Universität Hamburg

Faculty Economics
and Social Sciences
Chair for Economic Policy

GABRIEL AHLFELDT

A NEW CENTRAL STATION FOR A UNIFIED CITY: PREDICTING IMPACT ON PROPERTY PRICES FOR URBAN RAILWAY NETWORK EXTENSIONS IN BERLIN

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University of Hamburg
Faculty Economics and Social Science
Chair for Economic Policy
Von-Melle-Park 5
D-20146 Hamburg | Germany
Tel +49 40 42838 - 4622
Fax +49 40 42838 - 6251
http://www.uni-hamburg.de/economicpolicy

Editor: Wolfgang Maennig

P. Gabriel M. Ahlfeldt
University of Hamburg
Faculty Economics and Social Science
Chair for Economic Policy
Von-Melle-Park 5
D-20146 Hamburg | Germany
Tel +49 40 42838 - 5569
Fax +49 40 42838 - 6251
ahlfeldt@econ.uni-hamburg.de

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Gabriel Ahlfeldt

A New Central Station for a Unified City: Predicting Impact on Property Prices for Urban Railway Network Extensions in Berlin*

Abstract: This paper develops a framework for predicting impact of urban railway network extensions on property prices. Impact of market potential and access to employment is assessed within a hedonic model environment employing potentiality variables and highly disaggregated data. Based on empirical results, expected impact on property prices is assessed for proposed railway extensions connecting Berlin's new central station to the existing metrorail and suburban railway network. Relying on simulated changes in population and employment potentialities, expected increase in aggregated land value is compared for residential and business properties. Application of highly disaggregated data allows detailed mapping of expected pattern of impacts.

Keywords: Urban Transport, Market Access, Employment Access, Land Values, Polycentric City, Berlin
JEL classification: R12, R23, R42, R52

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1 Introduction

Rail based public transport typically represents the backbone of modern metropolitan transport due to high capacities and relatively low problems of pollution and congestion compared to private transport. However, investments in railway network extensions, particularly for underground lines, sum to huge amounts and affect the interests of numerous rivalling groups pronouncing their preferences in the political debate. Berlin represents a much interesting example for an ongoing debate on how to extend the ur-

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ban railway network. After unification, rail infrastructure was modernised including construction of an impressive new central station. Completed in 2006, this station now needs to be integrated into the metro and suburban railway network. While various extensions are proposed, serious budged constraints make it necessary to define priorities. Having to decide among various proposed network enlargements, decision makers depend on valid information about the extent to which residents and commerce will be affected by public investments. As attractiveness of urban location is immediately capitalised into real estate prices, positive impact on location desirability following network extension is expected to be reflected in price differences. Therefore, aggregated impact on property prices may provide a useful measure for comparing added values of considered extensions. Moreover, external effects being monetarily quantifiable and spatially locatable, politicians may take into account wealth effects on local residents and commerce to determine feasible compensations.

Mechanisms through which accessibility determines attractiveness of urban location have been formulated by ALONSO (1964) and New Economic Geography (FUJITA, KRUGMAN, & VENABLES, 1999; KRUGMAN, 1991). Basically, residents are assumed to desire to locate close to employment centres, which might also be interpreted as centres of provision of services in a more broader sense (AHLFELDT, 2007). Similarly, firms try to locate close to customers, consumers and employees (CRAFTS, 2005). Relying on these theoretical implications, this paper uses an empirical approach developed by AHLFELDT (2007) to assess the impact of urban rail network on property prices for commercial and residential properties. Following a long tradition in economic geography, accessibility is captured by potentiality variables referring to either population or employment (HARRIS, 1954). This approach accounts for urban polycentricity, which has theoretically proven to represent a stable equilibrium (LUCAS & ROSSI-HANSBERG, 2002) and is an obvious reality in many cities, including Berlin.

Based on empirical results and simulated changes in population and employment potentialities, expected impact of distinct network extensions is assessed for business and residential areas. Since all 15,937 statistical blocks of Berlin are related to each other by combined network distances allowing for distinct travel costs for train rides and walks, patterns of impacts can be derived for the whole metropolitan area. Aggregated impact on property prices provides an intuitively comprehensive measure for comparing expected benefits for residents and commerce associated to different projects. Moreover, application of highly disaggregated data enables detailed mapping and comparison of impact patterns.

The remainder of this article is organised as follows. The next section introduces into the current situation in Berlin. Section three presents the data. In section four empirical models are developed. Section five presents empirical results and compares impact on property prices for selected projects. The final section concludes.

2 Connecting the Central Station

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 modernisation after Germany's unification. Services had been carried out by relatively small stations within both parts of the city. At the beginning of the 1990th, 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 new the north-south with the old east-west track was chosen to be the location of Berlin's new central station which was inaugurated timely for the football world championship in 2006. The station was designed by the prominent architecture firm GMP and involved investments that summed to approximately € 1 billion for facilities and feeder lines. In total, modernisation of Berlin's railway tracks had cost over € 4 billion (HOPS & KURPJUWEIT, 2007). The new central station representing one of European's largest and most modern interchange stations and the huge investment amounts stand exemplarily for the post-unification euphoria at the beginning of the 1990th, when Berlin's economic perspectives had still been regarded very positively.

Meanwhile, following a considerable economic disillusion, Berlin is confronted with serious budged constraints on the one hand and the need to connect the new station to the existing urban railway network on the other. Placed on a strip of land formerly occupied by the Berlin Wall, the station, despite of its geographic centrality, is located within a largely undeveloped area and is only connected to the urban railway network through the suburban east-west railway track. Since the station is intended to represent the heart of a new district about to be developed, connectivity of central station not only affects travellers but might also be a key determinant for the acceptance of the new district by residents and commerce.

