Gabriel M. Ahlfeldt and Wolfgang Maennig

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Impact of Sports Arenas on Land Values: Evidence from Berlin

P. Gabriel M. Ahlfeldt
University of Hamburg
Faculty Economics and Social Sciences
Department of Economics and Business Administration
Chair for Economic Policy
Von-Melle-Park 5
20146 Hamburg
Germany
E-mail: ahlfeldt@econ.uni-hamburg.de
Phone: +49 (0)40 42838 – 5569
Fax: +49 (0)40 42838 – 6251

Wolfgang Maennig
University of Hamburg
Faculty Economics and Social Sciences
Department of Economics and Business Administration
Chair for Economic Policy
Von-Melle-Park 5
20146 Hamburg
Germany
E-mail: maennig@econ.uni-hamburg.de
Phone: +49 (0)40 42838 - 4622
Fax +49 (0)40 42838 - 6251

Abstract: This paper develops a hedonic price model explaining standard land values in Berlin. The model assesses the impact of three multifunctional sports arenas situated in Berlin-Prenzlauer Berg which were designed to improve the attractiveness of their formerly deprived neighbourhoods. Empirical results confirm expectations about the impact of various attributes on land values. Sports arenas have significant positive impacts within a radius of about 3000 meters. The patterns of impact vary, indicating that the effective impact depends on how planning authorities address potential countervailing negative externalities.

Keywords: Stadium Impact, Land Gradient, Hedonic Regression, Spatial Autocorrelation, Berlin
JEL classification: R31, R53, R58

1 Introduction

Due to a stadium construction boom, the economic impact of new stadium development has become a more controversial and discussed issue. Politicians who address the citizens' civic pride by spending large amounts of public money on subsidizing major stadium projects usually have familiar arguments. They affirm that the expenditures will be good investments, due to creation of construction jobs and attracting businesses and tourists, leading to stimulation of spending in the community and increased tax revenues. Critics maintain that high expectations are based upon unrealistic assumptions about multiplier effects, underestimation of substitution effects and by neglecting opportunity costs (Baade, 1996; Noll and Zimbalist, 1997; Rosentraub, 1997; , 2000; Zaretsky, 2001). Econometric ex-post evaluation has long supported scepticism regarding the economic benefits of new stadium projects, since few positive and often negative impacts have been found on income (Baade, 1988; Baade and Dye, 1990; Coates and Humphreys, 1999), employment (Baade and Sanderson, 1997) and wages (Coates and Humphreys, 2003). Relatively few studies have identified positive impacts on employment (Baim, 1990) or rents (Carlino and Coulson, 2004) on a city or metropolitan statistical area (MSA) level. Siegfried and Zimbalist (2006) provide a detailed discussion on why sports facilities have failed to stimulate local economies.

This debate, however, might neglect a crucial aspect. Critics themselves emphasize that stadiums and corresponding franchises are relatively small "businesses" compared to major cities or metropolitan areas and that impacts are therefore limited (Rosentraub, 1997). At the same time empirical studies usually use aggregated data on a city or MSA level, instead of focusing on areas for which impact might be expected. Sometimes neighbourhood activists tend to oppose new stadium construction, arguing that they expect emerging traffic congestion and crowds to lower property values nearby. Contrary to these expectations, Tu (2005), who was the first to empirically analyse stadium construction from the homeowner perspective by using transaction data on single-family properties, found a clear positive impact on property prices when investigating the impact of FedEx Field in Prince Georges County, Maryland, USA. Coates and Humphreys (2006) show that voters in close proximity to facilities tend to favour subsidies more than voters living farther from the facilities, indicating that benefits from stadia might exhibit an unequal spatial distribution.

The present study investigates the impact of two sports complexes completed during the 1990s in downtown Berlin, Germany, which were explicitly designed to improve neighbourhood quality. Impact will be assessed by using highly disaggregated data and a comprehensive hedonic model, which explains land value patterns for all of Berlin and provides valuable insights on land gradient behaviour and impacts. Our results show that sports arenas have an impact at the neighbourhood scale, although this may vary for different arenas.

The remainder of this article is organized as follows. In section 2 two projects are presented in detail. Section 3 and 4 discuss data, empirical strategy and methodological issues. Section 5 contains the empirical results and an interpretation. Section 6 concludes and gives an outlook.

2 Velodrom and Max-Schmeling-Arena

The two sports arenas investigated are the Max-Schmeling-Arena and Velodrom/Swimming-Arena, both located in Prenzlauer Berg, a district within former East Berlin.[1] The arenas were originally designed to the standards of the International Olympic Committee (IOC) as they played a role in the unsuccessful bid of Berlin for the Olympics of 2000. To simplify matters from hereon we refer to Velodrom/Swimming-Arena as Velodrom. As well as serving as Olympic venues for boxing (Max-Schmeling-Arena), track cycling and aquatics (Velodrom), all arenas were intended to be regarded as local amenities by neighbouring residents. Special attention was paid to appealing architecture of visible buildings and their incorporation into park landscapes, thereby providing recreational spaces in one of the most densely populated areas of Berlin. These integrated concepts were honoured with important architectural awards, including the German Architectural Award (Velodrom in 1999) and the IOC/IAKS Gold medal[2] (Max-Schmeling-Arena in 2001). As well as large arenas with capacities for 10000 spectators in the case of Max-Schmeling-Arena and 11500 for Velodrom, they have additional facilities for non-professional sports. The sites were chosen to connect well with local public transportation networks. Although no subsequent improvements in public infrastructure were necessary the project total expenditure, financed by land funds, reached remarkable dimensions. Max-Schmeling-Arena cost about $118 Million (205 Million DM, current prices) and Velodrom over $295 Million (545 Million DM)

[1] Exact location of arenas is shown in Figure 1 that also illustrates standard land value pattern for 2006.
[2] This prize is sponsored by the IOC and the International Association for Sports and Leisure Facilities (IAKS) and the only international prize awarded to sports and leisure facilities in operation.

(Myerson and Hudson, 2000; Perrault and Ferré, 2002).[3] The projects were finished in 1997 (Max-Schmeling-Arena) and 1999 (Velodrom) leaving more than five years to the time of this study.

<- INSERT FIGURE 1 ->

3 Data and Data Management

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. We use standard land values per square meter (Bodenrichtwerte) from the local Committee of Valuation Experts (Senatsverwaltung für Stadtentwicklung Berlin 2006a), which are aggregated market values for properties lying within block boundaries and are assessed on the basis of statistical evaluation of all transactions during the reporting period. Data on legal density of development according to the zoning regulations is provided in the form of typical floor space index (FSI) values for the zone.[4] 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. Zoning regulations also determine whether properties within a statistical block are to be used for business, industrial or residential purposes.

The data refers to the official statistical block structure, the most disaggregated level available at the Statistical Office of Berlin, as defined in December 2005. In this data

[3] Dollar values have been calculated based on the average exchange rates during the years of completion. For Max-Schmeling-Arena the average 1997 exchange rate of 1.7348 DM per dollar has been applied while values referring to the Velodrom complex rely to the average 1999 exchange rate of 1.0658 Euros per Dollar and 1.95583 DM per Euro.

[4] More information on sources and the process of collection of standard land values is in the data appendix.

Berlin consists of 15,937 statistical blocks with 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 was 271 (median 135).[5] To analyse this highly disaggregated dataset we employ GIS tools and a projected GIS map of the official block structure that brings a geographic dimension into our analysis. There is GIS information available for public infrastructure such as schools, playgrounds and railway stations enabling generation of impact variables that are discussed in more detail in the section below.[6] Information can be retrieved on location attributes, such as proximity to water spaces or above ground railway tracks. Furthermore, we use population data at block-level, including demographic characteristics from the Statistical Office of Berlin. All data used in this paper strictly refers to the end of 2005.[7]

4 Empirical Strategy, Data and Methodological Discussion

Our empirical strategy consists of two steps. First, we develop a hedonic pricing model explaining present land value pattern. In the second step we extend the basic model by a set of dummy- and distance-variables, capturing impacts of the arenas on land values. Hedonic models are commonly applied in real estate and urban economics since they treat real estate commodities as bundles of attributes, whose prices are estimated using multiple regression. Examples of hedonic pricing models in urban economic literature include; construction of house indices (Mills and Simenauer, 1996; Can and Megbolugbe, 1997; Munneke and Slade, 2001), impact

[5] Especially in the outer areas of Berlin there are much larger blocks. These typically cover recreational areas such as parks, forest and lakes which are undeveloped and unpopulated and are not included in the present study.

