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Chair for Economic Policy

GABRIEL AHLFELDT

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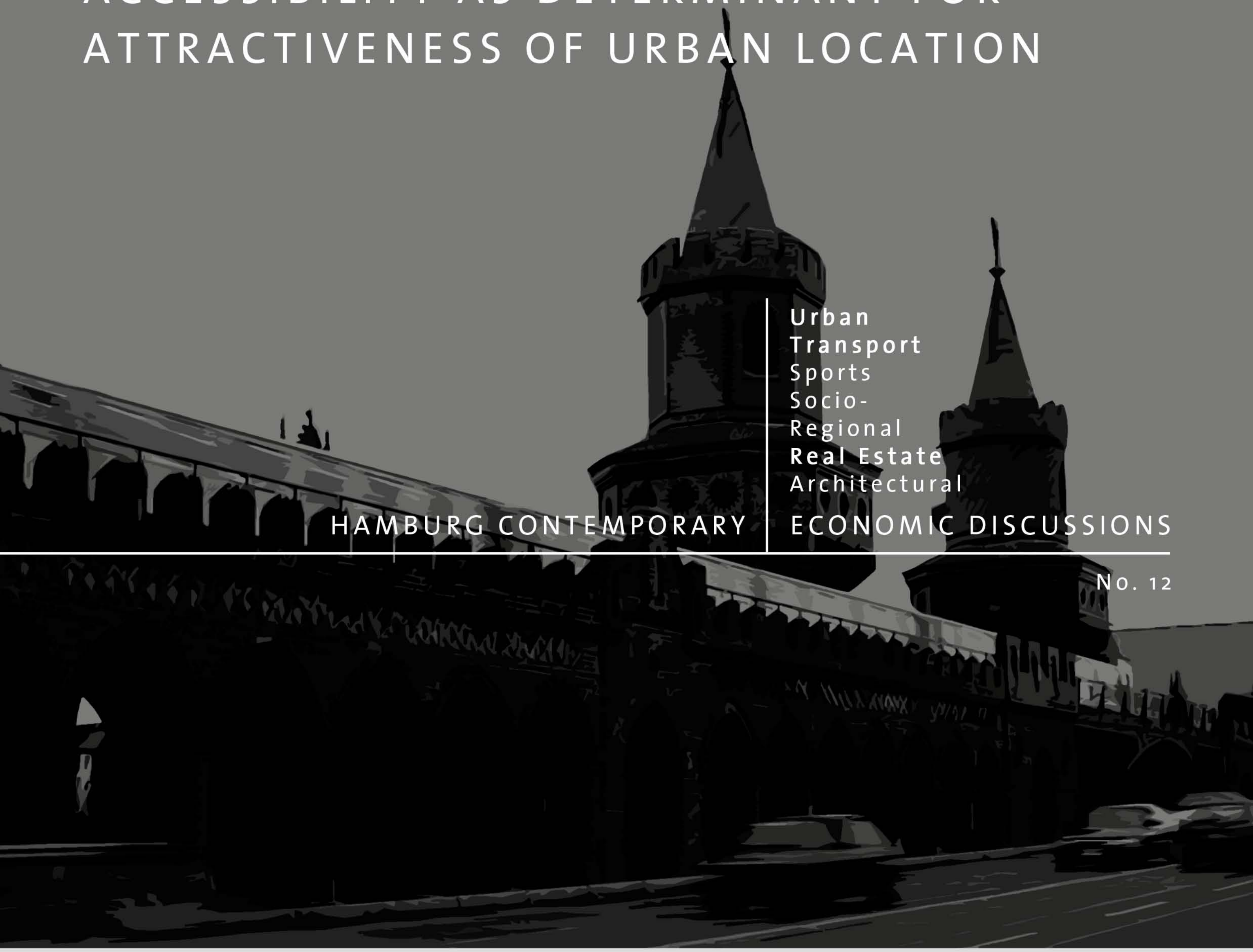

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University of Hamburg
Faculty Economics and Social Science
Chair for Economic Policy
Von-Melle-Park 5
D-20146 Hamburg | Germany
Tel +49 40 42838 - 4622
Fax +49 40 42838 - 6251
http://www.uni-hamburg.de/economicpolicy

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

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Gabriel Ahlfeldt

If Alonso Was Right: Accessibility as Determinant for Attractiveness of Urban Location*

Abstract: This paper assesses impact of accessibility corresponding to three distinct modes of urban transportation. The Alonso hypothesis of residents being fully compensated for rents increasing with proximity to CBD by employment opportunities is tested by application of a hedonic model using micro level data to explain standard land values in Berlin. Access to employment as well as location endowments with natural amenities and publicly and privately provided services are captured by potentiality variables. Similarly, impact of population potentiality is assessed for business properties. Accessibility generated by urban rail network is clearly found to have positive impacts on property prices and fully explains attractiveness of urban centrality for business. For residential properties, however, impact of proximity to CBD cannot be completely explained by employment opportunities revealing that the CBD provides additional services valued by residents.

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

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1 Introduction

Alonso's monocentric city model is probably one of the most prominent models in Urban Economics. Its key idea is typically summarised as employment being exogenously concentrated in the city's CBD making the urban periphery less attractive for residents due to travel cost associated with daily journeys to work. 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) and

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exogeneity of job distribution has become recently more and more questioned (ARAUZO-CAROD, 2007; BOARNET, 1994; LUCAS & ROSSI-HANSBERG, 2002; STEINNES, 1977; STEINNES & FISHER, 1974).

