amenities.

[11] Note that Bahnhof Zoo and Ostbahnhof in the before period, and Hauptbahnhof in the after period, carry out the full range of services, therefore areas that have these stations as nearest stations in the respective periods automatically receive an unweighted distance to these stations according to this definition.

new stations Hauptbahnhof, Gesundbrunnen and Südkreuz and the extension of Spandau, which at least partially compensates western areas for the closure of Bahnhof Zoo.

Fig. 3 Change in Average Distance to Inter-City Connections



Notes: Change in average distance refers to $AvDist_{yafter} - AvDist_{ybefore}$ as defined in (4). Ordinary kriging with spherical semivariogram model is used for spatial interpolation. Map created on the basis of the Urban Environmental Information System (Senatsverwaltung für Stadtentwicklung Berlin, 2006).

In Table 2 we report figures analogical to Table 1, based on the average distance definition from (4). The results are qualitatively similar to Table 1, although the effects are slightly alleviated. Compared to Table 1, there are considerably more areas that are positively, and fewer areas that are negatively, affected. The DD estimate indicates a relative reduction in mean distance for the positive group by 3.05 km compared to 4.31 km in Table 1. The estimated increase in price differential is reduced from 6% to 4%, again not statistically significant.

Tab. 2 Before-After-Comparison: Average Distances

	Full sample		Positive		Negative		Estimate
	Before	After	Before	After	Before	After	DD
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Distance	7.00	7.41	7.69	6.30	6.52	8.17	-3.05***
	(3.97)	(4.13)	(3.07)	(3.22)	(4.44)	(4.51)	(0.10)
Log price	6.04	6.01	5.99	5.98	6.08	6.03	0.04
	(0.36)	(0.40)	(0.30)	(0.32)	(0.40)	(0.44)	(0.03)
Sample	287	287	117	117	170	170	287

Notes: Log price refers to residual land prices as defined in (2), aggregated to traffic cells. Distance is defined as in (4). 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, 2007).

Nevertheless, there is still a citywide increase in the average distance to an inter-city train connection by 0.41 km and many more areas are affected negatively than positively. These figures support the notion that the majority was put in a worse position by the new transport plan. These figures appear even more impressive when expressed in terms of population and workplaces within these areas. The difference between inhabitants living within negatively and positively affected areas amounts to almost 800,000 (2005 population data). Considering employees (at workplace) contributing to social insurances in 2003, the respective difference is close to 200,000. Moreover, employees and residents who experience a strong decline of more than 1.5 km account almost entirely for the net-effects. Hence, a natural question to ask would be whether the negative picture drawn suffers from neglecting intra-urban transport accessibility. This, however, can quite clearly be denied. In Table A3 in the appendix we re-calculate the numbers of affected population and employment opportunities with respect to availability of metrorail and suburban railway connections. Instead of average distances we use an average travel time measure that covers the time needed to walk to an urban railway station as well as the travel time for the journey along the urban railway network to the main-line station of destination. In order to maximize precision we use the most disaggregated data available, referring to 15,937 statistical blocks. A more detailed description is in the Table A3 notes. Eventually, the resulting pattern looks pretty much like that in Table 3, with the imbalance of inhabitants living within negatively and positively affected areas increasing to almost 1 million. These findings affirm one of the most frequent arguments of the opponents against the closure of Bahnhof Zoo, who criticized the location of the new central station Hauptbahnhof for its poor connection to the intra-urban railway system.

Tab. 3 Before-After-Comparison: Affected Population and Employment

Change in	Population			Employment		
Av. Dist.	Positive	Negative	Net	Positive	Negative	Net
(km)	(1)	(2)	(3)	(4)	(5)	(6)
≤ 1.5	682,426	762,958	-80,532	242,094	231,624	10,470
> 1.5	587,254	1,302,474	-715,220	146,043	348,471	-202,428
Total	1,269,680	2,065,432	-795,752	388,137	580,095	-191,958

Notes: Positive (negative) denotes residents or employees who experience a decrease (increase) in average distance to mainline connections as defined in (4). Population (2005) and employment data obtained from Statistical Office of the Senate Department in Berlin. Employment considers employees at workplace who contributed to social insurances in 2003.