[6] All GIS maps were provided by the Senate Department of Urban Development (Senatsverwaltung für Stadtentwicklung) and are based on “The City and Environment Information System” of the Senate Department (Senatsverwaltung für Stadtentwicklung Berlin, 2006b).

[7] Standard land values of 2006 are assessed on the base of transactions from the reporting period year 2005.

assessment of of quality of public services (Gatzlaff and Smith, 1993; Bowes and Ihlanfeldt, 2001), school quality (Mitchell, 2000), group homes (Colwell, Dehring and Lash, 2000), churches (Caroll, Clauretie and Jensen, 1996) or even supportive housing (Galster, Tatian and Pettit, 2004). However, with the exception of Tu (2005), hedonic analysis of property values has not been applied to the impacts of sports stadium construction.

We assume that the 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*], where [*N*] can be assumed to cover accessibility attributes (Muellbauer, 1974; Rosen, 1974):

Following Tu (2005) the relationships in (1) and (2) can be formulated more precisely in a regression equation

$$ln(P) = \alpha + \beta_1 S_1 + ... + \beta_i S_i + \gamma_1 N_1 + ... + \gamma_j N_j + \delta_1 L_1 + ... + \delta_k L_k + \varepsilon \qquad (1)$$

where *i*, *j* and *k* represent the number of attributes, β, γ and δ are coefficients and ε is an error term. When interpreting regression results in log-linear specifications, 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, Schill, Susin and Schwartz, 2001).[8]

Any hedonic model must take into account structural and location characteristics such as floor space or accessibility to account for profitability and transport costs, theory does not ultimately determine which variables are to be used in an appropriate hedonic specification.. To compare property transactions it is necessary to correct all transactions for a complete set of unit characteristics. Indeed, as noted by Heikkila, et

[8] 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 and Palmquist, 1980)

al. (1989), a feasible correction for unit characteristics gives the analysis a character of referring to land values instead of property prices, while accessibility and other location and neighbourhood attributes ideally isolate the effects of land value components. As we directly focus on land values as the endogenous variable we can largely abstract from unit characteristics and even the price-lot size relationship.[9] We capture land use by dummy-variables that identify blocks where considerable retail or business activity takes place or where the main use is industrial,[10] the remaining blocks represent residential areas. We use a variable representing the typical block FSI value, allowing for a quadratic term, since land value is expected to increase at a declining rate with increased FSI.

Location characteristics are captured by a set of distance-variables reflecting accessibility and proximity to amenities. Following Von Thünen and Alonso (1964), the most important accessibility indicator is distance to CBD (Dubin and Sung, 1990; Cheshire and Sheppard, 1995; Isakson, 1997; Jordaan, Drost and Makgata, 2004), although Heikkila et al. (1989) find that distance to CBD prove to be an inferior indicator of accessibility in the Los Angeles region.

In contrast to the usual assumption of one single CBD, Berlin is characterised by duo-centricity. This characteristic emerged during the 1920s and was strengthened during the period of division (Elkins and Hofmeister, 1988). Modelling Berlin as a typical mono-centric city could lead to biased estimates (Dubin and Sung, 1990). The Senate Department of Berlin considers CBD West and CBD East to be of equivalent importance with regard to their functions as employment, retailing and cultural centres (Senatsverwaltung für Wirtschaft Arbeit und Frauen, 2004). Picking up the

[9] Lot size was typically found to have a concave functional impact on land values (Colwell and Sirmans, 1993; Colwell and Munneke, 1997) later a convex structure was indicated within metropolitan area central business districts (CBD) (Colwell and Munneke, 1999).

[10] The Committee of Valuation Experts provides information on land use for all land values. A detailed description of data sources is provided in the data appendix.

idea of access to employment being the major determinant for land valuation (Alonso, 1964), Ahlfeldt (2007) adopts a basic concept of new economic geography to represent employment centers in Berlin. Figure 2 highlights the duo-centric structure of Berlin. As a consequence our main accessibility measure consists of minimum distance to *either* CBD West *or* CBD East.[11]

<- INSERT FIGURE 2 ->

We believe this will make a valuable contribution to land-gradient discussion since there is little empirical evidence available in European and in particular German cities.[12] Allowing land-gradient to vary across land uses further enriches our contribution. Of course, distance to CBD is only an approximation, the degree to which local transportation infrastructure is developed may impact on accessibility. Impact of public transport on property prices has been investigated by Gatzlaff and Smith (1993) and Bowes and Ihlanfeldt (2001), who also discussed related sources of negative externalities. We capture the impact of the public transportation network on price pattern by using distances to metro and suburban railway stations. To capture externalities created by railroad noise, which have a negative impact on property values (Cheshire and Sheppard, 1995; Debrezion, Pels and Rietveld, 2006), we add distances to above ground railways. In the same way we consider the effects of proximity to bodies of water (lakes and rivers), natural amenities that are expected to be a major determinant for the emergence of high quality residential areas. We also include proximity to playgrounds and schools, providing information on the supply of public services infrastructure.

[11] We define CBD West 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).

[12] One of the few existing studies focuses on Munich and supports theoretical implications (Polensky, 1974).

As indicators of neighbourhood quality we add population density and proportions of foreign people (Dubin and Sung, 1990; Tu, 2005).[13]We also consider proportions of other potential low-income groups such as people over the age of 65, and young professionals and students between 18 and 27. Inclusion of the proportion of elder population will also control for positive impacts such as peaceful atmosphere (Andersson, 1994). To assess any impacts related to households with children we use proxy-variables of proportions of the population in the age classes: below 6, from 6 to 15, and from 15 to 18.

We use this concept to account for potential East-West heterogeneity by introducing a dummy-variable for West Berlin, which we allow to interact with all explanatory variables to allow for heterogeneity of all implicit attribute prices.

Spatial dependence may lead to autocorrelation, which violates the assumption of zero-correlation between residuals, leading to inefficient OLS estimates and biased test-scores. Intuitively spatial dependence can be imagined to be the result of external effects of surrounding areas. One explanation for spatial dependence in property prices and rents is that the buyer and seller consider previous transactions that have occurred in the immediate vicinity. To deal with spatial dependence, Can and Megbolugbe (1997) used a spatial autoregressive explanatory variable that represented a distance-weighted average of local sales prices that had occurred prior to the transaction.[14] The spatially lagged variable takes the following form for block *i*:

$$Spatial\_Lag_i = \sum_j [(1/d_{ij})/ \sum_j (1/d_{ij})] P_j \qquad (2)$$

[13] Inclusion of additional neighborhood characteristics such as income and education would have only been possible at the expense of geographic precision, since no data is available at the level of statistical blocks.

[14] Since assessed standard land values all refer to the same point in time we do not have to define any relevant pre-transaction period.

where P_j is the land value of neighbouring block *j* and $(1/d_{ij})$ represents the inverse of distance between centroids of blocks *i* and *j*.