However, whether employment is exogenous and concentrated or not, from a typical resident's perspective accessibility to employment opportunities obviously is a key determinant in location choice. Thus, more than the idea of employment being concentrated in the city's centre, which might be interpreted as a simplifying assumption (BOARNET, 1994; WHEATON, 2004), the key message of ALONSO (1964), MILLS (1972) and MUTH (1969) to keep in mind is that access to employment essentially determines urban patterns and attractiveness of location. Considering the theoretic debate about dispersion and endogeneity of urban employment distribution (ANAS & KIM, 1996; LUCAS & ROSSI-HANSBERG, 2002), empirical approaches need to be developed that account for the obvious reality of polycentricity when aiming at empirically assessing proximity effects of employment.

This paper investigates the role of employment access for residential property valuation in Berlin, Germany employing a completely decentralised empirical approach based on micro level data which makes any ex-ante definition of employment centres or distribution redundant. The underlying concept is related to approaches applied in the empirical economic geography literature where there is a long tradition in modelling market access as distance weighted population (HARRIS, 1954; REDDING & STURM, 2005). This concept is applied to assess impact of market access on business properties within an urban environment.

A major determinant for effective accessibility is metropolitan public transport, particularly the urban railway network. Network related particularities are to be addressed when assessing impact on property prices 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. Thus, due to relevance and complexity, 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). The approach applied in this study assesses the impact of employment and population access generated by Berlin's metro and suburban railway system on land values. Employing highly disaggregated data, 15,937 statistical blocks are related to each other based on combined network distances assuming distinct implicit travel costs for walks from and to stations and train rides.

If Alonso was right in emphasising the role of commuting cost, then, controlling for a feasible set of structural, location and neighbourhood characteristics, residential land gradient might be explained away by sophisticated accessibility indicators. Similarly, if the principles formulated by New Economic Geography apply to urban environments, effects of centrality are to be explained by market access and forces of agglomeration. While empirical results do not confirm the former, evidence is found for the latter.

The remainder of this article is organised as follows. The next section introduces into the data. Section three provides a brief discussion of methodological issues, particularly generation of potentiality variables, and presents the empirical strategy for assessing impacts of accessibility. In section four empirical results are presented while the final section concludes.

2 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 the Senate Department (SENATSVERWALTUNG FÜR STADTENTWICKLUNG BERLIN, 2006) are used which are based on all transactions during the reporting period (2005). The data reveal 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 characterised by major retail and business activity, industrial or residential use.

The data refer 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.[1]

3 Research Strategy

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. More recently, New Economic Geography has developed more complex and formal models putting emphasise on centripetal forces of agglomeration and centrifugal forces of congestion to explain uneven distribution of economic activity across space (FUJITA, KRUGMAN, & VENABLES, 1999; KRUGMAN, 1991). LUCAS & ROSSI-HANSBERG (2002) have proven that an equilibrium city may take forms others than one single CBD surrounded by residential areas. However, Alonso might still has been right in identifying accessibility to employment as the key determinant for attractiveness of resi-

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

dential areas, though in polycentric cities there is need for a more decentralised approach to capture capitalisation into property prices.

Empirical models are developed in the following subsections. A hedonic approach will be used to assess impact of various attributes on land values. Accessibility and numerous other attributes will be captured by potentiality variables whose generation is documented in sub-section 3.2.

3.1 Hedonic Modelling

If real estate markets are in equilibrium, attractiveness of location is fully capitalised into property prices. As attractiveness of a real estate commodity depends on various attributes hedonic models are applied in the empirical real estate and urban economic literature treating real estate commodities as bundles of attributes, whose implicit prices are estimated using multiple regression.

Following GALSTER, TATIAN & PETIT (2004) characteristics of real estate can be described by their structural attributes [*S*], and a set of attributes capturing the effects of the neighbourhood [*N*] and local public services [*L*] (MUELLBAUER, 1974; ROSEN, 1974):

$$H = f([S],[N],[L]) \tag{1}$$

H is the aggregated value of attribute characteristics, which translates into a market value or sales price (*R*) following a determined functional relationship

$$R = g\ (H) \tag{2}$$

In urban and real estate economics literature it is common to choose a log-linear specification, allowing for a non-linear relationship between price and attribute values and being more intuitively interpretable than other non-linear models. When interpreting regression results, 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).[2] Following TU (2005) the relationships in (1) and (2) can be formulated more precisely in a regression equation

$$\log(R) = \alpha + \beta_1 S_1 + \ldots + \beta_i S_i + \gamma_1 N_1 + \ldots + \gamma_j N_j + \delta_1 L_1 + \ldots + \delta_k L_k + \varepsilon \qquad (3)$$

where i, j and k represent the number of attributes, α, β, γ and δ are coefficients and ε is an error term.

Examples of hedonic pricing models in urban economic literature include; construction of house indices (CAN & MEGBOLUGBE, 1997; MILLS & SIMENAUER, 1996; MUNNEKE & SLADE, 2001), impact assessment of quality of public services (BOWES & IHLANFELDT, 2001; GATZLAFF & SMITH, 1993), school quality (MITCHELL, 2000), group homes (COLWELL, DEHRING, & LASH, 2000), churches (CAROLL, CLAURETIE, & JENSEN, 1996), aircraft noise (AHLFELDT & MAENNIG, 2007a), sports arenas (AHLFELDT & MAENNIG, 2007b; TU, 2005) or even supportive housing (GALSTER, TATIAN, & PETTIT, 2004).