3.3 Marginal Price Effect of Distance to Inter-City Connections

From the before-after-comparisons in the previous sub-section we know that a large part of the city was considerably affected by the transport innovation under investigation. At the same time, the simple DD estimated displayed in Tables 1 and 2 indicate no significant change in the average price differential between areas identified to be positively or negatively affected by the shock. So far, however, we have only used a small fraction of the available information, given that there is a lot of variation in accessibility within both areas that could potentially cause heterogeneous price adjustments. Such a variation can be used to assess the marginal value of access to inter-city connections and to disentangle the related land price effects from alternative origins for the increase in the relative attractiveness of central locations found in section 3.1. We therefore conduct a transport innovation analysis that shares the basic idea with the approach chosen by Gibbons & Machin (2005) in the sense that we exploit the distance to stations variation caused by the intervention.

We start with a simple spatial regression model that relates the mean residual land price (RLP_{yz}) within traffic cell y in period z to the distance to the CBD ($DistCBD_y$), a distance to inter-city connections measure ($DistIC_y$) defined according to (3) or (4) as well as unobserved time-invariant location effects (ν_y) and a random error component (ε_{yz}). A dummy variable is included that denotes the western of the formerly separated parts of the city ($West_y$) since we cannot reject the existence of a spatial disequilibrium due to the particular 20th-century history of the city.

$$\log RLP_{yz} = \alpha + \delta_z\, West_y + \gamma_z\, DistCBD_y + \tau_z\, DistIC_y + \vartheta_y + \varepsilon_{yz} \qquad (5)$$

In the time-difference form, the coefficient on the west-dummy picks up the effects of a potentially ongoing convergence process. Similarly, the coefficient on $DistCBD_y$ takes into account an inter-temporal change in the marginal price paid for proximity to the CBD. At the same time, specification (6) allows for a straightforward assessment of the marginal value of proximity to inter-city connections, assuming that the marginal price effect is the same in both periods ($\tau = \tau_z = \tau_{z-1}$).

$$\log RLP_{yz} - \log RLP_{yz-1} = \alpha + (\delta_z - \delta_{z-1})\, West_y + (\gamma_z - \gamma_{z-1})\, DistCBD_y + \tau\,(DistIC_{yz} - DistIC_{yz-1}) + (\varepsilon_{yz} - \varepsilon_{yz-1}) \quad (6)$$

The respective estimation results are presented in Table 4. In column (1) we test exclusively for a significant change in the marginal prices paid for proximity to the CBD and a change in the price differential between both formerly separated parts of the city. Accordingly, there is an increase in the marginal value of a 1 km reduction in distance to the CBD of about 2.2%, which fits precisely into the range suggested by Figure 1. This result is highly statistically significant. In contrast, the coefficient on the west-dummy variable is not statistically significant at conventional levels. Apparently, spatial arbitrage had been completed before our observation period started. In the next columns, we extend the specification by distance to inter-city connection measures in order to test for a significant accessibility effect. When employing the minimum distance specification described in (3), the estimated coefficient τ is not statistically significant and even shows an unexpected positive sign (2). The sign instead becomes negative when employing the more sophisticated average distance definition from (4) (column [3]). The negative relationship between property prices and access to inter-city connections is also revealed by a kernel regression of residuals from the base estimation in Table 4, column (1) on the change in average distance (Figure A2 in the appendix). Since the respective coefficient in Table 4, (3), however, again does not satisfy conventional significance criteria, this relationship seems to be very weak at best, if not accidental.