Two major railway network extensions are currently being considered for connecting the central station to the existing urban railway network. First, a northbound connection to the circular line of suburban railway system of approx. 1.7 km length is likely to be developed. According to the current plans, this extension would not be accompanied by inauguration of new stations. The second promising project is the westward extension of metro line 5 (U5) from Alexanderplatz, along the famous Boulevard "Unter den Linden" and "Brandenburg Gate" to the new central station and continuing through the residential area of Moabit district until connecting to the suburban circular line at station "Jungfernheide".[1] Following these plans, metro line 5 will be extended by approximately 9 km and 10 stations, of which 8 will be completely new. This extension is particularly interesting since it connects both residential and commercial areas and presumable will have positive effects for both residents and business. Presently, a section from Brandenburg Gate to main station is under construction whose completion is scheduled for 2009. While the remaining westbound section from Brandenburg Gate to Alexandeplatz is aimed to be completed until 2015, the eastbound extension of Metroline U5 might currently not be expected to be developed in close future. However, particularly in light of the desolate budgetary position of Berlin, there is much need for valid information about the expected impact of proposed extensions enabling decision makers to better define priorities.

[1] The structure plan also considers extension of the line to Tegel Airport and further norhtwards. However, due to the scheduled closure of Tegel Airport this extesion has become quite unlikely and will not be further considered. Effectively, even the westward extension from main station is seriously being questioned.

3 Data

The study area covers the whole of Berlin, capital city of Germany, which on July 30, 2006 had 3,399,511 inhabitants and an area of approximately 892 km^2. Standard land values per square meter from SENATSVERWALTUNG FUER STADTENTWICKLUNG are used representing aggregated market values for properties lying within block boundaries based on transactions during the reporting period (2005). The data reveals market values for undeveloped properties within the zone of valuation and refer to typical density of a development provided in the form of a typical floor space index (FSI) value for the zone. The FSI, also called floor space ratio (FSR), is the ratio of building total floor area to the area of the corresponding plot of land. Additionally, each standard land value is assigned to a class of land use, indicating whether the respective area is characterized by major retail and business activity, industrial or residential use.

The data refers to the 15,937 official statistical block structure, the most disaggregated level available at the Statistical Office of Berlin. The statistical blocks have a median surface area of less than 20,000 m^2, approximately the size of a typical inner-city block of houses. The mean population of the 12,314 populated blocks is 271 (median 135). To analyse this highly disaggregated dataset GIS tools and a projected GIS map of the official block structure are employed and merged with information for public infrastructure as e.g. schools, railway stations and network enabling generation of impact variables that are discussed in more detail in the section below. Based on the City and Environmental Information System of the Senate Department a full set of variables representing typical residential building structure at block level is also created by application of GIS tools. Furthermore, population data at block-level is used including demographic characteristics and origin of resident population. All data used in this paper strictly refers to the end of 2005 with the exception of employment at workplace, which was only available at the Senate Department for the end of 2003.[2]

[2] Employment at workplace data includes all employees contributing to the national social insurances.

4 Research Strategy

The research strategy basically consists of three steps. First, accessibility indicators are developed. In the second step impact of accessibility on property prices is empirically assessed using hedonic modelling. Finally, based on the empirical results, impact of network extension is assessed by simulating changes in employment and population potentialities. These results can be used to compare aggregated impact of on land value and to map patterns of impact.

Due to the obvious importance of metropolitan railway systems, impact on property prices has attracted much scholarly attention (BOWES & IHLANFELDT, 2001; DAMM, LERNER-LAM, & YOUNG, 1980; GATZLAFF & SMITH, 1993; GRASS, 1992; VOITH, 1991). Literature reviews and meta analyses are also available (DEBREZION, PELS, & RIETVELD, 2004; VESSALI, 1996). Railway accessibility is a complex concept since stations' impacts are expected to depend on their relative centrality within the network, the frequency of being chosen by residents (DEBREZION, PELS, & RIETVELD, 2006) and on whether they carry out hub-functions. However, in thins approach no hierarchy of stations has to be explicitly defined since stations located more centrally within the metropolitan railway network will automatically generate more population and employment potentiality. Similarly to approaches of forecasting future trip pattern (ORTÚZAR & WILLUMSEN, 2004), the approach followed in this paper allows for capturing network externalities and predicting impacts of network enlargements for the whole metropolitan area.

The following subsections develop the empirical models. Potentiality variables capturing accessibility are discussed in the next subsection. Impact on property prices is assessed using a hedonic approach presented in section 4.2.

4.1 Generating Potentialities

The original idea of land values decreasing with distance to the urban core dates back to von THÜNEN (1826). ALONSO (1964) later postulated the idea of increasing rents due to outbidding of residents appreciating proximity to employment which concentrates in the CBD. Following this reasoning, residents are compensated for higher rents by reduced commuting time. This concept has been under heavy criticism, mostly because it fails to describe polycentric distribution of employment (GARREAU, 1991; GIULIANO & SMALL, 1991; MCDONALD, 1987; WHEATON, 1982). Thus, particularly in polycentric cities, there is need for a more decentralised approach to capture capitalization into property prices.