Theory does not determine which variables are used in an appropriate hedonic model specification. In recent publications much attention has been paid to the characteristics of the real estate units (ELLEN *et al.*, 2001; GALSTER, TATIAN, & PETTIT, 2004; HEIKKILA *et al.*, 1989; TU, 2005). To compare property transactions it is necessary to correct all transactions for a complete set of unit characteristics. Indeed, as noted by HEIKKILA *et al.* (1989), a feasible correction for unit characteristics gives the analysis a character of referring to land values instead of property prices. Focussing on land values as the endogenous variable allows for abstracting from unit characteristics and even the price-lot size relationship.[3]

Following von THÜNEN (1826) and ALONSO (1964), the most important accessibility indicator is distance to CBD (CHESHIRE & SHEPPARD, 1995; DUBIN & SUNG, 1990; HEIKKILA

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[2] 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)

[3] Lot size was typically found to have a concave functional impact on land values (COLWELL & MUNNEKE, 1997; COLWELL & SIRMANS, 1993) later a convex structure was indicated within metropolitan area central business districts (CBD) (COLWELL & MUNNEKE, 1999).

et al., 1989; ISAKSON, 1997; JORDAAN, DROST, & MAKGATA, 2004). However, as noted above, this traditional CBD concept is not applicable to all cities, particularly since in recent decades urban decentralisation has much accelerated (BOARNET, 1994). Berlin is characterised by a striking duo-centricity which emerged during the 1920s and was strengthened during the period of division (ELKINS & HOFMEISTER, 1988). Modelling Berlin as an ideal mono-centric city could lead to biased estimates (DUBIN & SUNG, 1990). In past research, this issue has been addressed by considering minimum distances to both CBD (AHLFELDT & MAENNIG, 2007b).

3.2 Generating Potentialities

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

$$PP_i = \sum_j P_j e^{-a\, d_{ij}} \tag{4}$$

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.

$$d_{ii} = \frac{1}{3}\sqrt{\frac{Area_i}{\Pi}} \tag{5}$$

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

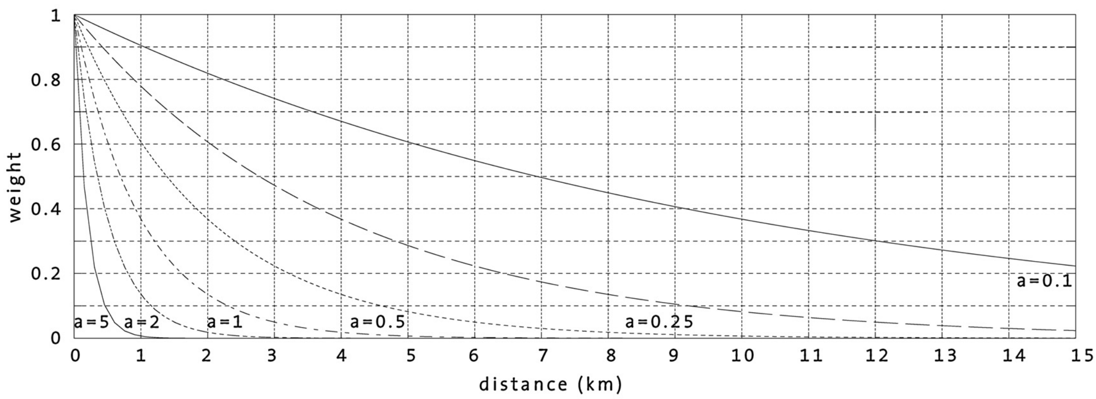
The same concept is applied to employment data to calculate employment potentialities for all blocks *i* in Berlin taking into account block's *i* employments as well as the distance weighted employment of all 15,936 surrounding blocks *j*. The resulting potentiality variable captures residents' access to employment which can be used to test the Alonso hypothesis while relaxing the assumption of employment being concentrated in the urban core. The main employment accessibility indicator thus takes following form:

$$EP_i = \sum_j E_j e^{-a\, d_{ij}} , \tag{6}$$

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 (5).

The distance decay parameter in equations (4) and (6) reflects residents' travel costs. It 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* or block's *i* internal distance respectively. Figure 1 exemplarily represents the implicit distance decay functions for varying coefficient values *a*.

Fig. 1 Distance Decay Factor and Implicit Decay Function



Notes: Graphs visualise the distance decay component *(exp) (-a d_{ij})* of equations (4) and (5)

In the empirical Urban Economics literature market access indicators are frequently applied in a relatively abstract context so that a conclusive definition of the decay parameter is missing. For simplicity, *a* is typically assumed to take the standard value of 0.5 (AHLFELDT & MAENNIG, 2007a; WU, 2000). Alternatively, inverse distances weights have also been applied in the literature (CRAFTS, 2005; REDDING & STURM, 2005). As this paper focuses explicitly on the role of employment accessibility while considering varying travel costs it is appropriate to verify the feasibility of chosen decay parameter values.