Having decided to use a spatial weight-matrix using inverse distance weights, then the spatial extent surrounding properties needs to be defined. Can and Megbolugbe (1997) found a 3000 m radius to be superior, considering only the three nearest properties. Tu (2005) used a very similar distance of 1.8 miles. To test which of the specifications proposed by Can and Megbolugbe (1997) best match our requirements we calculate inverse distance matrixes according to both specifications. Figure 3 shows Moran scatter plots for logarithms of land values for 2006. The plot based on a distance-matrix capturing three nearest blocks (Fig. 3b) clearly exhibits a more linear relationship, better capturing spatial dependence. This is confirmed by a larger Moran's I coefficient.[15]

<- INSERT FIGURES 3a AND 3b ->

Spatially lagged variables not only affect correlations of residuals but also have positive effects on the explanatory power of models. This additional advantage is the result of omitted attributes that are most likely correlated across space. Due to the large explanatory power of the spatial lag variable (i.e. Moran's I coefficient close to one) we emphasise that the explanatory power of our model depends only to a minor extent on the introduction of the lag-term. In Table 2 we compare the performance of our final hedonic baseline-regression (1) with the performance when omitting the lag-term (3). An R^2 of close to 0.9 indicates that our model performs well when neglecting spatial dependence. However, the improvements in residuals following the

[15] Comparing the effects of different spatial weight matrixes on nominal values yields similar results. We provide scatter-plots of logarithms since we use log-values as endogenous variables.

spatial model extension are substantial. In Figure 4 the residuals corresponding to model (3) (Table 2) are plotted in three dimensional space.[16, 17]

<- INSERT FIGURE 4 ->

The model specification can be expressed in the following way:

$$
\begin{aligned}
ln(P) = {} & \alpha + \beta_1 Business + \beta_2 Industry + \beta_3 West \\
& + STRUCT \; a_1 + LOC \; a_2 + NEIGH \; a_3 \\
& + (Business \times STRUCT) \; b_1 + (Business \times LOC) \; b_2 \\
& + (Business \times NEIGH) \; b_3 \\
& + (Industry \times STRUCT) \; c_1 + (Industry \times LOC) \; c_2 \\
& + (Industry \times NEIGH) \; c_3 \\
& + (West \times SRUCT) \; d_1 + (West \times LOC) \; d_2 + (West \times NEIGH) \; d_3 \\
& + \gamma \; Spatial\_Lag + \varepsilon
\end{aligned} \qquad (3)
$$

where *ln*(*P*) is the natural logarithm of standard land values, *Business*, *Industry* and *West* are dummy-variables capturing land use and spatial heterogeneity, *STRUCT*, *LOC* and *NEIGH* are vectors of structural, locational and neighbourhood characteristics and *Spatial_Lag* is the spatial autoregressive term from (2). α, β, γ and lower case letters represent the set of coefficients to be estimated and ε is an error term. In Table 1 is a detailed description of components. Attribute-variables interact with dummy-variables to allow implicit prices to vary across space and land use.

<- INSERT TABLE 1 ->

To capture irregularities in land value pattern due to the presence of Velodrom and Max-Schmeling-Arena dummy-variables are introduced, representing mutually exclusive distance rings surrounding the arenas. Distance-impact variables

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[16] These residual surfaces also serve as a useful tool to eliminate extreme values. The most western block, isolated and contiguous to Berlin's boundaries within a forest, has an extremely large residual. This indicates that our model, largely calibrated to inner-city areas, does not explain the valuation of an isolated area. Consequently we exclude this observation.

[17] To check for robustness we consider numerous lag-term specifications, including two, four, five and six nearest blocks as well as a specification which considered all blocks within 1500 m. However, Moran scatter plots and R^2 both suggest that the final model performs best in capturing spatial dependence.

representing distance from block centroids to the subject arena are introduced subsequently. We allow for quadratic terms in distances and interact dummy- with distance-variables to identify the most appropriate function.

5 Empirical Results

5.1 Baseline Hedonic Model

The baseline hedonic model (Table 2, column 1) performs satisfactorily with all coefficients showing the expected signs. The theoretically predicted negative distance-price relationship is much larger for West Berlin. The significantly negative coefficient on *West x Dist_Cent* can be interpreted as the persistence of different spatial equilibriums that emerged during the time of division, which has already been found for Germany on regional scale (Redding and Sturm, 2008). In East Berlin, no free markets were allowed for decades, so there may be continuing market segmentation between population segments with different preferences and/or budget constraints..

<- INSERT TABLE 2 ->

Land gradient varies across space and land use. As expected, for residential and industrial areas centrality is clearly important. However, the significant positive coefficient on *Business x Dist_Cent* shows that the location premium that business users are willing to pay is not linked strongly to distance from CBD. Apparently, remoteness is less problematic for business use. This may be explained by business, particularly retailers, having considerable market access in suburban areas. In contrast, for residents there is no alternative to the CBD for various specialized services. Proximity to metro and suburban railway stations has a significantly larger impact on prices paid for business real estate than for other land uses. In West Berlin the proximity to suburban railway stations appears to have a significantly larger impact on property valuation than in East Berlin, while for metro stations the opposite is true. This pattern might be partially attributable to the more developed metro network of West Berlin, whereas in East Berlin the suburban railway system dominates.[18] The implication is that if a particular service is provided relatively evenly across locations, residents then no longer recognize it as a local amenity. A similar argument applies for schools and playgrounds that have virtually no impact on land values.

Population density has a negative impact on area valuation and the effect is significantly stronger within West Berlin. The coefficient on proportions of foreigners is also significantly negative, indicating that foreign population indeed concentrates in areas of lower valuation, most probably due to lower incomes. This impact is similar in both parts of the city. The 18 to 27 year-olds also concentrate in areas of relatively lower valuation, probably since this group largely consists of trainees and students who have left home and are confronted with serious budget constraints. In contrast, people over 65 show no major concentration in economically deprived neighborhoods. The coefficient on the proportion of population below the age of six, a proxy for families with young children, is significantly positive.

5.2 Impact of Sports Arenas

We consider the general neighbourhood of each arena to be the area within a 5000 m radius, which had proved useful in the case of the larger FedEx Field (Tu, 2005). To capture neighbourhood fixed-effects we create two dummy-variables denoting all blocks lying within each of those impact-areas. In our first approach to assess arena impact we introduce two sets of mutually exclusive distance rings surrounding both

[18] Even before Berlin's division the largest part of the metro network was within the western part of the city. However, after separation this imbalance increased. Since the eastern Municipal Transport Services managed the suburban railway network, the western authorities focused on the improvement of metro infrastructure.

arenas, again represented by dummy-variables. For each arena, four 1000 m radius rings, the first from 0-1000 m, the second 1000-2000 m, etc. are added to capture effects across distance. The results of this basic impact model are presented in column (1) of Table 3, with robustness checked by comparison with individual estimations of each arena impact in columns (2) and (3).[19]

<- INSERT TABLE 3- >

Both neighbourhood effects show negative coefficient values, indicating that arenas are located in relatively undervalued areas. Coefficients estimates for distance rings 2000-4000 m were not significant, indicating no systematic effect on the neighbourhood. In contrast, coefficients for the 1000-2000 m distance ring have positive values of similar size and are statistically significant at conventional levels. These suggest a positive arena impact of around 3.5% within both areas. In the immediate proximities, however, results differ substantially for Velodrom and Max-Schmeling-Arena. In the case of Velodrom the impact in 0-1000 m is approximately 7.5% while for Max-Schmeling-Arena it is not significantly different from zero. These results suggest a positive impact of Velodrom on land values, decreasing with distance and disappearing within the 2000-3000 m ring. However, for Max-Schmeling-Arena a positive impact was only found at 1000-2000 m, implying an impact on land values that first increases and then decreases with distance and disappears within the 2000-3000 m ring.

Although both arenas are situated in general neighbourhoods in which properties appear to sell at a discount, this discount does not increase with proximity to the arenas as for the FedEx Field (Tu, 2005).Within the general neighbourhood, the arenas seem to have significant positive impacts. In immediate proximity to

[19] Results for individual and simultaneous estimation show the same general pattern.

Velodrom, for instance, positive impacts outweigh the general neighbourhood disadvantages.

To confirm these results and to find the most appropriate functional form of arena-impact, we introduce distance-based variables and set up two series of hedonic models (Table 4). Our results suggest that impacts are limited to a distance of 3000 m. We consequently omit the 3000-4000 m dummy-variable in following models. As suggested by Tu (2005), three distinct model specifications are tested. In column (1) of Table 4 (a and b) the specification used in Table 3 is repeated, but omitting the 3000-4000 m dummy-variable. Column (2) tests for a linear impact of distance to arena, therefore the 0-1000 m and 1000-2000 m dummy-variables are substituted with an interactive term that consists of the 0-3000 m dummy interacted with distance to arena. Column (3) specification allows for a quadratic term to account for non-linear effects, in particular for the potentially parabolic form of impact of Max-Schmeling-Arena.