There is some reason to believe that a negative shock to accessibility could have a stronger impact compared to a positive shock. This would be the case if access to inter-city connections represented an experience good whose benefits could only be fully ascertained upon consumption. Moreover, in the particular case under investigation, the final announcement has probably led to a more significant adjustment in expectations within the negatively affected areas. While the inauguration of Hauptbahnhof, Gesundbrunnen and Südkreuz were foreseen in the original plans, the moment of surprise in the final communication was clearly the degree to which the stations along the east-west track were reduced in significance, including the complete disconnection from Bahnhof Zoo mainlines. We therefore allow the marginal price effect of access to inter-city connections to vary across positively and negatively affected areas by interacting the change in average distance (Δ*AvDist*) with a dummy (*pos*) that denotes the positive group defined in Table 2. Results displayed in Table 4, (4), however, indicate neither a significant difference of the average distance measure to the explanation of land prices within the negative group, nor a significant difference in the estimated impact of accessibility between the positive and the negative group. Finally, one could argue that it is not a 1 km reduction or increase per se that causes a price reaction, but a change that is large relative to the ex-ante situation. When considering the log-differences in average distance in column (5) in order to reveal the elasticity of prices, the resulting coefficient is nonetheless not as significant as before. Notably, the coefficient on distance to the CBD takes virtually the same value throughout all specifications. The pattern of results also remains almost unchanged when including the announcement period into the before or after period. The only difference is a slightly reduced coefficient on *DistCBD*, now pointing to an increase in the marginal value of 1.8-1.9% for a 1 km reduction in distance to the CBD (see Table A4 in the appendix). Given these results, as well as those from the previous sub-sections, it is, after all, not possible to reject the idea that distance to inter-city connections has no, or only very limited impact, on property prices.

Tab. 4 Time-Difference Estimates

	(1)	(2)	(3)	(4)	(5)
West	0.016	0.017	0.010	0.010	0.015
	(0.0347)	(0.0351)	(0.0351)	(0.0351)	(0.0347)
DistCBD	-0.022***	-0.022***	-0.022***	-0.022***	-0.022***
	(0.0036)	(0.0036)	(0.0036)	(0.0036)	(0.0036)
Δ*MinDist*		0.002			
		(0.0079)			
Δ*AvDist*			-0.008	-0.010	
			(0.0087)	(0.0232)	
Δ*AvDist* x *pos*				0.004	
				(0.0387)	
Δlog(*AvDist*)					-0.035
					(0.0334)
Const.	0.154***	0.152***	0.159***	0.156***	0.160***
	(0.0421)	(0.0435)	(0.0561)	(0.0433)	(0.0777)
Obs.	287	287	287	287	287
R-squared	0.118	0.118	0.120	0.120	0.121

Notes: Dependent variable is log-difference in residual land price (*RLP*) aggregated to traffic cells in all models. Robust standard errors are in parenthesis. *** denotes statistical significance at the 1% level.

4 Results

This study is the first to investigate the intra-urban impact of access to inter-city rail connections using detailed property data covering an entire metropolitan area. It is also one of the first studies that explore real estate price effects of changes in rail infrastructure in Europe, broadly defined. Subject to analysis is one of the rare occasions where a city's inter-city rail network is completely reorganized. Four mainline stations have either been inaugurated or extended within the study area covering the whole of Berlin, Germany, while one of the former mainline stations was completely closed and the other considerably reduced in significance. We prove that large parts are strongly affected by the investigated intervention, which on average has led to a reduction in overall accessibility both from residents' and employees' perspectives. Yet, there is little evidence that access to inter-city rail connections has significant impact on rail estate prices. Neither is there any remarkable break in the evolution of property prices within the immediate station neighborhoods, nor do we find a significant change in the relative valuation of positively and negatively affected areas. At best, there are very weak signs of a negative relationship between property prices and proximity to inter-city rail connections when allowing for a complementary relationship between stations. The marginal price effect, however, clearly fails to satisfy conventional significance criteria. Also, our transport innovation models reveal that a considerable increase in the relative attractiveness of a central location is very unlikely to be attributed to the new transport plan, despite a remarkable coincidence with the final communication.