Employment potentiality as defined in equation (6) may be thought of representing employment opportunities. Following Alonso's reasoning areas with high employment potentiality will be attractive locations due to low commuting costs for many residents who thus are prepared to pay higher prices. So, if Alonso was right in his assumption that employment accessibility is immediately capitalised into property prices, implicit transport costs might be revealed by application of a simple hedonic model specification. The functional relationship, which can be estimated using non-linear least squares, takes a form very similar to the standard New Economic Geography market access equation (ROOS, 2001):[4]

$$\log(LV_k) = \alpha_1 + \alpha_2 \left(\sum_l E_l e^{-\alpha_3 d_{kl}} \right) + \varepsilon_k , \tag{7}$$

where

$$d_{kk} = \frac{1}{3} \sqrt{\frac{Area_k}{\Pi}} \tag{8}$$

Estimating equation (7) reveals the best fitting decay parameter value α_3. Due to constraints in computational power it is hardly possible to estimate this equation at block level since it involves data exceeding the capacity which can be handled by standard statistical applications running on conventional desktop systems. Thus, for purposes of calibration, estimation (7) is estimated using data referring to the less disaggregated level of 195 official statistical areas.[5] LV_k is the average standard land value for residential areas within statistical area k, E_l represents aggregated employment of area l, d_{kl} is the straight-line distance between geographic centroids of areas k and l and $Area_k$ is the surface area of statistical area k. α_1, α_2 and α_3 are coefficients to be estimated and ε_k is an error term. Relying on estimation results, potentiality variables corresponding to equations (4) and (6) may subsequently be created at block level.

[4] Beside of using different endogenous and exogenous variables, the specification only alters from the traditional market access equation in that it is log-linear. The log-linear specification is chosen since it corresponds to extended hedonic model specification chosen in models below.

[5] Even the computation of potentiality variables at block-level of disaggregation using fixed decay parameters was only realisable on high performance computing systems of the regional computer centre.

The estimated coefficient value for α_3 is 0.518, revealing that the standard value of 0.5 chosen in the literature is very plausible.[6] When combining equation (7) with a simple land gradient model, it can be shown that by introduction of the suggested employment accessibility measure the coefficient on distance to CBD is reduced remarkably, although not rendered completely insignificant (Table A1). This implies that in this simple model attractiveness of living close to CBD can be largely, however not fully, explained by access to employment.

Urban travel costs may be reasonably assumed to depend largely on travel time and thus average speed of the chosen mode of transportation. Three modes of transportation are modelled representing the categories walking, driving and taking rail based public transport. As private vehicle traffic and public railway account for the vast majority of commuting in Berlin, the estimated decay parameter value of 0.5 represents a feasible approximation for the implicit travel cost function referring to the categories driving and rail based transport.[7] Pedestrians' mobility can be reflected by choosing a distance decay parameter corresponding to a much steeper decay function implying that surrounding employment and population is spatially discounted stronger. Since average speed of trains and car is approximately 33km/h and thus more or less five times the speed of a resident walking fast or driving modestly by bike, a distance decay function with a halfway distance of one fifth compared to the one reflecting car velocity is assumed to be a feasible approximation. Therefore, when referring to walking speed, a decay parameter value of 2 is chosen. This parameter value can also be employed for capturing neighbourhood externalities of relatively limited range.

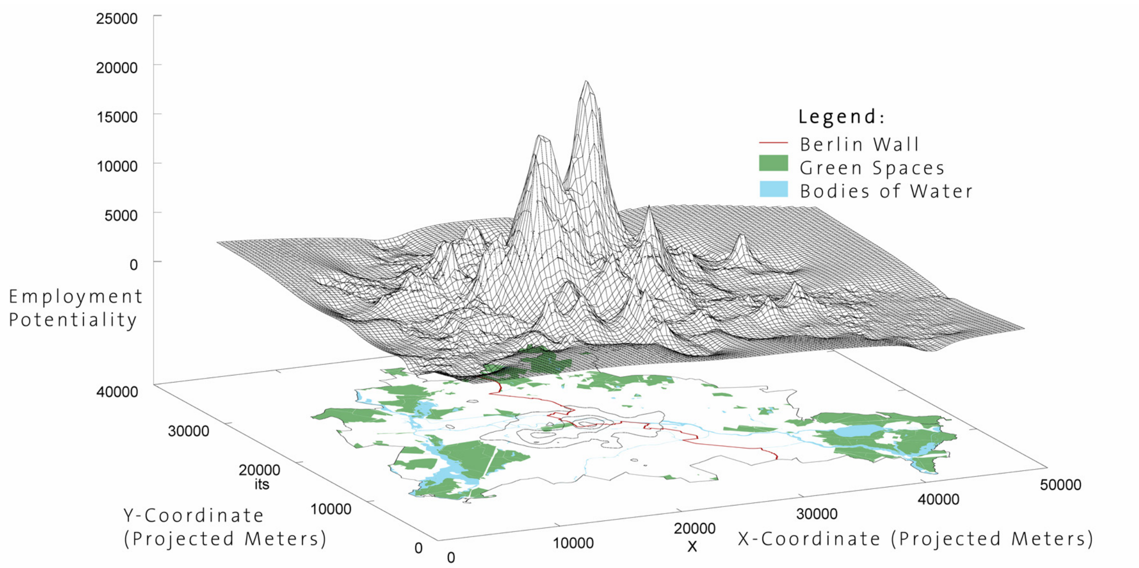
Figure 2 represents the employment potentiality surface determined by equation (6) employing a decay parameter of 2. It indicates employment potentiality within walking distance for all 15,937 statistical blocks in Berlin. Iso-lines on the bottom 2D-projection

[6] The coefficient is statistically significant at the 1% level. Full estimation results are provided in the appendix. The coefficient is not significantly different from 0.5.