<- INSERT TABLES 4a AND 4b ->

The results in Table 4 are similar to those of Table 3. For Velodrom, we find a highly significant linear distance-price relationship. The quadratic distance term is not statistically significant. For Max-Schmeling-Arena, in contrast, specification (3) clearly provides a better fit. Both interactive distance terms are significant, revealing that the pattern of land value impact is in a parabolic form. Having identified the appropriate functional form for each arena we finally estimate coefficients for both arenas, assuming that the land value-distance relationship is linear for Velodrom and quadratic for Max-Schmeling-Arena. Level-effects are now omitted for Max-Schmeling-Arena since the corresponding dummy-variable was not statistically significant in specification (3) of Table 4b.[20] Estimations for our final hedonic specification are presented in Table 5.

<- INSERT TABLE 5 ->

These results are presented graphically in Figure 5 where the relative land value gradients are plotted, based on the corresponding coefficient estimates.

To provide a better spatial impression of both overlapping arena-impacts the differences in residuals were plotted, between our final hedonic impact specification (Table 5) and the hedonic baseline specification of column (1) Table 4 in three dimensional space (Figure 6). It can be shown that these differences correspond to the estimated arena impacts. Assuming that

$$ln(P) = \alpha + BASE\ \beta + \varepsilon \tag{4}$$

represents our hedonic baseline specification and

$$ln(P) = \alpha + BASE\ \beta + VELO\ \gamma + MS\ \delta + \mu \tag{5}$$

is our final hedonic impact specification, where *BASE* is a vector of attribute variables included in our baseline model, *VELO* is a vector of impact variables related to Velodrom and *MS* is similar for Max-Schmeling-Arena. β, γ and δ represent sets of coefficients to be estimated and ε and μ are error terms. Taking differences yields:

$$\varepsilon - \mu = VELO\ \gamma + MS\ \delta \tag{6}$$

In our econometric specification this relationship corresponds to taking differences between residuals in order to visualize the additional explanatory power provided by the introduction of impact variables.

<- INSERT FIGURES 5 and 6 ->

[20] We only omit the 0-3000 m dummy-variable for Max-Schmeling-Arena. Neighbourhood fixed effects are still captured in two 0-5000 m area dummy-variables.

Figures 5 and 6 demonstrate how irregularities in land value pattern are attributable to the locations of Max-Schmeling-Arena and Velodrom. For both arenas there is a consistent pattern of impacts at distances ranging from 1500 to 3000 m. Impacts are positive, decrease with distance and disappear after 3000 m. If these positive impacts are attributable to the presence of the arenas, one would intuitively expect location premium to be highest in the immediate proximity, since positive external effects should lose intensity with increasing distance. While this story fits the results for Velodrom, it conflicts with the estimations for the immediate vicinity of Max-Schmeling-Arena.

However, the estimated pattern of impact becomes more conclusive when countervailing externalities are considered (Galster, Tatian and Pettit, 2004). Instead of assuming the existence of just one positive (or negative) externality, various positive *and* negative externalities should be considered. Assuming that distinct externalities differ in range, size and sign; externalities may cancel each other out within a certain distance range, while at other distances one externality may dominate. As previously discussed, Velodrom and Max-Schmeling-Arena are comparable in terms of utilization, architectural quality, physical size and provision of new recreational spaces, suggesting that positive externalities should be comparable. The distinct impacts may be caused by negative externalities of limited range that are associated with Max-Schmeling-Arena. Ahlfeldt and Maennig (2008) provide a detailed discussion on how parking scarcity caused by a lack of additional parking facilities adversely impacts on property prices in proximity to Max-Schmeling-Arena.[21] Moreover, in contrast to Velodrom, Max-Schmeling-Arena is the

[21] The original plans for Max-Schmeling-Arena included an underground car park. These plans were abandoned after Berlin's bid for the 2000 Olympics was rejected by the IOC (Meyer, 1997).

home of two sports clubs of national importance.[22] The regular presence of highly involved fans may represent a source of noise and disturbances that might have an additional price depreciating effect. This potentially affects land values by particularly discouraging car-owning households. In the case of Velodrom an adjoining empty lot was transformed into a car-park, whereas the absence of such available space in the proximity of Max-Schmeling-Arena has meant that the problem is still unsolved.

6 Conclusion

This paper contributes to the wider discussion on land value behaviour as well as to the more specific debate on stadium impact. Application of GIS techniques and highly disaggregated data allowed the development of a cross-sectional hedonic model capturing the full range of structural and location attributes, as well as spatial spill-over effects. While controlling for location and neighbourhood characteristics, land values in Berlin show some peculiarities. One and a half decades after re-unification the land gradient is significantly flatter for East Berlin, indicating that the possible effects of four decades of centralized allocation of land are still persistent. At least we find two segmented markets in disequilibrium that if at all, tend towards an integrated equilibrium very slowly. This finding points to high transaction costs associated to spatial arbitrage and is particularly striking in light of the ongoing debate about the existence of multiple equilibria in spatial distribution of economic activity. Allowing for variation of land gradient reveals that the location premium that business is willing to pay is less sensitive to remoteness than that of residents. These findings reflect the presence of numerous and relatively strong sub-centers in suburban areas of Berlin where business finds considerable market access. The more

[22] Resident teams are the basketball team of “Alba Berlin” and the handball team of “Füchse Berlin”.

distinct relation of business land values and distance to public transportation highlights the importance of market access for business. The results suggest that for residents the specialized services of the CBD are less substitutable by those of sub-centers.

The baseline hedonic model was extended by a set of geographic variables attributing unexplained land value variation to the location of Velodrom and Max-Schmeling-Arena. While the presence of Velodrom has a significantly positive impact on land values, decreasing with distance, Max-Schmeling-Arena has more ambiguous effects; there are no positive effects in close proximity, but relative land values increase in more distant proximity. Since positive externalities emanated by arenas are expected to be comparable, the distinct patterns of impact on land values can be explained by the presence of countervailing negative externalities of limited range that surround Max-Schmeling-Arena. Besides potential problems caused by fans, traffic congestions following unrealistic assumptions about visitors' travel customs prove to be obvious explanation. Bearing in mind that arenas were suited with a sophisticated design in order to contribute to an increase in location desirability of their neighbourhoods, our results suggest that the relatively large investments, for which the projects had been criticized, may be justifiable from ex-post perspective. However, results do not allow for a precise separation of effects associated to the original functions of sports facilities and those related to sophisticated architecture and urban design.

Our results suggest that the arenas have an impact within a radius of approximately 3000 m. This result is to be compared with Tu (2005), who identified a three-mile impact area for the much larger FedEx Field. Empirical results of studies using aggregated data should be interpreted carefully in light of these findings. It confirms the insights of Coates and Humphrey (2006) who – on the basis of analysing voting behaviour in Stadia polls – argue that researchers should focus on the spatial aspects of sport-related economic effects. Any impact that does not exceed a range of a few miles may hardly be expected to significantly influence aggregated values for entire metropolitan areas. Consequently, the absence of measurable effects at high levels of aggregation does not imply an absence of impact at the neighbourhood scale.

Data Appendix

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 have been publishing these atlases 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, then 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. This short cut accelerated data entry enormously, with limited losses in data quality. However, for the areas of potential arena impact consisting of Prenzlauer Berg and the adjoining, land values were on block level for all land uses.

