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Form or Function? The Impact of New Sports Stadia on Property Prices in London

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Abstract

Professional sports facilities are among the most expensive development projects. Assessing the external effects related to these and the channels through which these effects operate is a challenging task. We propose a strategy to value the external effects stadia deliver to their neighbourhoods based on the variation of property prices. Our strategy allows for unobserved spatial heterogeneity, anticipation effects, and disentangles the stadium's function as a sports facility from its form as a physical structure that (visually) dominates the neighbourhood. We apply this strategy to two of the largest stadium projects of the recent decade, the New Wembley and the Emirates Stadium in London. Our results suggest there are positive stadium effects on property prices, which are large compared to construction costs. Notable anticipation effects are found immediately following the announcement of the stadium plans. We further argue that stadium architecture plays a role in promoting positive spillovers to the neighbourhood.

Keywords: Property prices; Neighbourhood amenities; Stadium impact; Sport

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1 Introduction

One explanation of why cities emerge is the comparative advantage in the production of goods and services: firms benefit from agglomeration economies and labour is pulled towards these due to the interplay of higher wages and reduced commuting costs. A complementary view has more recently been developed acknowledging that there are not only scale economies in the production of goods and services, but also in the provision of consumption amenities (Glaeser et al., 2001). Specific amenities that address diverse tastes (e.g. ethnic restaurants, theatres, and other entertainment establishments) require a large consumer base to operate efficiently. Residents are attracted to places with a favourable endowment in consumption amenities as they benefit from quick access to these.

Sports stadia are among the largest and most popular of these amenities. The benefits they can deliver to residents and neighbourhoods have become a central argument of proponents of large investments into professional sports facilities (Alexander et al., 2000) – as in the case of the recent London 2012 Olympic Games. Quantifying though whether, and to what degree, these benefits exist is empirically challenging for a number of reasons. First, the presence of professional sports facilities may induce a variety of effects that need to be considered, including consumption benefits to users and economic stimuli to the neighbourhood through spending, added prestige to the community and neighbourhood, and form effects (i.e. positive externalities from sophisticated architecture and urban landscape design). Second, the location of these facilities and various locational features are often jointly determined (e.g. distance from the city centre and transport infrastructures, availability of space, etc.). Third, stadia potentially not only induce economic benefits, but also costs (e.g. related to noise and congestion) which may cancel each other out at various distances.

This study focusses on isolating various forms of stadium externalities by means of capitalisation effects into property prices. At the heart of our empirical strategy we assume that all the external costs and benefits of a (local) consumption amenity are embedded in the value of a property, so that the willingness to pay (WTP) for an amenity can principally be inferred from the spatial variation in the price of surrounding properties. The general theme emerging from the related literature is that professional sports facilities tend to impact positively on the location desirability of the neighbourhood. Rising property prices relative to comparable neighbourhoods directly reflect a higher WTP by owners. Indirectly, a respective neighbourhood appreciation can also be reflective of a higher WTP by private renters, which increases the expected future stream of rental revenues and thus the value of a property. The distributional consequences are more complex (see for example Fischel, 2001; Cellini et al., 2010). Established property owners benefit from a neighbourhood improvement and the associated capital gains. While established private renters will usually be more than compensated for the benefits by increases in rental price levels (Ahlfeldt, 2011a), established social renters will experience a net-benefit if increases in private rental prices are not fully passed on to social rents. Owners and renters moving into the neighbourhood after the improvement has taken place pay for the higher amenity value via higher purchasing or rental prices and are indifferent with respect to the neighbourhood change if they can choose from a large variety of distinct neighbourhoods (Tiebout, 1956). In this study we shed light on the overall effect of stadium construction on house prices and the WTP of local owners. We largely abstract from the distributional consequences, though we acknowledge that these can have important implications for urban policies.