In the economic geography literature there is a long tradition which dates back to HARRIS (1954) in representing access to markets by distance weighted sum of population. For instance, let P_i be block's *i* population, than

$$PP_i = \sum_j P_j e^{-a\, d_{ij}} \tag{1}$$

is block's *i* population potentiality (PP_i), where P_j is the population of block *j*, *a* is a distance decay factor implicitly determining transport costs and d_{ij} is the straight-line distance between blocks' *i* and *j* geographic centroids. As we deal with blocks of different size a basic concept of empirical economic geography (CRAFTS, 2005; KEEBLE, OWENS, & THOMPSON, 1982) is employed to generate a block internal distance measure based on the surface area which can be used to determine the self-potential.

$$d_{ii} = \frac{1}{3}\sqrt{\frac{Area_i}{\Pi}} \tag{2}$$

d_{ii} is block's *i* internal distance equalling one third of the diameter of a circle of block's *i* surface area *($Area_i$)*.

The same concept is applied to capture access to employment:

$$EP_i = \sum_j E_j e^{-a\, d_{ij}}\ , \tag{3}$$

where EP_i is the employment potentiality at block *i* and E_j employment at workplace. d_{ii} is block's *i* internal distance as defined in equation (2).

Decay parameter *a* determines the weight with which neighbouring blocks' *j* population or employment enters the potentiality of block *i* depending on the distance from block *i* to *j*. Thus, the parameter may be used to reflect different travel cost corresponding to distinct modes of urban transport. While the standard parameter value of 0.5 (WU, 2000) is plausible for the implicit travel cost function referring to average velocity of local trains, pedestrians mobility has been found to be feasibly approximated by choosing a decay parameter value of 2 (AHLFELDT, 2007). This parameter value, which spatially discounts surrounding areas stronger, can also be employed for capturing neighbourhood externalities of relatively limited range.

Formulas (1) and (3) may be may be employed to reflect access to population and employment within walking distance. A more sophisticated approach is required to capture accessibility generated by rail-based transportation systems since commuting trips involve train rides and walks from home to railway-station, from railway-station to workplace and vice versa respectively. Moreover, trains are forced to follow determined network-routes which can deviate substantially from straight-line distances. Assuming that residents strictly walk to the next station, choose the shortest network connection within the combined metro and suburban railway network and descend the railway system at the station located closest to their place of work, generation of employment potentiality basically consists of three steps.[3]

Firstly, the employment potentiality of each station within the network is the distance weighted sum of surrounding blocks' employment:

$$SP_m = \sum_j E_j e^{(-b\, d_{mj})}, \quad (4)$$

where SP_m is the employment potentiality of station m, E_j is employment at workplace of block j, b is a distance decay factor taking the value of 2 and d_{mj} is the straight-line distance between station m and block j.

Secondly, employment potentiality generated by the rail network is the distance weighted sum of station potentialities of all other stations within the network:

$$NSP_s = \sum_m SP_m e^{(-a\, d_{sm})}, \text{ for } m \neq s \quad (5)$$

[3] The combined Berlin metro and suburban railway network consists of 275 stations and has a length of 475 km. Yearly passenger numbers add to approximately 790 Million (2006).

NSP_s is the employment potential of station *s*, which can be imagined of being the potential a resident encounters who lives immediately adjoining station *s* and desires to commute by rail-based public transportation. *a* is a distance decay parameter taking the value of 0.5 and d_{sm} is the shortest network distance between station *s* and *m*. Stations' self-potentials are not considered since residents living and working within the catchment area of the same station will obviously not take the train.[4]

Finally, as commuters typically do not live within railway stations, network station potentiality has to be discounted with distance to residence to reflect transport costs of walking to the next railway station:

$$EP\_Rail_i = NSP_s \; e^{(-b \; d_{is})}, \tag{6}$$

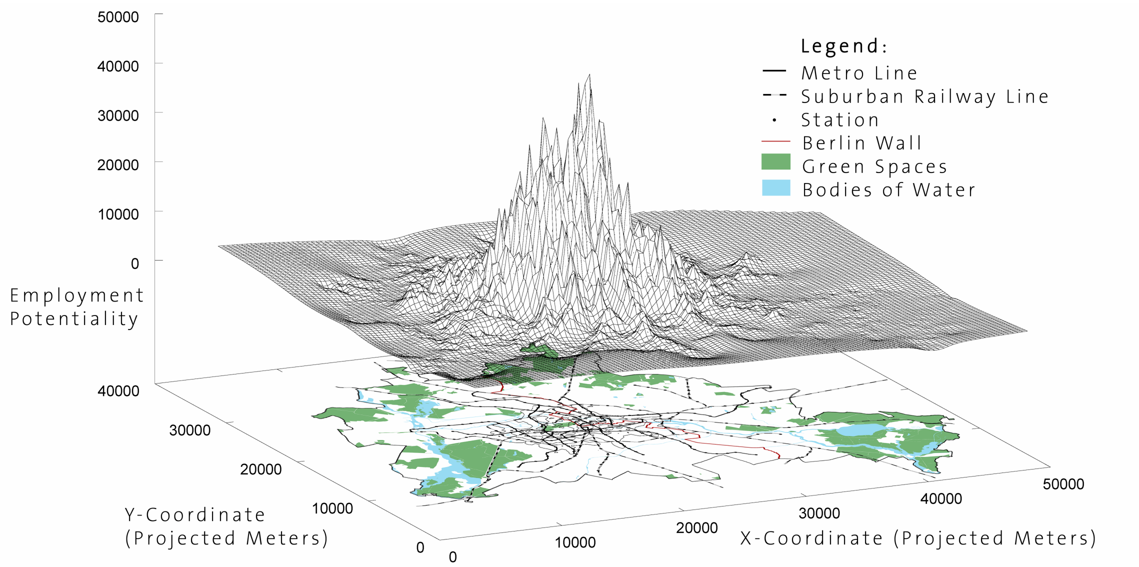
where EP_Rail_i is the employment potential generated by the urban railway network at block *i*, *b* takes the value of 2 and d_{is} is the distance from block *i* to the nearest station *s*. Combining equations (4) – (6), the employment potentiality generated by the railway network can be written as:

$$EP\_Rail_i = e^{(-b \; d_{is})} \sum_m \left(\sum_j E_j e^{(-b \; d_{mj})} \right) e^{(-a \; d_{sm})}, \text{ for } m \neq s \tag{7}$$