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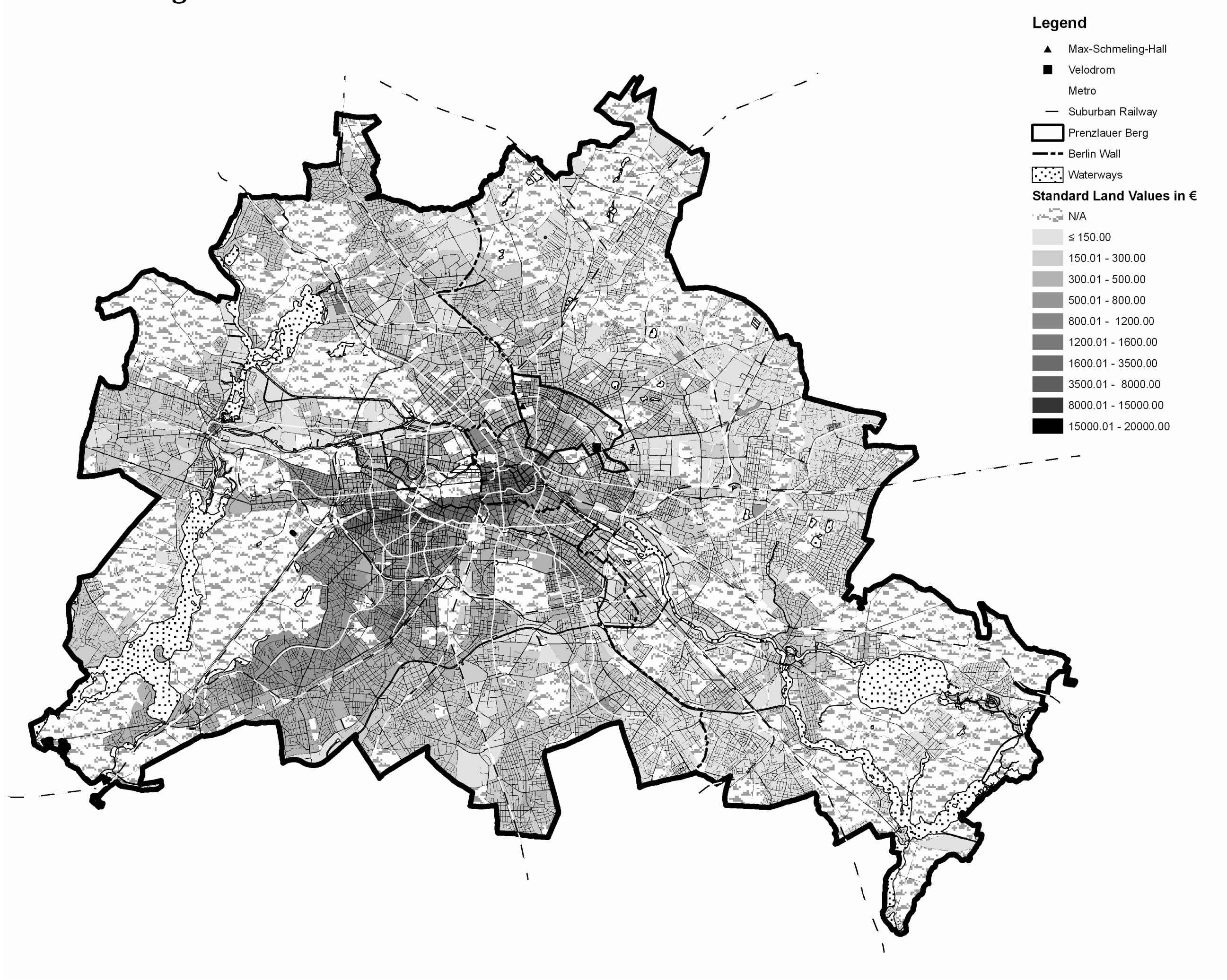
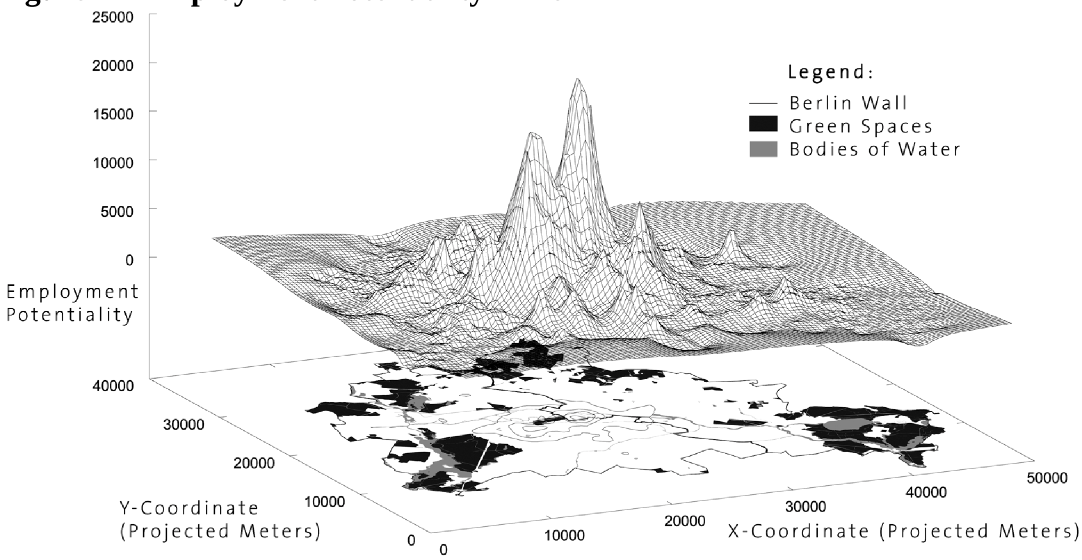
Figure 1 – Standard Land Values 2006



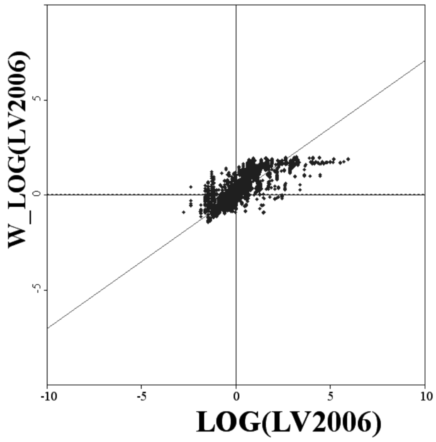
Notes: Map was created on the base of the "City and Environment Information System" of the Senate Department. (Kartengrundlage: Informationssystem Stadt und Umwelt der Senatsverwaltung für Stadtentwicklung)

Figure 2 – Employment Potentiality in Berlin



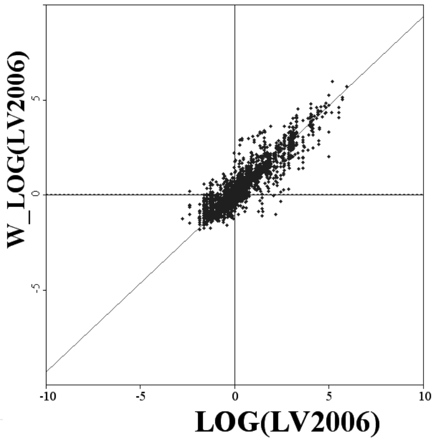
Source: (Ahlfeldt, 2007).

Figure 3a – Spatial Dependence with 3000 meter Specification



Notes: LOG(LV2006) are natural logarithms of the standard land values of Berlin for 2006. W_LOG(LV2006) are the corresponding spatial lag values calculated on the basis of the respective spatial weight matrix. The corresponding Moran's I test statistics is 0.7051.

Figure 3b – Spatial Dependence with 3 Nearest Blocks Specification



Notes: LOG(LV2006) are natural logarithms of the standard land values of Berlin for 2006. W_LOG(LV2006) are the corresponding spatial lag values calculated on the basis of the respective spatial weight matrix. The corresponding Moran's I test statistics is 0.9346.