We investigate two of the largest stadium projects of recent years – the New Wembley and the Emirates Stadium in London. These qualify as interesting cases since: (a) both involve massive investments and represent large structures; (b) the New Wembley is characterised by a sophisticated design and architecture, whereas the Emirates is a more conventionally designed stadium; (c) the New Wembley was built in place of the old stadium which was demolished (i.e. no change in location), whereas the Emirates was constructed within an otherwise comparable neighbourhood very close to the old stadium; and (d) both stadia are based within the same market area, London, ensuring that market perceptions of positive and negative externalities are comparable. Both stadia replaced old stadia, maintaining the same functionality as football venues, which helps to separate form and functionality effects.

To separate these two types of stadium effects we also make use of the particular physical settings. The (New) Wembley visually dominates its surroundings as a widely visible structure, not least due to its 130m iconic arch that is illuminated at night. Since there are no buildings of similar height or volume in the neighbourhood, the likelihood of having a good view of the stadium can be approximated by the straight-line distance to it. The related form effect can be separated from functionality effects in principle by controlling for accessibility using accessibility measures that take into account the transport geography. The Emirates, instead, is embedded into a relatively dense urban fabric. Areas with pontential views of the stadium are contained within a relatively small area that can be approximated based on the limited open space surrounding the Emirates. Not least, the choice of these two stadia is also convenient due to limited major infrastructural investments – such as transport connectivity, which would complicate the evaluation of property price effects.

We estimate the impact these stadia have using difference-in-differences (DiD) models, which essentially compare changes in property prices that are likely to be affected by the announcement/construction of the stadium to changes in prices of properties located further away, which are thus less likely to be affected, over two time periods: before and after the construction/announcement of each stadium. Our implementation of the DiD methodology is useful in overcoming a number of limitations of previous studies – i.e. a separation of effects related to the form (architecture) and function (access to sports services) of the stadium, a more explicit investigation of stadium-related congestion externalities, and a more thorough isolation of characteristics and trends in the neighbourhood that are correlated with (and thus bias) estimated stadium effects. Determining the 'before' and 'after' periods is not, however, a trivial task. It rests with the investigator to choose, for example, whether the stadium's announcement date or its subsequent construction period should be used as the cut-off point between these two time periods. As a further major innovation, instead of making arbitrary choices to determine the intervention period, we use a flexible estimation strategy that identifies the adjustment process to the presence of a new stadium from the data in order to justify the chosen intervention date for each stadium.

Using property transactions data from the Nationwide Building Society we find significantly positive and large stadium effects. The evidence indicates that form in addition to functionality effects may be present, stressing the potential role of architecture and urban design as a catalyst of neighbourhood revitalisation more generally. Our analysis further suggests that real estate markets tend to value stadium effects in anticipation, which is an important finding for future intervention analyses both within and outside the realm of the stadium impact literature.

The rest of this study is structured as follows. Section 2 provides an overview of the related literature and offers background information on the two stadia. Section 3 describes the data and methodology used. The results are presented in section 4. Section 5 concludes.

2 Background and Literature

2.1 Sports Stadia and Surrounding Properties

The literature has long been investigating the links between property prices and neighbourhood amenities, such as schools (Black, 1999; Clapp et al., 2008), airports (Tomkins et al., 1998; Nelson, 2004), transport amenities (Baum-Snow and Kahn, 2000; Bowes and Ihlanfeldt, 2001; Gibbons and Machin, 2005), and crime (Lynch and Rasmussen, 2001; Gibbons, 2004). As a characteristic of the neighbourhood, sports stadia can also potentially impact the value of proximate properties. Ahlfeldt and Maennig (2010b) provide a typology of stadium effects, categorised into effects that are related to their functionality as a sports venue or their external design and architecture (i.e. form). Among other things, stadium-related effects encompass spending effects by sports fans, consumption benefits from attending games, and civic pride related to a (prestigious) home team being located close by.