[7] In 2002, over 85% of Berliner commuters chose either their car or public transport for their daily journey to work. Based on railway schedules average velocity of all Berlin metro line is 30km/h compared to 37.5km/h for the suburban railway lines. These values are pretty close to the average commuting velocity by car which was found to be 33km/h in a major study on mobility (FEDERAL MINISTRY OF TRANSPORT, 2002).

emerge east- and westwards from Tiergarten, the main downtown green-area, confirming that employment potentiality peaks at locations of CBD-East and CBD-West. Numerous minor employment centres are identifiable as well.

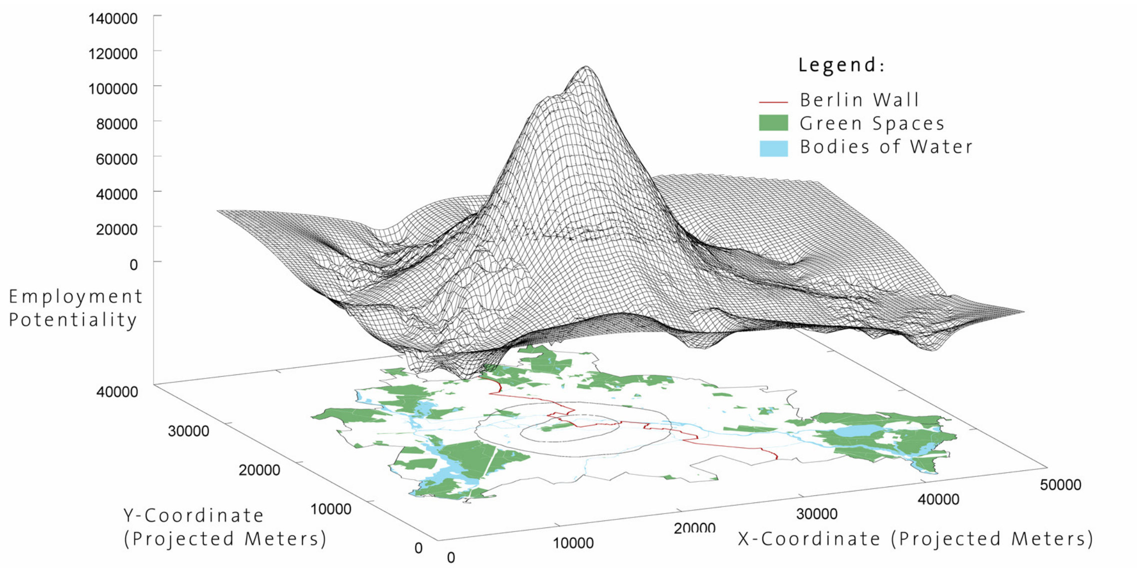
Fig. 2 Employment Potentiality Surface (Walking Speed)



Notes: The figure represents block level employment potentiality as defined in equation (6) assuming a decay parameter *a* of 2. Coordinates refer to the “Soldner” coordinate system used by the Senate Department of Berlin.

In contrast, from a motorised resident’s perspective, Berlin’s employment distribution looks a lot more mono-centrically. Figure 3 visualises the smoothing effect of choosing a decay parameter of 0.5 in equation (6).

Fig. 3 Employment Potentiality Surface (Car Velocity)



Notes: The figure represents block level employment potentiality as defined in equation (5) assuming a decay parameter *a* of 0.5. Coordinates refer to the "Soldner" coordinate system used by the Senate Department of Berlin.

Since Berlin's geography is characterised by absence of major natural barriers, potentiality variables created on the basis of straight-line distance matrices represent a feasible approximation when modelling employment opportunities corresponding to individual transport. However, modelling the impact of rail based transport requires a slightly more sophisticated approach. Firstly, trains are forced to follow determined network-routes which can deviate substantially from straight-line-connections. Secondly, any commuting trip involving a train ride also involves a journey from home to railway-station, from railway-station to workplace and vice versa respectively. Residents are assumed to strictly walk to the closest station, to choose the shortest network connection within the combined metro and suburban railway network and to descent the railway system at the station located closest to their workplace.[8] Modelling employment potentiality generated by the railway-network thus basically consists of three aspects.

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

[8] 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).

$$SP_m = \sum_j E_j e^{(-b\, d_{mj})}, \tag{9}$$

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:

$$NSP_s = \sum_m SP_m e^{(-a\, d_{sm})}, \text{ for } m \neq s \tag{10}$$

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.[9]