Figure 4 – Gridded Residual Surface of Spatially Extended Model

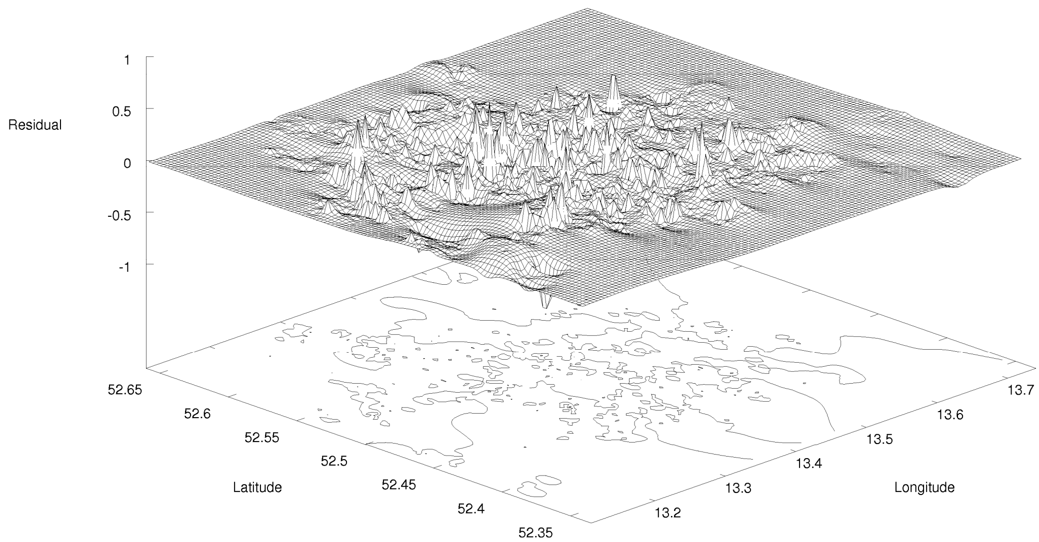
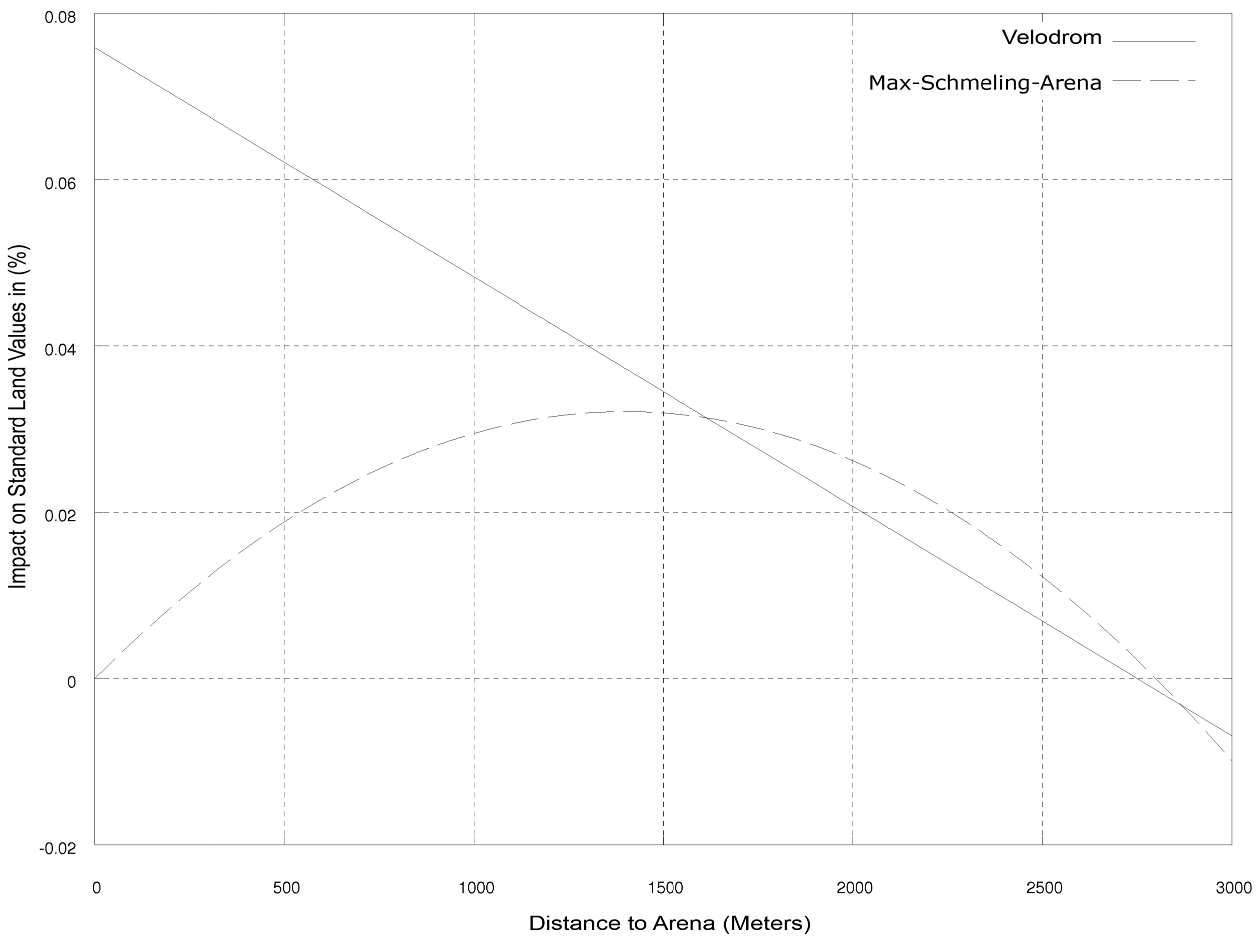
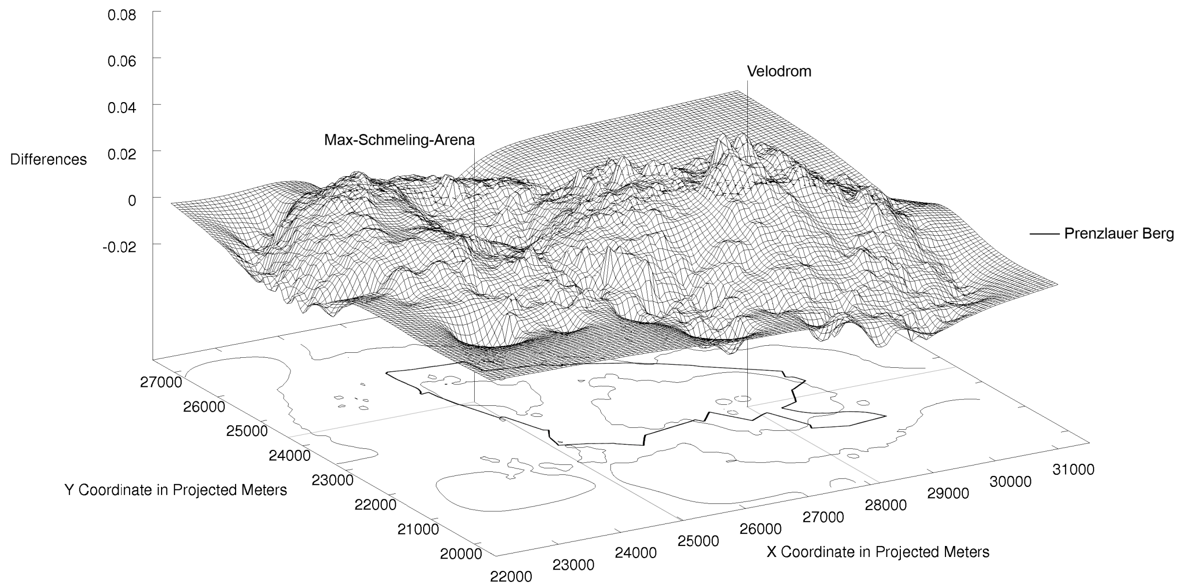


Figure 5 – Estimated Impact of Velodrom and Max-Schmeling-Arena on Standard Land Values



Notes: The graphs displayed in this figure are the graphical illustrations of coefficient estimates represented in table 5.