With a sophisticated architecture, an amenity effect related to the aesthetic quality of the neighbourhood can be induced. 'Iconic' elements have been particularly popular in recent stadium projects. Examples include Durban's 2006 FIFA World Cup stadium, Beijing's 2008 Olympics National Stadium, Munich's Allianz-Arena, and the London 2012 Aquatics Centre. It is plausible that iconic architecture serves as a catalyst for the increased identification of citizens and fans and thus amplifies some of the direct stadium effects. Additional effects emerge from the spending of tourists, perceived social capital and consumer optimism, as well as the identification and involvement of citizens and fans who are proud of their new landmark.

A number of studies identifying stadium externalities on property prices have emerged over the last decade. Carlino and Coulson (2004) find that the presence of a National Football League (NFL) franchise increases annual rents by 8% in the city and about 4% in the wider metropolitan area. The resulting question, however, is whether these effects are attributed to the presence of the stadium or the franchise – a limitation with important theoretical and policy implications. Focussing on the construction of a brand new stadium, Tu (2005) suggests that the price of proximate properties significantly increases by about 5% following each completion phase of the construction process. Along the same lines, Feng and Humphreys (2008) find positive property price effects attributed to two stadia in Columbus, Ohio. Similar findings have been documented on land values in Berlin (Ahlfeldt and Maennig, 2009, 2010a).

Empirical analyses of voting preferences support these findings in the US (Coates and Humphreys, 2006; Dehring et al., 2008), though not in Germany (Ahlfeldt and Maennig, 2012), suggesting that perceived proximity costs and benefits may vary across countries.

Stadium construction announcements have similar effects. Dehring et al. (2007) find a positive impact of stadium announcements to host an NFL team on property prices, and Kavetsos (2012) estimates a positive price effect following the announcement of London's successful bid to host the 2012 Olympics.

Overall, the existing evidence is indicative of sports facilities having a positive effect on property values within a range of 3–5km. However, the literature has not yet been able to identify whether such effects are mainly related to the functionality of the stadium as a professional sports facility or the (dis)amenity effect exhibited in its design. This is a crucial limitation in light of the increasingly important role that iconic design plays in contemporary stadium architecture, especially given that the aesthetic component of a neighbourhood (both in terms of the natural as well as the built environment) has been documented to be a significant determinant of location desirability (Jim and Chen, 2009). For example, Ahlfeldt and Mastro (in press) have evaluated the effect of iconic architecture on surrounding property prices based on proximity to 24 residential buildings designed by world famous architect Frank L. Wright in Oak Park (Chicago), Illinois. They find a significant proximity premium of up to 5–8%, declining in distance to these buildings. Recent research also suggests that the perceived beauty or aesthetic character of a location is among the most significant determinants of community satisfaction (Florida et al., 2011).

2.2 The New Wembley and Emirates Stadium

We investigate the cases of the New Wembley and Emirates Stadium in London due to their attractive settings that facilitate the separation of functionality and form effects. The construction of sports stadiums is usually accompanied by considerable infrastructural investments, such as improvements in transport connectivity, which may partially drive estimated stadium effects. Such improvements are limited here. New Wembley was developed on the exact same site of the previous stadium, where all necessary transport infrastructures were already available. The Emirates Stadium was built within a densely populated area, just 0.5km away from the old stadium. This central London area was already excellently connected by several underground and regional rail stations. A careful analysis of newspaper archives did not indicate any other *major* development project related to these stadiums that could confound our estimates.

Key milestones and timelines related to the construction/renovation of both stadiums are summarised in Table 1. New Wembley is the home of the English national football team and continues to host various music events just as it did in the past. Jointly funded by Sport England, the Department for Culture Media and Sport, the London Development Agency, and the Football Association (FA), it is Europe's most expensive and second largest football

Table 1: Key Timelines and Milestones

	Wembley Stadium		*Emirates Stadium*
Oct 2000	Old Wembley closes.	Nov 1999	Proposals to move to a new stadium (current Emirates site) are announced.
Dec 2001	The FA confirmed Wembley was their desired location for a new national stadium, although the final decision would take place within a year's time.	Nov 2000	Planning application submitted. Stadium project unveiled to the public.
Oct 2002	Demolition of Old Wembley and construction of New Wembley begins.	Feb 2004	Construction of stadium begins.
Jun 2004	Arch raised and lit up.	Oct 2004	New stadium named Emirates Stadium.
Mar 2007	Completion of New Wembley.	Jun 2005	Construction reaches halfway stage.
		Aug 2006	Inauguration of Stadium. Redevelopment of old stadium begins.