Figure 1 visualises the employment potentiality surface generated by the integrated urban railway network. Rail network population potentiality is generated analogically. A more detailed description of accessibility indicators adopted in this paper is provided by AHLFELDT (2007).

[4] The employment potential is captured by the employment access indicator based on walking speed.

Fig. 1 Employment Potentiality Surface (Railway Network)



Notes: The figure represents block level employment potentiality as defined in equation (12) assuming a decay parameters *a* and *b* of 0.5 and 2. Coordinates refer to the "Soldner" coordinate system used by the Senate Department of Berlin.

4.2 Hedonic Modelling

If real estate markets are in equilibrium, attractiveness of location is fully capitalised into property prices. Attractiveness of a real estate commodity can be assumed to depend on structural attributes *[S]*, a set of attributes capturing the effects of the neighbourhood *[N]* and local amenities *[L]* whose implicit prices are estimated using multiple regression (GALSTER, TATIAN, & PETTIT, 2004; MUELLBAUER, 1974; ROSEN, 1974). A typical hedonic regression equation may take following form (TU, 2005).

$$\log(R) = \alpha + \beta_1 S_1 + \ldots + \beta_i S_i + \gamma_1 N_1 + \ldots + \gamma_j N_j + \delta_1 L_1 + \ldots + \delta_k L_k + \varepsilon \quad (8)$$

where *i*, *j* and *k* represent the number of attributes, α, β, γ and δ are coefficients and ε is an error term. Log-linear specifications are commonly chosen since they allow for non-linearity and are intuitively interpretable. The attribute coefficient gives the percentage impact of changes in attribute value on property value. For coefficient values smaller than 10% this rule may also be applied to dummy-variables (ELLEN *et al.*, 2001).[5]

[5] For larger coefficient values a simple formula is strongly recommended, providing a much better approximation. For a parameter estimate *b* the percentage effect is equal to ($e^b - 1$) (HALVORSEN & PALMQUIST, 1980)

Two hedonic models are set up to explain standard land values for residential and commercial properties. Models employed in this paper capture density of development by floor space index determined in the zoning regulations while blocks' typical building structure is captured by a full set of dummy variables. Location attributes are represented by potentiality variables similar to equations (1) and (3). Assuming that neighbourhood externalities spread at walking speed, a distance decay parameter of 2 is used to spatially discount blocks' water and green spaces measured in hectare. By the same way, a school potentiality indicator is created based on the ratio of number of schools and the relevant age group of 6-18 years-olds. Shopping has theoretically proven to be relevant for residents' location choice (ANAS & KIM, 1996). However, potentiality variables corresponding to a reduced retail gravity model (EPPLI & SHILLING, 1996) were found to be collinear with employment and are dropped from the model (AHLFELDT, 2007). Neighbourhood is captured by density and composition or resident population, particularly focusing on potentially income-weak population groups. To account for effects of proximity to CBD which are not captured by employment and population potentialities, distance to CDB enters the model *(Dist_CBD)*.[6] A dummy variable is added denoting all blocks lying within the borders of former East-Berlin *(EAST)* which might account for spatial east-west heterogeneity potentially caused by persistent effects of division. By interacting the dummy variable with distance to CBD, land gradient is allowed to vary across space.

The full hedonic model specification employed to assess impact of employment accessibility for residential properties takes following form:

$$\begin{aligned}\log(LV) = \alpha &+ \beta_1 East + \beta_2 Dist\_CBD + \beta_3 (Dist\_CBD \times East) \\ &+ STRUCT\ c_1 + LOC\ c_2 + NEIGH\ c_3 + EA\ c_4 \\ &+ \gamma\ Spatial\_Lag + \varepsilon\end{aligned} \tag{9}$$

[6] Distance to CBD is defined as the minimum distance to either CBD-East or CBD-West. CBD-West is defined as a point on Breitscheidplatz, the place where the Kaiser-Wilhelm Memorial Church stands. CBD-East is defined as the crossroads of Friedrichstrasse and Leipziger Strasse. Centrality of this point is highlighted by the nearby metro-station called Downtown (Stadtmitte).

where *STRUCT* is a vector of structural attributes capturing building density and building structure, *LOC* is a vector of location attributes capturing natural endowments and public and private services provision, *NEIGH* is a vector capturing blocks' population density and composition and *EA* is a vector of employment potentiality variables. α, β_x, γ and c_x represent the set of coefficients to be estimated and ε is an error Term. A detailed description of variables is in table A1 in the appendix. *Spatial_Lag* is a spatial autoregressive term accounting for spatial autocorrelation which might be caused by omitted variables being correlated across space.[7] The lag term is a distance weighted average of neighbouring properties and takes following form for block *i*:

$$Spatial\_Lag_i = \sum_j \frac{(1/d_{ij})}{\sum_j 1/d_{ij}} LV_j, \tag{10}$$

where LV_j is the standard land value of neighbouring residential block *j* and $(1/d_{ij})$ represents the inverse of distance between centroids of blocks *i* and *j*. Here, the lag term considers the three nearest residential blocks. This specification was proposed by CAN & MEGBOLUGBE (1997) and proved to be efficient (AHLFELDT & MAENNIG, 2007).