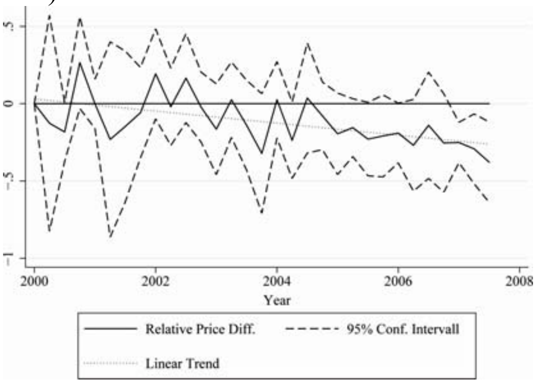
So if any, there is a very weak relationship between proximity to inter-city rail connections and property prices, which is not strong enough to reject the hypothesis of station location having no impact. In principle, anticipation effects would provide a feasible explanation for the absence of significant accessibility effects. If real estate markets had anticipated the change in accessibility before our observation period started, we would naturally underestimate the impact of accessibility. Following the argumentation of Gibbons & Machin (2005), it is, however, quite unlikely that anticipation effects fully capitalized into prices long before changes became effective within the entire metropolitan area. Moreover, the final communications hold a considerable moment of surprise, at least regarding the negatively affected areas, and in particular the Bahnhof Zoo catchment area. As indicated by the imbalance between negatively and positively affected residents and employees, which was expressed in heavy opposition of lobby groups, this decision is somewhat difficult to understand and was therefore hardly foreseeable.

We conclude that the intra-city location of central rail hubs seems to be an issue of limited relevance to individuals, at least as long as stations are sufficiently well-connected to the intra-urban transport network. If households and firms heavily discount distance to inter-city rail connections, we should find a significant marginal price effect of accessibility as well as significant price adjustments. Our results instead indicate a more global nature of the services provided by main stations. Still, in many cities, large facilities and track beds of central stations and feeder lines occupy much of the most productive sites within the city center. Authorities aiming at making these areas usable for commercial or residential use may therefore consider a relocation to a less central location instead of expensive tunnel construction works, although more evidence would be desirable in order to affirm the generalizability of our findings.