Figure 6 – Estimated Impact of Velodrom and Max-Schmeling-Arena on Standard Land Values



Notes: This plot represents the gridded surface of residuals' differences between our hedonic baseline specification and the final impact model. It covers the estimated area of impact for both arenas. Coordinates are given in projected meter units of the "Soldner" coordinate system which is used by the Senate Department of Berlin. The origin of this coordinate system is the most soutwestern point of Berlin.

Table 1 – Description of Variables and Abbreviations

Variable	Description
Business	Dummy-variable; 1 for blocks where a considerable amount of retail and/or office activity takes place
Industry	Dummy-variable; 1 for blocks where land is at least partially used for industrial purposes
West	Dummy-variable; 1 for blocks lying within the area of former West-Berlin
FSI	Floor-Space-Index: Quotient of full storey-area and plot-area
FSI^2	Floor-Space-Index squared
Dist_Cent	Shortest great circle distance to CBD East or West in meters
Dist_Metro	Great circle distance to next metro-station in meters
Dist_Suburban	Great circle distance to next suburban railway-station in meters
Dist_Water	Great circle distance to next water space in meters (lake or river)
Dist_Schools	Great circle distance to next school in meters
Dist_Play	Great circle distance to next playground in meters
Dist_Rail	Great circle distance to over-ground railway tracks in meters
Pop_Prop_Sub6	Proportion of population below the age of 6
Pop_Prop_6_15	Proportion of population of age group: 6 to 15 years
Pop_Prop_15_18	Proportion of population of age group: 15 to 18 years
Pop_Prop_18_27	Proportion of population of age group: 18 to 27 years
Pop_Prop_65plus	Proportion of population above the age of 65
Pop_Density	Population density (inhabitants per square meter)
Prop_Foreigners	Proportion of foreign population
Prop_Male	Proportion of male population
Spatial_Lag	Spatial autoregressive term as described in the methodology section
STRUCT	Vector of structural characteristics including FSI and FSI^2
LOC	Vector of locatioal characteristics including Dist_Cent, Dist_Metro, Dist_Suburban, Dist_Water, Dist_Schools, Dist_Play, Dist_Rail
NEIGH	Vector of neighbourhood characteristics including Pop_Prop_Sub6, Pop_Prop_6_15, Pop_Prop_15_18, Pop_Prop_18_27, Pop_Prop_65plus, Pop_Density, Prop_Foreigners, Prop_Male

Table 2 – Baseline Empirical Results of Hedonic Analysis (1-3)

	(1) Land Value (Log)	(2) Land Value (Log)	(3) Land Value (Log)
Intercept	1.419380*** (0.067685)	1.409932*** (0.069337)	4.770188*** (0.013161)
Business	-0.476554*** (0.178338)	-0.555828*** (0.206850)	0.049848 (0.226227)
Industry	-0.201496*** (0.052465)	-0.659793*** (0.184922)	-0.483550*** (0.072417)
West	0.677466*** (0.038296)	0.678161*** (0.041387)	2.105208*** (0.032986)
FSI	0.241159*** (0.016054)	0.250090*** (0.015889)	0.702962*** (0.014560)
FSI^2	-0.025354*** (0.005085)	-0.030463*** (0.004964)	-0.056465*** (0.005059)
Dist_Cent	-0.00000438*** (0.000000587)	-0.00000444*** (0.000000599)	-0.0000179*** (0.00000084)
Dist_Metro	-0.00000211*** (0.000000625)	-0.000018*** (0.000000659)	-0.00000865*** (0.00000118)
Dist_Suburban	-0.0000113*** (0.00000341)	-0.0000104*** (0.00000362)	-0.0000485*** (0.00000392)
Dist_Water	-0.0000118*** (0.00000201)	-0.0000113*** (0.000002)	-0.0000415*** (0.00000253)
Dist_Schools		0.000000299 (0.0000041)	
Dist_Play		-0.0000019 (0.00000302)	
Dist_Rail	0.0000122*** (0.00000327)	0.0000117*** (0.0000034)	0.0000468*** (0.0000042)
Pop_Prop_Sub6	0.062190** (0.025417)	0.054859** (0.025282)	0.103997** (0.051869)
Pop_Prop_6_15		0.006943 (0.019842)	
Pop_Prop_15_18		-0.006325 (0.024015)	
Pop_Prop_18_27	-0.046841*** (0.0057)	-0.040212** (0.019973)	-0.235991*** (0.034376)
Pop_Prop_65plus		-0.026906** (0.013406)	
Pop_Density	-0.737185*** (0.0012)	-0.705164*** (0.225787)	-0.846712*** (0.253823)
Prop_Foreigners	-0.085958*** (0.018556)	-0.059999* (0.035007)	-0.096806*** (0.030934)
Prop_Male		0.006376 (0.017495)	
Business x FSI	0.355788*** (0.104214)	0.371846*** (0.110039)	0.138966 (0.129089)
Business x FSI^2	-0.030011* (0.015922)	-0.027947* (0.016820)	0.024650 (0.019060)
Business x Dist_Cent	0.0000499*** (0.00000637)	0.0000534*** (0.00000699)	0.0000783*** (0.0000114)
Business x Dist_Metro	-0.0000304* (0.0000161)	-0.0000435** (0.0000167)	-0.000119*** (0.0000187)

Table 2 – Baseline Empirical Results of Hedonic Analysis (2-3)

Business x Dist_Suburban	-0.000064* (0.0000347)	-0.0000927* (0.0000532)	-0.000188*** (0.0000442)
Business x Dist_Water	0.0000402*** (0.0000127)	0.0000430*** (0.0000129)	0.0000240 (0.0000153)
Business x Dist_Schools		-0.00000580 (0.0000806)	
Business x Dist_Play		-0.0000188 (0.0000885)	
Business x Dist_Rail		0.0000512 (0.0000498)	
Business x Pop_Prop_Sub6		-0.235726 (0.202178)	
Business x Pop_Prop_6_15	-0.577296** (0.273710)	-0.476419 (0.315174)	-0.864808*** (0.256952)
Business x Pop_Prop_15_18		-0.105855 (0.353263)	
Business x Pop_Prop_18_27	-0.288284*** (0.102699)	-0.228749** (0.100348)	-0.421970* (0.244511)
Business x Pop_Prop_65plus		0.178150 (0.139387)	
Business x Pop_Density	-2.547692*** (0.907527)	-2.555855*** (0.882346)	-2.082144* (1.211372)
Business x Prop_Foreigners	0.188215*** (0.058839)	0.182792*** (0.068185)	0.360568*** (0.107345)
Business x Prop_Male		-0.014353 (0.089939)	
Industry x FSI		0.103909 (0.137109)	
Industry x FSI²		0.018786 (0.031367)	
Industry x Dist_Cent		0.0000161** (0.00000693)	
Industry x Dist_Metro		0.0000401 (0.0000285)	
Industry x Dist_Suburban	-0.0000862** (0.0000339)	-0.0000768* (0.0000456)	-0.0000303 (0.0000407)
Industry x Dist_Water		-0.00000984 (0.0000211)	
Industry x Dist_Schools	-0.000180* (0.000105)	-0.000111 (0.000107)	0.0000422 (0.000150)
Industry x Dist_Play	0.000354*** (0.000117)	0.000240* (0.000126)	0.000281* (0.000167)
Industry x Dist_Rail		0.0000387 (0.0000645)	
Industry x Pop_Prop_Sub6	0.780610** (0.352927)	0.530378 (0.361221)	0.204225 (0.408747)
Industry x Pop_Prop_6_15		0.050427 (0.390445)	
Industry x Pop_Prop_15_18		0.018953 (0.200147)	
Industry x Pop_Prop_18_27	0.344214** (0.352927)	0.312817** (0.129166)	0.469512*** (0.160178)
Industry x Pop_Prop_65plus		-0.098714 (0.126594)	

Table 2 – Baseline Empirical Results of Hedonic Analysis (3-3)