According to the mechanisms formulated by New Economic Geography, firms appreciate central location due to access to employees, customers and consumers. In equilibrium firms are fully compensated for higher prices by market access. The hedonic model employed the assess Impact of market access on business property prices takes a reduced form since an amenity based approach less applicable when modelling urban firm location.[8]:

$$\begin{aligned} \log(LV) = {} & \omega + \delta_1 East + \delta_2 Dist\_CBD + \delta_3 (Dist\_CBD \times East) \\ & + STRUCTB\ d_1 + MA\ d_4 + \sigma\ Spatial\_Lag + \varepsilon \end{aligned} \tag{11}$$

7 An intuitive explication for the existence of spatial auto-correlation in real estate prices is that buyers and sellers orientate at previous transactions in the neighbourhood when negotiating prices.

8 For specialized industries like media, amenities like proximity to scenic districts or bodies of water may matter. However, for business and service oriented industries in general, as considered in this paper, there are hardly striking amenities imaginable. Moreover, as residents can be assumed to be relatively immobile between cities, but mobile within cities, there is rather an incentive for firms to locate in attractive cities then particularly close to local amenities when aiming to attract employees.

where again, Greek and lower case letters represent coefficients to be estimated, *STRUCTB* is the same as *STRUCT* in equation (15) excluding dummies for building structure and *MA* is a vector of population potentiality variables. New Economic Geography has also emphasized forces of agglomeration (FUJITA, KRUGMAN, & VENABLES, 1999; HELPMAN, 1997; KRUGMAN, 1991) resulting from spill-overs and economies of scale. High economic activity within the vicinity will be reflected in high prices for surrounding properties and thus captured by the spatial lag term.[9]

5 Results

5.1 Hedonic Estimates

Empirical Results corresponding to equation (9) are represented in Table 1. Column (2) results are obtained after stepwise deletion of insignificant variables from full model specification (1).[10] Coefficient estimates are intuitively plausible, showing expected signs and confirming previous results (AHLFELDT, 2007; AHLFELDT & MAENNIG, 2007). Inline with theory, coefficients for employment potentiality variables are positive and statistically significant, highlighting the importance of accessibility for residential properties.

Table 2 results corresponding to equation (11) reveal that attractiveness of urban centrality for commerce is completely explained by market access and forces of agglomeration. Neither the coefficients on *Dist_CBD* nor on the interactive term (*Dist_CBD x East*) are statistically significant at conventional levels. Column (2) presents the final hedonic model specification after deleting insignificant variables from full model specification (1). As expected, coefficients for market access indicators are positive and statistically significant.

[9] The spatial lag term considers three nearest blocks independently of land use. A three nearest block specification just considering blocks used for business purposes might be misleading since there are business blocks lying isolated within residential blocks so that the distance weighted average does not reflect the immediate vicinity.

[10] Insignificant structural dummies are not excluded since building structure is only feasibly captured by the full set of structural dummies which might be thought of representing structural fixed effects.

Tab. 1 Empirical Results for Residential Land Values

	(1) Land Value (Log)		(2) Land Value (Log)	
	Est. Coeff.	S.E.	Est. Coeff.	S.E.
East	-0.568291***	0.016413	-0.562632***	0.016465
Dist_CBD	-0.071027***	0.001784	-0.070204***	0.001744
Dist_CBD x East	0.024678***	0.001474	0.024053***	0.001465
FSI	0.150421***	0.023763	0.198049***	0.007948
FSI²	0.017859**	0.008053		
BS_High90	0.000503	0.018653	0.000368	0.018595
BS_Prefab8090	0.000503	0.018653	0.000217	0.028099
BS_High4580	-0.071146***	0.014539	-0.075964***	0.014567
BS_Prefab50	-0.032677**	0.000404	-0.034800**	0.014877
BS_Block2030	0.012470	0.014073	0.008500	0.014158
BS_Wilhelm_Highd	0.011376	0.016054	0.014930	0.016088
BS_Wilhelm_HighdM	0.027545	0.018738	0.027667	0.018844
BS_Wilhelm_Lowd	0.071120***	0.014267	0.064984***	0.014235
BS_Village	-0.006698	0.045125	-0.003767	0.044823
BS_Lowd90	0.042278	0.033876	0.000482	0.008345
BS_Lowd50plus	0.152591***	0.019661	0.153006***	0.019667
BS_Villas50	0.267240***	0.014702	0.266941***	0.014690
BS_Lowd00	-0.001516	0.008401	0.000482	0.008345
Water_P	0.002251***	0.000386	0.002126***	0.000374
Green_P	-0.000148	0.000156		
School_P	0.015927***	0.001420	0.015699***	0.001388
Pop_Density	-0.000813**	0.000404	-0.000718*	0.000406
Prop_Pop_Sub6	0.002235***	0.000731	0.002386***	0.000672
Prop_Pop_6_15	0.000337	0.000667		
Prop_Pop_15_18	-0.003527***	0.000981	-0.003420***	0.000949
Prop_pop_18_27	-0.001882***	0.000495	-0.001945***	0.000494
Prop_Pop_65plus	0.001770***	0.000279	0.001740***	0.000277
Prop_Foreigners	-0.003161***	0.000502	-0.003096***	0.000495
EP_Walking	0.004115**	0.001935	0.004375 **	0.001842
EP_Rail	0.004915***	0.000765	0.005454***	0.000741

Empirical Results for Residential Land Values (continued)

	(1)	(2)
Spatial Lag	Yes	Yes
Sample	Residential	Residential
Observations	9234	9234
R^2	0.791357	0.791886
R^2 adjusted	0.790654	0.791231

Notes: Endogenous variable in models (1) and (2) is standard land values taken into logarithm. Exogenous variables are defined in Table A2 in the appendix. Model (1) represents the full hedonic model specification. Model (2) is obtained after stepwise deletion of insignificant variables. FSI², significant in model (1) became insignificant when deleting insignificant variables and was dropped. Sample is all areas that are purely used for residential purposes. Standard errors are heteroscedasticity robust. * denotes significance at the 10% level; ** denotes significance at the 5% level; *** denotes significance at the 1% level.