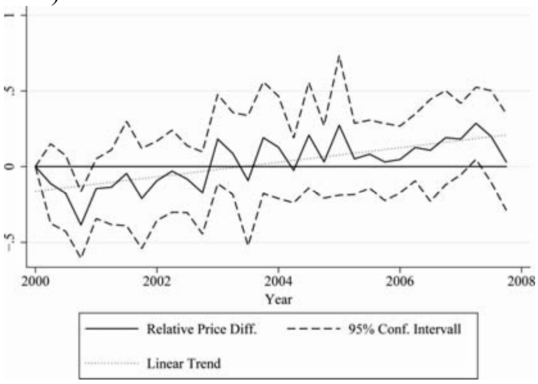
Appendix

Fig. A1: Relative Price Differentials within Station Neighborhoods

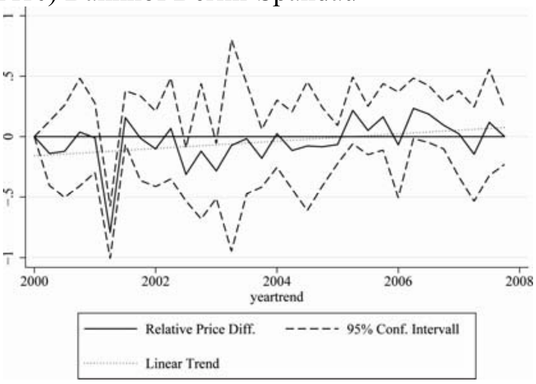
A1a) Bahnhof Zoo



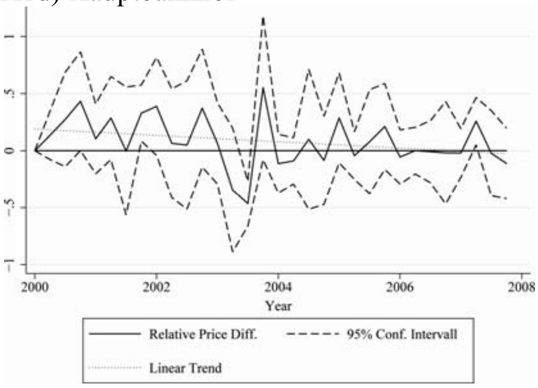
A1b) Ostbahnhof



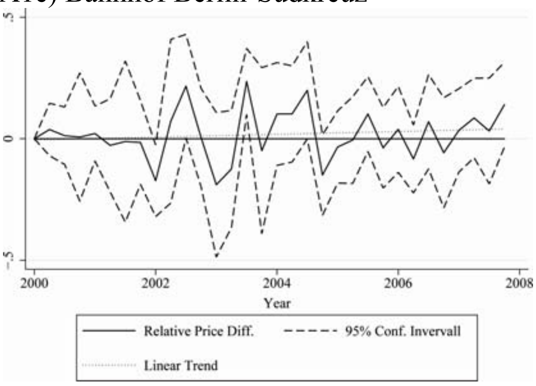
A1c) Bahnhof Berlin-Spandau



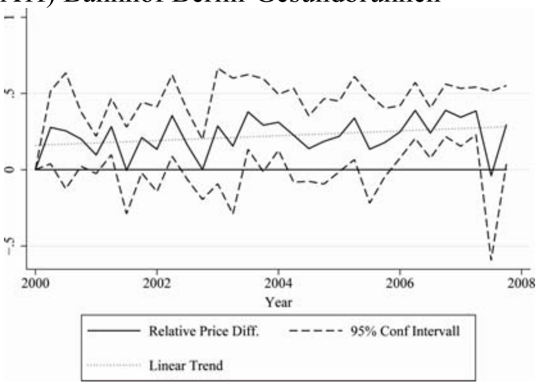
A1d) Hauptbahnhof



A1e) Bahnhof Berlin-Südkreuz

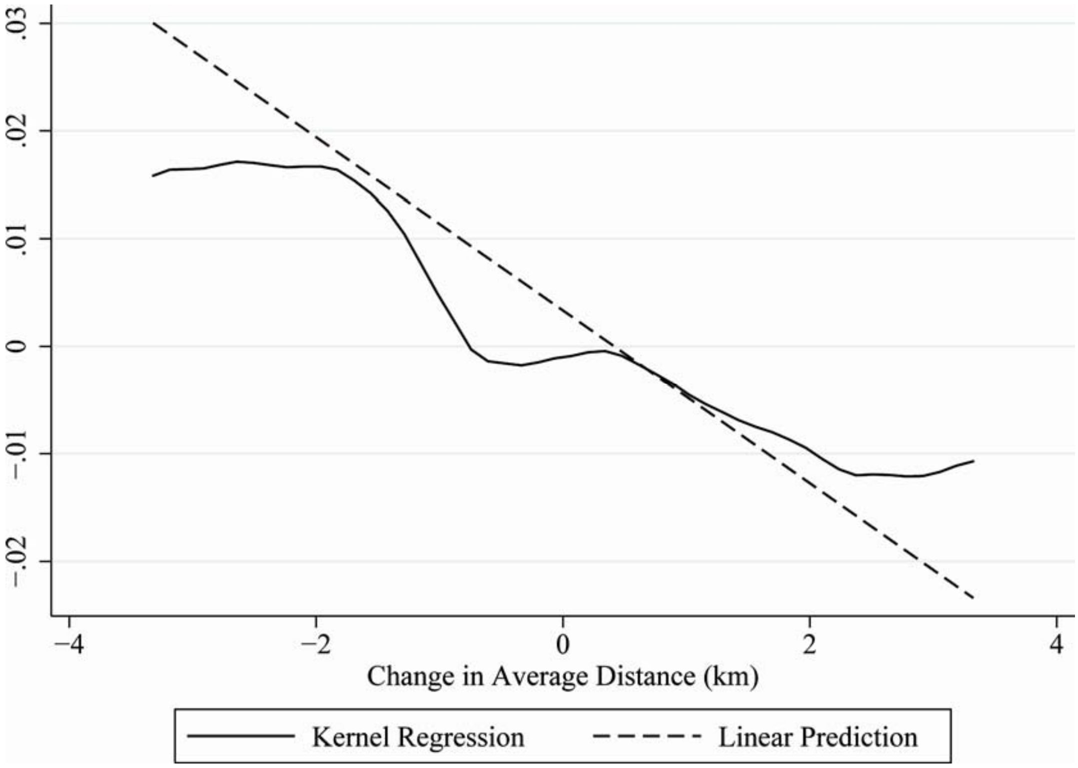


A1f) Bahnhof Berlin-Gesundbrunnen



Notes: Figures created analogically to Figure 1.

Fig A2: Kernel Residual Regression



Notes: Figure shows kernel regression of residuals from Table 4, (1) regression on change in average distance as defined in (4). Kernel uses the Epanechnikov function.

Tab. A1: Baseline Hedonic Estimates

	(1)		(2)	
	Coeff.	s.e.	Coeff.	s.e.
Commercial Land Use	0.354^{***}	0.0493	0.363^{***}	0.0485
Floor Space Index (FSI)	0.439^{***}	0.0167	0.443^{***}	0.0166
Plot Area (m^2)	-2.99e-06	2.03e-06	-2.84e-06	2.99e-06
Property Located at Frontage	-0.020	0.0370	-0.023	0.0372
Property Located at Corner	-0.030	0.0388	-0.037	0.0388
Property Located at Multiple Frontages	0.033	0.0505	0.030	0.0516
Demoted Property	-0.151^{***}	0.0437	-0.151^{***}	0.0439
Backyard Property	0.0330	0.0408	0.026	0.0408
Small House	-0.126^{**}	0.0501	-0.113^{**}	0.0522
One/Two Family House	0.145^{***}	0.0369	0.149^{***}	0.0371
Townhouse	0.682^{***}	0.0900	0.757^{***}	0.0817
Villa	0.226^{***}	0.0451	0.224^{***}	0.0449
Multi Family House	-0.038	0.0369	-0.050	0.0373
Multi Family House with Commerce	0.0460	0.0370	0.033	0.0374