Industry x Pop_Density		2.107667 (2.572701)	
Industry x Prop_Foreigners		-0.077971 (0.078824)	
Industry x Prop_Male		0.140772 (0.089877)	
West x FSI	-0.268710*** (0.020125)	-0.263000*** (0.020561)	-0.851855*** (0.023213)
West x FSI²	0.039513*** (0.004624)	0.038739*** (0.004887)	0.121320*** (0.006546)
West x Dist_Cent	-0.0000317*** (-0.00000194)	-0.0000319*** (0.00000196)	-0.000103*** (0.00000193)
West x Dist_Metro	0.0000236*** (0.00000186)	0.0000236*** (0.00000198)	0.0000727*** (0.00000309)
West x Dist_Suburban	-0.00000769* (0.00000398)	-0.00000815* (0.00000421)	-0.0000322*** (0.00000556)
West x Dist_Water	0.00000979*** (0.00000236)	0.00000963*** (0.00000234)	0.000038*** (0.00000359)
West x Dist_Schools		0.00000277 (0.00000764)	
West x Dist_Play		0.0000497*** (0.00000863)	
West x Dist_Rail	-0.0000302*** (0.00000430)	-0.0000307*** (0.00000445)	-0.0000842*** (0.00000682)
West x Pop_Prop_Sub6		0.032696 (0.052924)	
West x Pop_Prop_6_15		-0.028291 (0.034885)	
West x Pop_Prop_15_18	-0.156947*** (0.040899)	-0.145205*** (0.048004)	-0.432046*** (0.093982)
West x Pop_Prop_18_27		-0.035878 (0.041474)	
West x Pop_Prop_65plus		0.020985 (0.024180)	
West x Pop_Density	-0.595791*** (0.297937)	-0.549493* (0.302441)	-3.295263*** (0.404408)
West x Prop_Foreigners		-0.032307 (0.041970)	
West x Prop_Male	-0.134591*** (0.025066)	-0.141145*** (0.032014)	-0.311987*** (0.047581)
Spatial_Lag	Yes	Yes	
Block Sample	Berlin	Berlin	Berlin
Observations	11184	11184	11184
R^2	0.966127	0.966472	0.893846
Adjusted R^2	0.966002	0.966255	0.893465

Model (1) is our baseline hedonic model, which we obtain after stepwise deletion of statistically insignificant variables of model (2). In (3) we repeat our baseline regression omitting the spatial lag-variable. The dependent variable is the natural logarithm of standard land values in all models. Independent variables are described in Table 1. Standard errors (in parentheses) are heteroscedasticity robust. * denotes significance at the 10% level; ** denotes significance at the 5% level; *** denotes significance at the 1% level.

Table 3 – Empirical Results of Baseline Impact-Models

	(1) Land Value (Log)		(2) Land Value (Log)	(3) Land Value (Log)
Impact Area	Velodrom	Max-Schmeling	Velodrom	Max-Schmeling
0-1000 m	0.076287***	-0.014916	0.047019***	-0.025293
	(0.018011)	(0.019143)	(0.002779)	(0.018605)
1000-2000 m	0.037178***	0.035705***	0.020877***	0.025153***
	(0.012739)	(0.012628)	(0.011617)	(0.011895)
2000-3000 m	0.002686	-0.005757	0.013639*	-0.004855
	(0.013498)	(0.013051)	(0.212798)	(0.013132)
3000-4000 m	0.009350	-0.018397	0.007239	-0.014858
	(0.010437)	(0.012352)	(0.010420)	(0.012130)
Neighbourhood	-0.013436*	-0.033593***	-0.017581**	-0.030855***
	(0.007272)	(0.007023)	(0.007344)	(0.006849)
Spatial Lag	Yes		Yes	Yes
Block Sample	Berlin		Berlin	Berlin
Observations	11184		11184	11184
R-squared	0.966402		0.966168	0.966329

Notes: The basic model is the same as in (1) of Table 2. To reduce the table size we only display variables indicating impact of either Velodrom or Max-Schmeling-Arena. Log of standard land values is the endogenous variable in models (1) – (3). 0-1000 m, 1000-2000 m, 2000-3000 m, 3000-4000 m are dummy-variables taking the value of 1 for blocks lying within corresponding one kilometre distance rings surrounding the respective arena, and 0 otherwise. Neighbourhood is defined in a similar way, capturing general neighbourhood effects within 0-5000 m distance. In (1) impact variables for both arenas entered the model simultaneously while in (2) and (3) impact of each arena is estimated individually. Standard errors (in parentheses) are heteroscedasticity robust. * denotes significance at the 10% level; ** denotes significance at the 5% level; *** denotes significance at the 1% level.

Table 4a – Empirical Results of Alternative Models for Velodrom

	(1) Land Value (Log)	(2) Land Value (Log)	(3) Land Value (Log)
Impact Area	Velodrom	Velodrom	Velodrom
0-1000 m	0.073995*** (0.019412)		
1000-2000 m	0.034716** (0.012383)		
0-3000 m	-0.001965 (0.012383)	0.075524*** (0.021105)	0.121969*** (0.036593)
0-3000 m x Distance		-0.0000289*** (0.00000934)	-0.0000893** (0.0000422)
0-3000 m x Distance²			0.0000000165 (0.0000000112)
Spatial Lag	Yes	Yes	Yes
Neighbourhood-Effects	Yes	Yes	Yes
Block Sample	Berlin	Berlin	Berlin
Observations	11184	11184	11184
R^2	0.966398	0.966377	0.966384

Notes: The basic model is the same as in (1) of Table 1. We capture the effects of Max-Schmeling-Arena by introducing the full set of dummy-variables represented in column (3) of Table 3. To reduce the table size we only display variables indicating impact of Velodrom. Log of standard land values is the endogenous variable as in the tables above. 0-1000m, 1000-2000m, and 0-3000 m are dummy-variables representing multiple distance rings as defined as in Table 3. Distance is defined as the distance from each blocks centroid to the corresponding arena, in meters. Neighbourhood effects are defined as in Table 3. Standard errors (in parentheses) are heteroscedasticity robust. * denotes significance at the 10% level; ** denotes significance at the 5% level; *** denotes significance at the 1% level.

Table 4b – Empirical Results of Alternative Models for Max-Schmeling-Arena

	(1) Land Value (Log)	(2) Land Value (Log)	(3) Land Value (Log)
Impact Area	Max-Schmeling	Max-Schmeling	Max-Schmeling
0-1000 m	-0.009482 (0.021002)		
1000-2000 m	0.041065*** (0.015273)		
0-3000 m	0.003211 (0.013001)	0.030773 (0.023960)	-0.049672 0.041028
0-3000 m x Distance		-0.00000718 (0.0000111)	0.000100** (0.0000505)
0-3000 m x Distance²			-0.0000000301** (0.0000000147)
Spatial Lag	Yes	Yes	Yes
Neighbourhood-Effects	Yes	Yes	Yes
Block Sample	Berlin	Berlin	Berlin
Observations	11184	11184	11184
R^2	0.966390	0.966342	0.966365

Notes: The basic model is the same as in (1) of Table 2. We capture effects of Velodrom by introducing the full set of dummy-variables represented in column (2) of Table 3. To reduce the table size we only display variables indicating impact of Max-Schmeling-Arena. All variables are the same as in Table 4a. Standard errors (in parentheses) are heteroscedasticity robust. * denotes significance at the 10% level; ** denotes significance at the 5% level; *** denotes significance at the 1% level.

Table 5 – Empirical Results of Final Hedonic Specification

	(1) Land Value (Log)	
Impact Area	Velodrom	Max-Schmeling
0-3000 m	0.073160***	
	(0.021013)	
0-3000 m x Distance	-0.0000276***	0.0000459**
	(0.00000953)	(0.0000206)
0-3000 m x Distance²		-0.0000000164**
		(0.00000000826)
Spatial Lag	Yes	
Neighbourhood-Effects	Yes	
Block Sample	Berlin	
Observations	11.184	
R^2	0.966337	

Notes: The basic model is the same as in model (1) of Table 2. To reduce the table size we only display variables indicating impact of Velodrom and Max-Schmeling-Arena. All variables are the same as in Table 4. Standard errors (in parentheses) are heteroscedasticity robust. * denotes significance at the 10% level; ** denotes significance at the 5% level; *** denotes significance at the 1% level.