Tab. 2 Empirical Results for Commercial Land Values

	(1) Land Value (Log)		(2) Land Value (Log)	
	Est. Coeff.	S.E.	Est. Coeff.	S.E.
EAST	-0.328908***	0.039066	-0.341872***	0.027438
DIST_CBD	0.000005	0.000008		
DIST_CBD x EAST	-0.000004	0.000007		
FSI	0.368027***	0.080503	0.348600***	0.069292
FSI²	0.056335***	0.012264	0.058675***	0.011135
PP_Walking	0.000009***	0.000002	0.008960***	0.002129
PP_Rail	0.000003**	0.000001	0.002541**	0.001117
Spatial Lag	Yes		Yes	
Sample	Commercial		Commercial	
Observations	1038		1038	
R^2	0.825835		0.825769	
R^2 adjusted	0.824481		0.824755	

Notes: Endogenous variable in models (1) and (2) is standard land values taken into logarithm. Exogenous variables are defined in Table A2 in the appendix. Model (1) represents the full hedonic model specification. Model (2) is obtained after stepwise deletion of insignificant variables. Sample is all areas that are purely used for by business or service orientated industries. Standard errors are heteroscedasticity robust. * denotes significance at the 10% level; ** denotes significance at the 5% level; *** denotes significance at the 1% level.

5.2 Simulating Effects of Network Extension

Having estimated the impacts of employment and population potentialities on residential and commercial land values, effects of railway network improvement may be predicted on the basis of changes in potentiality surfaces.

The great advantage of the decentralized approach to accessibility employed in this paper is that all 15,937 blocks are set into relation to each other. A distance-to-station based approach might be limited to assessment of impact for properties surrounding stations that are newly developed or stations ascending in the network hierarchy. In contrast, this approach enables simulation of changes in accessibility, and thus prediction of impacts on property prices, for all properties in Berlin. As found by AHLFELDT (2007), centres of employment fall together with retailing centres. Employment accessibility generated by the railway network may thus be interpreted as a proxy for centrality in a more general sense implicitly capturing shopping, cultural and other central activities which, due to problems of multicollinearity, might not be modelled explicitly.

Coefficients on *PP_Rail* and *EP_Rail* in Tables 1 and 2 have been estimated in log-linear model specifications. Therefore they represent the percentage change in the endogenous variable when increasing the relevant right-hand side variable by one. Multiplying estimated coefficients with simulated change in potentiality following network extension yields percentage impacts on property prices predicted by the models:[11]

$$\Delta LV_R = \theta_{EP\_Rail}\left(EP\_Rail_{SIM_R} - EP\_Rail_{CUR_B}\right) \quad (12)$$

$$\Delta LV_B = \theta_{PP\_Rail}\left(PP\_Rail_{SIM_B} - PP\_Rail_{CUR_B}\right) \quad (13)$$

where ΔLV_R is the percentage change in standard land value of residential block *R*, ΔLV_B is the same for business block *B* and θ_{EP_Rail} and θ_{PP_Rail} are the estimated coefficient values for *EP_Rail* and *PP_Rail* represented in tables 1 and 2. EP_Rail_{CURR} is employment potentiality for block *R* as defined in equation (7) based on the current network in operation while

[11] Due to the limited size of considered network extension, variation of potentiality variables will be relatively small. Impact of accessibility generated by the railway network is not expected to be changed dramatically by the networks' extension and thus coefficients may be assumed to not suffer major bias.

EP_Rail$_{SIMR}$ is the same for the extended network. Similarly *PP_Rail*$_{CURB}$ is the population potentiality for block *B* corresponding to the current network and *PP_Rail*$_{SIMB}$ for the extended one. Expected pattern of impact can be visualized by mapping ΔLV_R and ΔLV_B allowing for identifying regions that benefit of determined extension projects. Figures 2, 3 and 4 compare expected pattern of impact for different scenarios.

Fig. 2 Effects of Northbound Extension

Notes: Map created on the basis of the "City and Environment Information System" of the Senate Department (SENATSVERWALTUNG FÜR STADTENTWICKLUNG BERLIN, 2006b).

Although the northbound connection to suburban railway network does not include new stations and therefore does not connect new areas to the network, the increase in effective accessibility following reduced travel time for residents is large enough to have considerable impact. Particularly areas in immediate proximity to central station are likely to benefit. Effects might also spread through the existing network towards CBD-East where commerce benefits from improved access to residential areas in the north-west. At the same time residential areas north-westward of central station and in proximity to Alexanderplatz are likely to benefit from improved accessibility to CBD-East and industrial employment centres in the north-west. However, compared to metro line extensions illustrated in Figures 3 and 4, increase in market access and thus impact on property prices is limited since no residents and businesses are newly connected to the network.