Storey	0.005	0.0076	0.005	0.0076
Age (Years)	-0.010^{***}	8.65e-04	-0.096^{***}	8.95e-04
Age (Years) squared	$4.96e\text{-}05^{***}$	5.94e-06	$4.93e\text{-}05^{***}$	6.12e-06
Condition: Good	0.324^{***}	0.0210	0.337^{***}	0.0218
Condition: Bad	-0.429^{***}	0.0281	-0.426^{***}	0.0288
Flat Roof	0.003	0.0225	0.015	0.0226
Pent Roof	0.056	0.0362	0.066*	0.0360
Span Roof	-0.029	0.0203	-0.018	0.0197
Berlin Roof	0.011	0.0338	0.013	0.0350
Hipped Roof	-0.006	0.0229	0.004	0.0228
Mansard Roof	0.034	0.0242	0.048^{**}	0.0235
Domed Roof	0.011	0.0399	0.019	0.0418
Attic Flat	0.093^{***}	0.0125	0.092^{***}	0.0127
Elevator	-0.006	0.0322	0.008	0.0305
Basement	0.111^{***}	0.0309	0.115^{***}	0.0307
Underground Car Park	0.114	0.0955	0.142	0.1000
Seller: (Public) Authority	-0.197^{***}	0.0269	-0.203^{***}	0.0265
Seller: Housing Association	-0.112^{***}	0.0335	-0.130^{***}	0.0344
Seller: (Private) Juristic Person	0.075^{***}	0.0178	0.072^{***}	0.0178
Buyer: (Public) Authority	0.133	0.1220	0.140	0.1110
Buyer: Housing Association	-0.128	0.1070	-0.118	0.1110
Buyer: (Private) Juristic Person	0.121^{***}	0.0164	0.141^{***}	0.0154
Charge for Local Public Infrastructure	-0.062^{***}	0.0230	-0.051^{**}	0.0230
Property is not Occupied by Renter	0.063^{***}	0.0149	0.071^{***}	0.0157
Share (%) Secondary Structure at Price	-2.695^{***}	0.4490	-2.615^{***}	0.4490
Constant	5.751^{***}	0.1250	5.732^{***}	0.0800
Location Effects (traffic cells)	Yes		Yes	
Time Effects (quarters)	Yes		Yes	
CBD Gradient Effects	Yes		–	
Obs	32,763		32,763	
R squared	0.770		0.766	