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:

$$EP\_Rail_i = NSP_s\ e^{(-b\, d_{is})}, \tag{11}$$

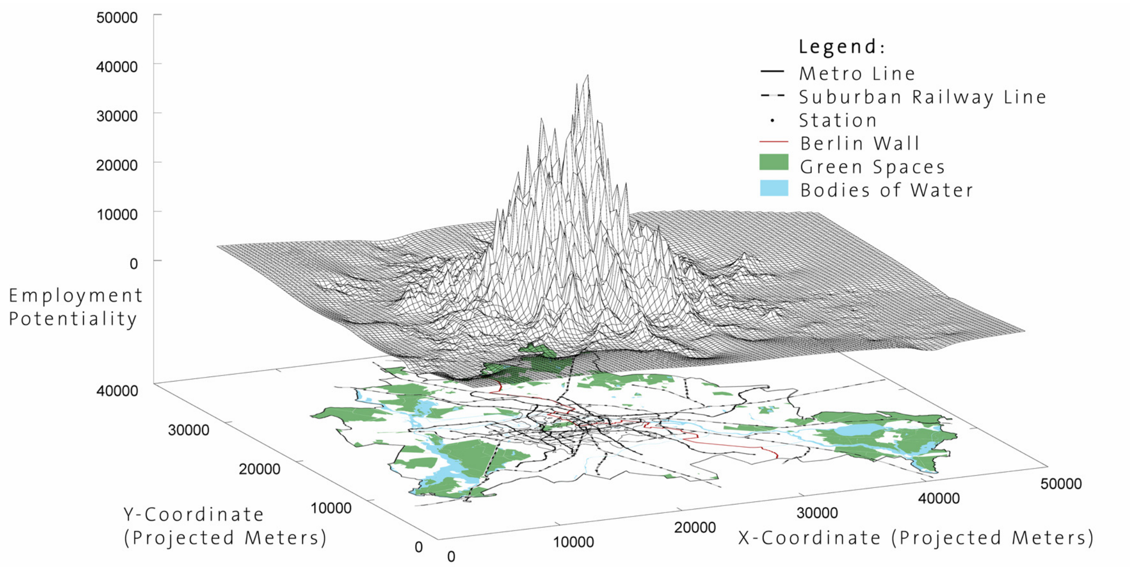
where EP_Rail_i is the employment potential generated by the urban railway network at block i, b takes the value of 2 and d_{is} is the distance from block i to the nearest station s. Combining equations (9) – (11), the employment potentiality generated by the railway network can be written as:

$$EP\_Rail_i = e^{(-b\, d_{is})} \sum_m \left(\sum_j E_j e^{(-b\, d_{mj})} \right) e^{(-a\, d_{sm})}, \text{ for } m \neq s \tag{12}$$

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

Figure 4 visualises the employment potentiality surface generated by the integrated urban railway network.

Fig. 4 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.

3.3 Empirical Strategy

To empirically assess the impact of employment access on attractiveness of residential location, employment potentialities are introduced into a fully specified hedonic model environment capturing structural, location and neighbourhood characteristics. Varying density of development is captured by floor space index determined in the zoning regulations while the blocks' typical building structure is captured by a full set of dummy variables. Location attributes are introduced analogically to accessibility using potentiality variables similar to equations (4) and (6). 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 based on straight-line distances and blocks' internal distances defined in equation (5). In contrast to traditional distance-based approaches, potentiality variables account for both proximity *and* size of the relevant amenities. 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. Since shopping has theoretically proven to be relevant for residents' location choice (ANAS & KIM, 1996) two potentiality variables representing a reduced Retail Gravity Model (EPPLI & SHILLING, 1996) are added to capture shopping opportunities in terms of spatially discounted retail area:[10]

$$RP_i = \sum_r RA_r e^{(-a\, d_{ir})}\,, \tag{14}$$

where RP_i is the retailing potential for block i, RA_r the aggregated retail area of centre r as defined in the centre atlas published by the Senate Department (SENATSVERWALTUNG FUER WIRTSCHAFT ARBEIT UND FRAUEN, 2004) and d_{ir} is straight-line distance from block's i geographic centroid to the officially defined central location of retailing centre r.[11] Neighbourhood is captured by density and composition or resident population, particularly focusing on potentially income-weak population groups. To figure out whether employment accessibility does fully explain land gradient as predicted by the Alonso model, distance to CBD enters the empirical model.[12] If Alonso was right, then the coefficient on distance to CBD *(Dist_CBD)* would be expected to be insignificant since attractiveness of urban centrality would be captured by employment potentiality variables. To account for Berlin's particular 20th century history, which might be reflected in spatial east-west heterogeneity due to persistent effects of division, a dummy variable is added denoting all blocks lying within the borders of former East-Berlin *(EAST)*. This dummy variable is also interacted with distance to CBD allowing land gradient to vary across space. The full hedonic model specification takes following form:

$$\begin{aligned} \log(LV) = {} & \alpha + \beta_1 East + \beta_2 Dist\_CBD + \beta_3 (Dist\_CBD \times East) \\ & + STRUCT\ c_1 + LOC\ c_2 + NEIGH\ c_3 + EA\ c_4 \\ & + \gamma\ Spatial\_Lag + \varepsilon \end{aligned} \tag{15}$$

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10 Shopping potentiality generated by the railway network is not computed since it is expected to be collinear with the corresponding employment accessibility indicator.

11 The centre atlas defines 28 major and minor retailing areas.

12 As suggested by Figure 2, 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 A2 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.[13] The lag term is a distance weighted average of neighbouring properties and takes following form for block *i*:

$$Spatial\_Lag_i = \sum_j \frac{(1/d_{ij})}{\sum_j 1/d_{ij}} LV_j , \tag{16}$$

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, 2007b).

Following theories of New Economic Geography, centrality is not only a major determinant for location choice of residents, but also for firms depending on access to markets. As noted above there is a tradition in modelling market access as distance weighted sum of population. Applied to an urban environment, firms, particularly business enterprises and service orientated industries, may be thought of trying to locate close to customers, consumers and employees. Thus they maximise market access which can be represented by population potentiality indicators as defined in equation (4).[14] Similarly to employment potentiality, indicators can be created for distinct modes of transportation. Population potentiality generated by the urban railway system consequently takes following form:

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13 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.