Fig. 3 Effects of Northbound and Eastbound Extensions

Notes: Map created on the basis of the "City and Environment Information System" of the Senate Department (SENATSVERWALTUNG FÜR STADTENTWICKLUNG BERLIN, 2006b).

Figures 3 and 4 illustrate scenarios where, additionally to the northbound suburban railway extension, metro rail network is extended eastwards (Figure 3) or east- and westwards respectively (Figure 4). Obviously, areas in close proximity to newly developed stations are most likely benefit from increase in accessibility. According to the estimated impact of accessibility and simulated changes in market access, the eastward extension may be expected to raise property prices up to 7.5%. Residential areas along the westward extension might even experience an increase of up to 11%. Moreover, impacts are also predicted for properties lying along the existing network. Business and residential areas to the north, east and south of CBD-East are likely to benefit from the eastbound metro line extension running through CBD-East. Similarly, the westward extension running largely through residential areas of Moabit and Charlottenburg will induce positive effects for CBD-West profiting from improved access to markets. Minor effects on property prices revealing network externalities are to be expected even for remote properties lying along the railway network at distances up to approximately 7 km.

Fig. 4 Effects of Nothbound, Southbound and Westbound Extensions

Notes: Map created on the basis of the "City and Environment Information System" of the Senate Department (SENATSVERWALTUNG FÜR STADTENTWICKLUNG BERLIN, 2006b),

Based on *ΔLV*, expected impact on property prices may be aggregated for residential and commercial areas.

$$AI = \sum \Delta LV_R \times LV_R \times SOI_R \times AREA_R + \sum \Delta LV_B \times LV_B \times SOI_B \times AREA_B \quad (14)$$

where *AI* is aggregated impact on property prices, *ΔLV* is defined in equations (12) and (13), *LV* stands for standard land value of residential block *R* or business block *B*, *SOI* (site occupancy index) represents the extend to which properties may be developed according to the zoning regulations and *AREA* is block's total surface area. Table 3 compares aggregated impact on property prices for business and residential areas for different scenarios of railway network extension.

Tab. 3 Aggregated Impact on Property Prices

Extension	Aggregated Impact (€) on Residential Areas	Aggregated Impact (€) on Commercial Areas	Total Aggregated Impact (€)
Northbound (Suburban Railway)	4,500,005.36	11,321,411.89	15,821,417.25
Westbound (Metrorail)	18,851,967.36	27,160,432.55	46,012,399.91
Eastbound (Metrorail)	11,449,037.86	81,439,004.46	92,888,042.32
Nortbound and Eastbound (Suburban and Metrorail)	13,335,557.01	85,451,876.18	98,787,433.19
Northbound, Eastbound and Westbound	28,759,348.99	103,872,210.30	132,631,559.30

Notes: Aggregated impact assessed according to equation (11) based on empirical results and simulated changes in potentialities.

Results reveal that aggregated impact might generally be expected to be larger for business properties compared to residential properties. This might by explained by the fact that property prices for commercial areas are generally higher compared to residential areas. Moreover, business properties are legally allowed to be developed more extensively leading to relatively larger wealth effects. As suggested by Figures 2 – 4, impact of northbound extension is limited compared to the discussed east- and westward metrorail extensions. The combined northbound and eastbound extension is the most likely scenario to be realised following the current political debate. While in this scenario positive impact is expected mainly for commercial areas, the westbound extension would have more considerable effects for residential property owners.

6 Conclusion

This paper contributes to the empirical urban and transport economics literature by developing a framework for predicting impact of railway network extension on property prices. Impact of rail-based urban transportation network is modelled adopting the idea of access to employment determining residential property prices postulated by ALONSO (1964) and the role of market access for firms' location emphasised by New Economic Geography. Accessibility and other location attributes are captured by potentiality variables whose implicit prices were estimated using hedonic modelling. Empirical results support theory in that accessibility indicators where found to positively influence attractiveness of urban location. Changes in accessibility are modelled for distinct proposed network extensions which on the basis of empirical results are used to assess expected impact on property prices. Due to application of micro-level data disaggregated to an extent that potentiality variables had to be generated on high-performance computing systems, expected patterns of impact can be mapped allowing for spatial impression and intuitive interpretation. Impact being aggregated for business and residential properties provides a useful tool for comparing overall wealth effects, which generally proved to be larger for business than for residential properties due to higher property prices and more densely built-up areas. Taking into account overall wealth effects and spatial distribution of impact, decision makers are enabled to better define priorities.

While stations located in immediate proximity of newly developed stations obviously are likely to experience the largest raise in property prices, effects may also be expected to spread along the existing network. Even the northbound connection to the suburban railway network, which does not include development of new stations, can be expected to have considerable impact on attractiveness of location for business and residential properties. Although the eastbound extension of metro line U5 is criticised for running parallel to the existing east-west suburban-railway track, wealth effects are found to be large compared to the other suggested extensions. However, impact of the most probable scenario of combined northbound and eastbound extension is likely to benefit predominantly owners of commercial properties within CBD-East, while the westbound extension might be preferable from residential property owners' perspectives. Particularly In light of scarcity of public funds, these results raise a simple question: Who should be charged for infrastructural improvements if not the very profiteers?

Appendix

Data Collection

We collected data on standard land values, FSI values and land use as determined by zoning regulations from atlases of standard land valuation (Bodenrichtwertatlanten) (SENATSVERWALTUNG FÜR STADTENTWICKLUNG BERLIN, 2006a). The Committee of Valuation Experts in Berlin has published this data at intervals of one to four years, since 1967.