Source: Official stadium websites: www.wembleystadium.com and www.arsenal.com/emirates-stadium.

stadium to date (construction cost: £900m; capacity: 90,000 seats). Its distinctive feature is an immense steel arch raised on top of it. The Emirates Stadium was a privately funded project. It is the home of Arsenal FC, a major English football club, and is one of the largest recent stadiums in Europe (construction cost: £390m; capacity: 60,355 seats). The old stadium was redeveloped and parts of the old structure have been converted into residential units.

3 Data and Methodology

3.1 Data

We use transaction price data of residential properties spanning over the period January 1995–July 2008. We make use of a data set provided by the Nationwide Building Society, which has received popularity in recent academic research (e.g. Gibbons and Machin, 2005) due to the wide range of transaction characteristics it includes. One limitation of these data is that, unlike the Land Registry records, it does not provide a coverage of the entire population of transactions, but only those properties for which Nationwide has issued mortgages. Since Nationwide, with a market share of about 10%, is one of the top three mortgage providers in England, we believe that this limitation is more than compensated for by the ability to control for property characteristics which will result in the estimation of a 'cleaner' stadium effect. We further note that we have replicated all key-stages of the analysis with the Land Registry data set and found consistent results.

All transactions come with a full postcode reference, which typically contains 10–15 households. This corresponds to a high spatial detail within which we are able to merge properties with electronic maps of the Greater London Authority area in a GIS environment, which facilitates the construction of distance, location, and environmental variables. Other sources of data include the 2001 census, which features output area data on the total housing stock, and the national pupil database where postcode level key-stage 2 (KS2) scores are obtained. The KS2 are externally marked national tests occurring upon completion of primary school education at age 11. Similar measures have been found to be a significant determinant of property prices (e.g. Gibbons and Machin, 2006).

3.2 Empirical Strategy

The key challenge in identifying the effect of a new stadium on surrounding property prices lies in the difficulty of separating the effect the facility exhibits on nearby properties from that of other locational characteristics. In multivariate statistical analysis, the effect of observable location characteristics can be held constant when analysing how property prices change with respect to distance to the stadium. This approach is enjoying increasing popularity in applied urban economics and is conventionally referred to as 'hedonic' analysis (Rosen, 1972).

To the extent that some of the location characteristics are unobservable, there is a risk of erroneously attributing their effects to the stadium if the stadium impact is identified from a comparison of prices across space alone. This problem corresponds to the standard identification problem in social sciences of separating spillover (or treatment effects) from correlated individual effects.

Our approach to dealing with this problem is borrowed from experimental research where individuals are observed before and after a treatment and the outcome is compared to the level of treatment they received. By focussing on changes over time, unobserved individual differences that affect an outcome irrespectively of a treatment can be differenced out on average. This (quasi)experimental research methodology has become well-known under the label *difference-in-differences* (DiD) analysis. In our case, we compare changes in property prices in areas we deem to have been likely to have been affected by the stadium (treatment) with changes in prices of properties located further away which we deem not to have been affected (control), between two time periods: before and after construction/announcement. The outcome is measured as a price effect that reflects the WTP for a property's location.

While this methodology has theoretically compelling advantages, the credibility of the estimated treatment effect rests on the assumption that the treatment can be measured appropriately, the outcome would follow the same trend for all properties (treated and untreated) in the absense of the stadium intervention (i.e. construction or announcement), and that the stadium intervention occurs at a single point in time which is known *a priori*. The latter is generally a problematic assumption, but particularly so in our case since the effect of a stadium may in principle capitalise into property prices in anticipation or with delay with respect to an announcement, depending on how markets process available information.