14 Centrality defined by this way tend to be of largest importance when transport costs are neither very high nor very low (MIDELFART-KNARVIK *et al.*, 2000). For urban transportation, whether with regard to commuting or shopping trips, one might reasonably assume that transport costs are neither prohibitively high nor negligible.

$$PP\_Rail_i = e^{(-b\ d_{is})} \sum_m \left(\sum_j P_j e^{(-b\ d_{mj})} \right) e^{(-a\ d_{sm})}\text{, for } m \neq s \tag{17}$$

Firms bidding out each other for centrally located properties, downtown land values will increase until in equilibrium firms are fully compensated for higher prices by market access. Impact of market access on business property prices may be assessed within a reduced hedonic model environment since an amenity based approach less applicable when modelling urban firm location.[15] The reduced hedonic model for business property prices thus takes following form:

$$\begin{aligned} \log(LV) = {} & \omega + \delta_1 East + \delta_2 Dist\_CBD + \delta_3 (Dist\_CBD \times East) \\ & + STRUCTB\ d_1 + MA\ d_4 + \sigma\ Spatial\_Lag + \varepsilon \end{aligned} \tag{18}$$

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. The spatial lag term representing a distance weighted average of surrounding property prices also captures forces of agglomeration relevant for firms. Very high property prices in the vicinity indicate high economic activity and potential sources of spill-overs and economies of scale which are an essential part of New Economic Geography models (FUJITA, KRUGMAN, & VENABLES, 1999; HELPMAN, 1997; KRUGMAN, 1991).[16]

4 Empirical Results

Empirical Results corresponding to equation (15) are represented in Table 1. In Column (2) results of the final hedonic model specification are represented which are obtained

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[15] For specialised 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.

[16] Therefore, the spatial lag term will takes account all three nearest blocks independently of land use. Moreover, just considering three nearest business blocks might result in misleading values since there are business blocks lying isolated within residential areas so that the distance weighted average does not refer to the immediate vicinity.

after stepwise deletion of insignificant variables from the full model specification (1).[17] Green spaces and shopping have no statistically significant impact on land values.[18] Virtually all other coefficients show the expected signs confirming results of previous research (AHLFELDT & MAENNIG, 2007b).[19] Coefficients for all employment potentiality variables are positive and statistically significant providing evidence for the role of employment accessibility postulated by Alonso and confirming the more general results of Table A1. However, as for the more aggregated level of statistical areas, results of Table 1 based on micro-level data and accounting for distinct transportation modes reveal that effects of proximity to CBD cannot be fully explained away by employment accessibility as predicted by the Alonso hypothesis. Spatial heterogeneity was found for Berlin in that residential land gradient is less precise for East Berlin revealing that centrality is still a less important determinant for property prices in that part of the city where economic activity had been allocated almost evenly across space for decades.[20]

In contrast, results of Table 2 corresponding to equation (18) show that neither for the western part, nor for the eastern part there is any unexplained impact of centrality remaining after controlling for population potential and forces of agglomeration.[21] These results provide strong support for the related concepts of New Economic Geography. Column (2) presents the final hedonic model specification after deleting insignificant variables of full model specification (1). Population potentiality variables corresponding to car velocity and urban railway network are collinear, reflecting that the network connects most of Berlin residents. Therefore *PP_Car* is dropped in both models.[22]

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[17] 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.

[18] For the shopping potentiality variable corresponding to car velocity this is probably caused by multicollinearity as employment and retail centres typically fall together. The correlation coefficient for *RP_Car* and *EP_Car* is 0.95.

[19] While AHLFELDT & MAENNIG (2007b) found no significant impact for schools using simple distance impact variables, school potentiality relative to the relevant population group clearly has a positive impact highlighting the enhanced capacities of potentiality variables to capture location endowments.

[20] The coefficient on the interactive term *(Dist_CBD x East)* is positive and statistically significant.

[21] Neither the coefficients on *Dist_CBD* nor on the interactive term (*Dist_CBD x East*) are statistically significantl at conventional levels.

[22] The correlation coefficient for *PP_Car* and *PP_Rail* is 0.8.