Notes: Endogenous variable is log of sales price per square meter of land. Robust standard errors are clustered on traffic cells. $^{***}/^{**}/^{*}$ denote significance at the 10/5/1% level.

Tab. A2: Daily Inter-City Connections

Station	before n_{jz}	after n_{jz}	after n_{jz}/N_z	after n_j/N_z
Hauptbahnhof	0	174	0	100
Gesundbrunnen	0	40	0	23
Ostbahnhof	164	90	100	52
Spandau	66	111	36	64
Südkreuz	0	82	0	47
Bahnhof Zoo	164	0	100	0

Source: DB Station & Service AG (2008)

Tab. A3: Before-After-Comparison: Affected Population and Employment

Change in Av. Travel Time (min)	Population Positive (1)	Population Negative (2)	Population Net (3)	Employment Positive (4)	Employment Negative (5)	Employment Net (6)
≤ 3	364,258	748,315	-384,057	115,227	215,922	-100,695
> 3	823,919	1,398,620	-574,701	237,527	399,556	-162,029
Total	1,188,177	2,146,935	-958,758	352,754	615,478	-262,724

Notes: Positive (negative) denotes residents or employees who experience a decrease (increase) in average travel time to mainline connections. Travel times refer to the combined journey for a walk from origin to the next metro or suburban railway station and the shortest train ride through the combined metro- and suburban railway network to the mainline station of destination. We assume an average walking speed of 3 km/h, an average train velocity of 33 km/h and a 2.5 min waiting time at the station of departure. Analyses are conducted within the framework of 15,937 statistical blocks. Population (2005) and employment data obtained from Statistical Office of the Senate Department in Berlin. Employment considers employees at workplace who contributed to social insurances in 2003.

Tab. A4: Time-difference Estimates Including Announcement Period

	Announcement included in "Before"			Announcement included in "After"		
	(1)	(2)	(3)	(4)	(5)	(6)
West	0.035	0.038	0.033	-0.016	-0.016	-0.0238
	(0.0317)	(0.0321)	(0.0322)	(0.0325)	(0.0328)	(0.0327)
DistCBD	-0.019***	-0.019***	-0.018***	-0.019***	-0.018***	-0.018***
	(0.0033)	(0.0033)	(0.0032)	(0.0034)	(0.0034)	(0.0034)
$\Delta MinDist$		0.004			-0.001	
		(0.0074)			(0.0074)	
$\Delta\log(AvDist)$			-0.004			-0.0112
			(0.0081)			(0.0082)
Const.	0.095***	0.092***	0.097***	0.156***	0.156***	0.162***
	(0.0389)	(0.0404)	(0.0397)	(0.0381)	(0.0392	(0.0384
Obs.	291	291	291	291	291	291
R-squared	0.104	0.105	0.104	0.095	0.095	0.100

Notes: Dependent variable is log-difference in residual land price (*RLP*) aggregated to traffic cells in all models. Announcement period from June 30, 2005, to April 1, 2006, is assigned to the before period in columns (1-3) and to the after period in (4-6). Due to the increased number of transactions considered in the analyses, the number of traffic cells included in the analysis increases by 4 compared to Table 4. Robust standard errors are in parenthesis. *** denotes statistical significance at the 1% level.

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