We address these challenges in a stepwise approach. Similar to Ahlfeldt (2011b), we (a) first identify areas that are subject to stadium effects (section 3.2.1); (b) estimate time-varying stadium effects (i.e. treatment effects for each year in our sample relative to a base year) which allows us to evaluate relative trends in property prices prior to the stadium announcement and identify changes in relative trends from the data. This step is useful for identifying a plausible intervention date, rather than arbitrarily assuming one, which will essentially allow us to divide the sample into 'pre' and 'post' intervention periods (section 3.2.2); and (c) use the identified intervention date to estimate the stadium post-intervention treatment effect (section 3.2.3). In this approach, we view the estimation of the time-varying stadium effects as an auxiliary step towards the estimation of an unbiased post-intervention treatment effect that uses all available observations before and after the intervention.

While implementing this estimation approach, the main challenge we encounter is to separate the potential effects of the form (architectural design) and function (access to sports services) of a stadium from correlated effects that change over time – e.g. regeneration policies, congestion effects, and changes in sports team performance. To the extent possible, we address these challenges in robustness checks in section 4.3, where we also critically evaluate the identifying assumptions imposed by our estimation strategy in light of the empirical results.

3.2.1 The Study Area and Distance Measures

Depending on the stadium under examination, we define two separate study areas based on properties located (a) at a maximum distance of 5km to the New Wembley, and (b) at a maximum distance of 5km to *either* the Emirates *or* the old Arsenal stadium. The existing evidence uniformly suggests a sphere of influence of sports stadiums within this threshold (e.g. Tu, 2005; Ahlfeldt and Maennig, 2009, 2010a, 2012; Coates and Humphreys 2006). In our robustness checks, we also check there are no spillover effects beyond this distance. The two 5km impact areas do not overlap, which means that the two stadium effects do not interfere and can be analysed in isolation. With 5,263 (Wembley) and 9,933 (Arsenal) observations over the study period (of which 1,511 and 6,473 observations fall into the identified *POST* period, respectively), the Nationwide data set provides a reasonable coverage in both study areas.

Within these study areas a set of distance measures capture the location of a property, i, with respect to a stadium, j.

(a) The simplest measure is a linear distance, D_{ij}. We denote this measure as X_i^a. In our empirical models, this measure is used to compare how the marginal effect of distance to the stadium (outcome) changes over time as the stadium is announced or constructed.

(b) Our second distance measure separates distances into n consecutive, and mutually exclusive, distance rings. We denote this measure as X_i^b. The straightforward advantage of this measure is that it allows for a non-linear effect of the stadium on surrounding properties. For the Emirates case, these radius rings denote areas based on the minimum distance to *either* the Emirates *or* the old Arsenal stadium. We choose 1km intervals in the case of (new) Wembley and 0.5km intervals for the Arsenal stadia to ensure that all grid cells are reasonably well populated with observations. Even in the least populated, innermost, rings we observe 132 (Wembley) and 243 (Arsenal) transactions, of which 29 (Wembley) and 176 (Arsenal) fall into the identified $POST$ periods. For all other radius rings we observe more than 100 transactions before and after the identified interventions.

In our empirical models, this distance measure corresponds to a series of difference-in-differences estimates where changes in prices (outcome) in each of the inner distance rings following the announcement/construction of a stadium are compared to changes in prices within the outermost distance ring, which serves as a control area (base category).

(c) Our third distance measure only applies to the Emirates case. Given the proximity the old stadium has to the Emirates, it measures the change in (log)distance to the stadium after $(z+1)$ and before (z) the change in the stadium's location. We denote this measure as $X_i^c = log\,(D_{ijz+1}) - log\,(D_{ijz})$. We choose to measure the treatment via the log-difference in distances to both stadia. We prefer this measure over differences in levels of distances since the experienced change in distance is expressed as a proportion of the initial distance. The measure thus takes into account that at different distances from the old stadium the same absolute change in distances is likely to be perceived differently. Nonetheless, we have experimented with differences in levels in unpublished robustness checks and found consistent results. In our empirical models, this specification identifies the effect of log-distance (treatment) on log-prices (outcome) from a comparison of the situation before and after the stadium intervention.