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	-0.554473***	0.018947	-0.547030***	0.016390
Dist_CBD	-0.064150***	0.002367	-0.063244***	0.002227
Dist_CBD x East	0.022791***	0.001708	0.021989***	0.001494
FSI	0.141666***	0.023662	0.186179***	0.007974
FSI²	0.016694**	0.007977		
BS_High90	0.008580	0.018528	0.009999	0.018488
BS_Prefab8090	0.010776	0.027606	0.009247	0.027926
BS_High4580	-0.064527***	0.014614	-0.069264***	0.014601
BS_Prefab50	-0.033154**	0.014818	-0.035031**	0.014944
BS_Block2030	0.015381	0.014125	0.011574	0.014175
BS_Wilhelm_Highd	0.010236	0.016024	0.013466	0.016018
BS_Wilhelm_HighdM	0.024690	0.018665	0.024751	0.018769
BS_Wilhelm_Lowd	0.078439***	0.014381	0.072465***	0.014245
BS_Village	-0.006162	0.044528	-0.003273	0.044185
BS_Lowd90	0.043494	0.034049	0.046010	0.033624
BS_Lowd50plus	0.155073***	0.019743	0.155719***	0.019693
BS_Villas50	0.269441***	0.014882	0.269209***	0.014775
BS_Lowd00	0.001652	0.008403	0.003561	0.008349
Water_P	0.002122***	0.000387	0.001994***	0.000372
Green_P	-0.000191	0.000154		
School_P	0.017531***	0.001582	0.017342***	0.001550
RP_Car	-0.000321	0.003065		
RP_Walking	0.000068	0.005590		
Pop_Density	-0.001000**	0.000405	-0.000909**	0.000406
Prop_Pop_Sub6	0.002245***	0.000729	0.002425***	0.000670
Prop_Pop_6_15	0.000383	0.000668		
Prop_Pop_15_18	-0.003357***	0.000973	-0.003241***	0.000941
Prop_pop_18_27	-0.001768***	0.000494	-0.001826***	0.000493
Prop_Pop_65plus	0.001775***	0.000278	0.001747***	0.000276
Prop_Foreigners	-0.003194***	0.000507	-0.003131***	0.000497
EP_Car	0.001899***	0.000473	0.001867 ***	0.000355
EP_Walking	0.004435**	0.001939	0.004821 ***	0.001861
EP_Rail	0.001672*	0.001031	0.002137**	0.000974

Empirical Results for Residential Land Values (continued)

	(1)	(2)
Spatial Lag	Yes	Yes
Sample	Residential	Residential
Aggregation	Statistical Blocks	Statistical Blocks
Observations	9234	9234
R^2	0.79208	0.791886
R^2 adjusted	0.79131	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	Business		Business	
Aggregation	Statistical Blocks		Statistical Blocks	
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 Conclusion

This paper contributes to the empirical urban economics and economic geography literature by developing a framework for modelling impacts of accessibility and other location attributes on the basis of potentiality variables. Empirical evidence is provided by application of data disaggregated to an extent that impact variables have to be generated on high performance computing systems. Better capturing location endowments and public infrastructure, this approach revealed effects on prices were previous distance-based research had failed to find significant impacts. Very interesting, impact of distance to CBD is less precise for East-Berlin, probably revealing persistent effects of division and supporting the idea of multiple equilibria existing in spatial distribution of economic activity which is recently becoming more and more discussed in the empirical economic geography literature (DAVIS & WEINSTEIN, 2002; REDDING & STURM, 2005; REDDING, STURM, & WOLF, 2007).

Empirical results provide evidence for the role of market access for firms' location as predicted by New Economic Geography within an urban environment. Effects of centrality are explained away by population potentiality variables reflecting firms' access to markets. Market access generated by urban railway network is found to positively affect location attractiveness for firms. Similarly, access to employment generated by railway network also positively influences attractiveness of residential location. However, compared to the role of market access for firm's location, employment accessibility proves to be a less striking determinant for residential property prices.

If Alonso was right in his assumptions, residents would be fully compensated for increasing distance to employment by decreasing land values. In a simple gravity-like model, choosing a lower level of disaggregation due to constraints in computational power, impact of centrality on residential land values could be almost explained away by access to employment. However, distance to CBD still remained significant. Results of a fully specified hedonic model based on micro-level data also revealed that attractiveness of living close to CBD cannot be fully explained by employment access. As this study controlled, beside of employment accessibly, for the built environment as well as for natural endowments, public services provision and shopping opportunities, the key to ultimately understand attractiveness of central metropolitan areas probably lies in additional factors such as cultural, ethnical and social diversity.

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, 2006). 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. A1 Empirical Results for Gravity Estimates on Statistical Area level

	(1) Land Value (Log)		(2) Land Value (Log)		(3) Land Value (Log)	
	Est. Coeff.	S.E.	Est. Coeff.	S.E.	Est. Coeff.	S.E.
α_1	5.96340***	0.100374	4.72577***	0.08928	5.13533***	0.22324
α_2			0.00002*	0.00001	0.00002	0.00001
α_3			-0.51809***	0.18376	-0.68530**	0.34465
Dist_CBD	-0.08113***	0.009832			-0.00003**	0.00001
Sample	Residential		Residential		Residential	
Aggregation	Statistical Areas		Statistical Areas		Statistical Areas	
Observations	118		118		118	
R^2	0.370108		0.43210		0.44191	
R^2 adjusted	0.364678		0.42222		0.42722	

Notes: Endogenous variable in models (1) – (3) is standard land values taken into logarithm. $\alpha_1 - \alpha_3$ are defined in equation (7) and Dist_CBD is the minimum distance to either CBD-West or CBD-East. Model (1) is a simple land gradient model where log of standard land values is regressed on a constant and distance to CBD. Model (2) corresponds to equation (7) and model (3) extend model (2) by distance to CBD. After introduction of the gravity term described in equation (7) the coefficient on Dist_CBD is reduced remarkably in magnitude, however still remaining significantly different from zero. Underlying employment data is aggregated to the level of statistical areas and land value is the mean of maximum and minimum land value within a statistical area. 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. 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)

RP_Car	Potentiality variable as defined in equation (14) and a distance decay parameter *a* of 0.5.
RP_Walking	Potentiality variable as defined in equation (14) and a distance decay parameter *a* of 2.
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_Car	Potentiality variable: Blocks' employment in thousands spatially discounted with a decay parameter of 0.5.
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_Car	Potentiality variable: Blocks' population in thousands spatially discounted with a decay parameter of 0.5.
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 (16).

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