Data collection was conducted by assigning values represented in atlases of standard land valuation to the official block structure as defined in December 2005. If more than one value was provided by an atlas of standard land valuation for one particular block, an average of the highest and lowest values was used. Price data has been collected individually for blocks, which were not used for purely residential purposes. In contrast, for pure residential areas data on land values at a lower level of disaggregation (Statistische Gebiete) was used, since variation was typically much smaller. Since Berlin consists of 195 statistical areas (Statistische Gebiete), this ensured that price data for residential areas was sufficiently disaggregated to draw a comprehensive picture. Aggregation to statistical area-level was by averaging the highest and lowest standard land values within the respective area. To guarantee that averages represented a feasible proxy of overall area valuation a threshold for the ratio of maximum-to-minimum land value within a statistical area was introduced. If this ratio was > 2, then the extreme values were entered individually and averages were taken over the remaining blocks until the ratio had fallen below the threshold value. This had to be done in only very few cases, since generally maximum and minimum values were close.

Tab. A2 Variables Description

East	Dummy-variable; 1 for blocks lying within the area of former East-Berlin
Dist_CBD	Minimum streight-line distance to CBD-East or CBD-West in kilometers
FSI	Floor-Space-Index: Quotient of full storey-area to plot-area
FSI²	Floor-Space-Index squared
BS_High90	Dummy variable; 1 for blocks characterised by 1990th housing block structure of 4 or more storeys
BS_Prefab8090	Dummy variable; 1 for blocks characterised by 1980th and 90th mixed row and block structure of prefabricated 2 – 5 storey buildings.
BS_High4580	Dummy variable, 1 for blocks characterised by post war (1945-1980th) 6 or more storey buildings arranged in rows separated by open spaces.
BS_Prefab50	Dummy variable, 1 for blocks characterised by 1950th 5 storey buildings arranged in rows separated by open spaces.
BS_Block2030	Dummy variable, 1 for blocks characterised by 1920th and 1930th mixed row and block structure of 3 – 4 storey buildings.
BS_Wilhelm_Highd	Dummy variable, 1 for blocks characterised by Wilhelminian (1870-1918) 5 -6 storey block developments with many backyards and sidewings.
BS_Wilhelm_HighdM	Dummy variable, 1 for blocks characterised by Wilhelminian (1870-1918) 5 -6 storey block developments mixed with post-war developments.
BS_Wilhelm_Lowd	Dummy variable, 1 for blocks characterised by Wilhelminian (1870-1918) 4 story block developments with relatively few backyards and sidewings.
BS_Village	Dummy variable, 1 for blocks characterised by village-like 1 – 2 storey buildings.
BS_Lowd90	Dummy variable, 1 for blocks characterised by 1990th 1 – 3 storey town houses and single family developments.
BS_Lowd50plus	Dummy variable, 1 for blocks characterised by 1 – 3 storey apartment houses within green spaces developed during the 1950th and later.
BS_Villas50	Dummy variable, 1 for blocks characterised by 2-storey villas surrounded by park-like gardens and mixed with apartment houses and single family housing.
BS_Lowd00	Dummy variable, 1 for blocks characterised by early 20th century low density developments of 1 – 2 storey single family and duplex houses.
Water_P	Potentiality variable: Blocks' water areas in hectare spatially discounted with a decay parameter of 2.
Green_P	Potentiality variable: Blocks' green areas in hectare spatially discounted with a decay parameter of 2.
School_P	Potentiality variable: Ratio of block's number of schools and 6-18-years olds in thousands spatially discounted with a decay parameter of 2.

Variables Description (continued)

Pop_Density	Population density in thousand inhabitants per square meter.
Prop_Pop_Sub6	Proportion of population below the age of 6.
Prop_Pop_6_15	Proportion of population aged between 6 and 15.
Prop_Pop_15_18	Proportion of population aged between 15 and 18.
Prop_pop_18_27	Proportion of population aged between 18 and 27.
Prop_Pop_65plus	Proportion of population older then 65.
Prop_Foreigners	Proportion of foreign population.
EP_Walking	Potentiality variable: Blocks' employment in thousands spatially discounted with a decay parameter of 2
EP_Rail	Employment potential generated by the urban railway network as defined in equation 12. Parameters a and b are chosen to be 0.5 and 2.
PP_Walking	Potentiality variable: Blocks' population in thousands spatially discounted with a decay parameter of 2.
PP_Rail	Population potential generated by the urban railway network as defined in equation 12. Parameters *a* and *b* are chosen to be 0.5 and 2.
STRUCT	Vector of structural attributes: FSI, FSI², BS_High90, BS_Prefab8090, BS_High4580, BS_Prefab50, BS_Block2030, BS_Wilhelm_Highd, BS_Wilhelm_HighdM, BS_Wilhelm_Lowd, BS_Village, BS_Lowd90
	BS_Lowd50plus, BS_Villas50, BS_Lowd20
STRUCTB	Vector of structural attributes: FSI, FSI²
LOC	Vector of location attributes: Water_P, Green_P, School_P, RP_Car, RP_Walking
NEIGH	Vector of neighbourhood attributes: Pop_Density, Prop_Pop_Sub6, Prop_Pop_6_15. Prop_Pop_15_18, Prop_pop_18_27, Prop_Pop_65plus, Prop_Foreigners
EA	Vector of employment accessibility variables: EP_Car, EP-Walking, REP
MA	Vector of market access variables: PP_Car, PP_Walking, PP_Rail
Spatial_Lag	Spatial Lag term. Spatially discounted average of surrounding property values as defined in equation (7).

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