3.2.2 Time-Varying Stadium Effects

In the second step of our analysis we regress the log-price (P_{it}) of property i, transacted at time t, on m property and location characteristics (Y_m). The semi-log model is widely used in modelling the determinants of property prices (Sirmans et al., 2005). Property characteristics include, for example, the internal area, and number of bedrooms; location characteristics cover accessibility, endowment with natural and public amenities or disamenties that make an area more/less attractive and include distance to the central business district (CBD) (Holborn tube station, as defined in Gibbons and Machin, 2005), distance to the nearest tube station, distance to the nearest lake, river or canal, average KS2 test scores, and distance to a prison in the Emirates neighbourhood. Note that, while any location of a CBD is to some degree arbitrary, our choice is 'central' with respect to the Greater London Authority area, the area enclosed by the M25 ring road and the employment concentrations in the City and the City of Westminster. Given the locations of the stadium neighbourhoods analysed relative to the city centre, marginal variations of the CBD location will hardly affect the resulting measure.

We additionally include year effects (y_t) to control for macroeconomic shocks that are common to the study area, and location fixed effects (c_q) to capture time-invariant location characteristics. Location fixed effects are defined based on groups of postcodes at the two-digit level (e.g. WC2A 2A groups together properties in WC2A 2AE, WC2A 2AB, etc.) for the Arsenal study area and postcode sectors (e.g. WC2A 2) for the Wembley study to account for the lower number of observations in the area.

Introducing the distance measures defined above and interacting them with the yearly time dummies (y_t), yields a set of time-varying stadium effects relative to the base year, which we set to 2000.

$$log\left(P_{it}\right) = \beta_{n1}^{N} X_i^N + \sum_{t=1995, t\neq 2000}^{t=2008} \left(\beta_{nt}^{N} X_i^N \times y_t\right) + \sum_m \gamma_{m1} Y_{itm} + \sum_t \varphi_{t1} y_t + \sum_q \psi_{q1} c_q + \varepsilon_{it} \quad (1)$$

where $N = \{a, b, c\}$ specifies the distance measure defined in section 3.2.1, and n the number of distance rings (only relevant if $N = b$). Greek letters are coefficients to be estimated and ε_{it} is a random error term. Following Bertrand et al. (2004), we cluster standard errors on postcode sectors to account for potential serial correlation in the error term. The main coefficients of interest here are the β_{nt}^{N}, which correspond to DiD estimates for all years included in the sample relative to the base year (2000). Together, they form indices which we use to evaluate (relative) trends and discontinuitites in order to identify a plausible 'stadium intervention date'.

3.2.3 Stadium Post-Intervention Treatment Effects

Having indentified a stadium's plausible intervention date, we are now able to estimate a typical (i.e. before vs. after) DiD in order to estimate a post-intervention treatment effect:

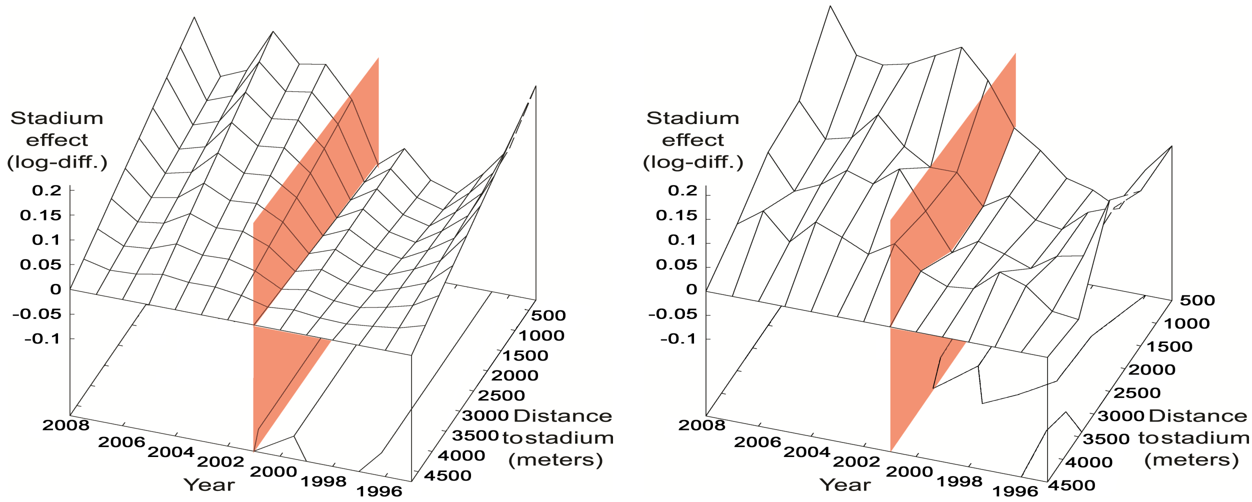
$$log\left(P_{it}\right) = \beta_{n2}^{N} X_i^N + \beta_{nPOST}^{N} \left(X_i^N \times POST_t\right) + \sum_m \gamma_{m2} Y_{itm} + \sum_t \varphi_{t2} y_t + \sum_q \psi_{q2} c_q + u_{it} \quad (2)$$

where $POST_t$ is a dummy variable equal to one in the period after the intervention date, and zero otherwise.

The estimated coefficient(s) $\hat{\beta}_{nPOST}^{N}$ give the post-intervention treatment effect(s). For the simple (linear) distance measure, X^a, this coefficient reflects the percentage increase in the change of (log)transaction prices between the before (PRE) and after ($POST$) periods as one moves one kilometre away from the stadium. A positive effect will be reflected by a negative sign of the coefficient: $\beta_{POST}^{a} = {}^{[log(P_{iPOST}) - log(P_{iPRE})]}/_{D_{ij}}$.

For the case of X^b, the distance measure based on radius rings, this coefficient compares changes in average (log)transaction prices within a treated radius ring, n, to the respective changes in the control radius ring (outermost, excluded ring): $\beta_{nPOST}^{b} = \left[\overline{log\left(P_{POST}^{n}\right)} - \overline{log\left(P_{PRE}^{n}\right)}\right] - \left[\overline{log\left(P_{POST}^{control}\right)} - \overline{log\left(P_{PRE}^{control}\right)}\right]$.

For the third distance measure, X^c, the post-intervention treatment coefficient provides an estimate of the marginal price effect of (log)distance to a stadium in first-differences form.



Notes: Figure illustrates estimated coefficients based on specification (1), using the linear distance measure, X^a (left), and consecutive radius rings, X^b (right). The vertical wall depicts the last date prior to the suggested intervention date. The lines on the bottom of the 2-dimension projection are iso-lines indicating a zero stadium effect.

Figure 1: Time-varying treatment effect: New Wembley

Due to the log-log functional form it can be interpreted as an elasticity coefficient: $\beta^c_{POST} = {}^{[log(P_{iPOST})-log(P_{iPRE})]}\!/\!{}_{[log(D_{ijz+1})-log(D_{ijz})]}$.

4 Empirical Results

4.1 New Wembley Results

Based on the resulting time-varying estimates of equation (1), we create a 3D surface with the following dimensions: Years (x-axis), distance to New Wembley (y-axis) and stadium effect expressed as the impact on property prices relative to the margin of the 5km impact area.

The left panel of Figure 1 graphs the linear distances of properties to the stadium (measure X^a) and the right panel graphs distances based on consecutive 1km radius rings (measure X^b). In both cases we observe a relatively sharp and persistent increase in property prices at proximate locations starting in 2002, with notable peaks in 2004 and 2008. In the surface showing stadium effects estimated by year and distance rings (right panel), the 2004 effect is particularly evident at intermediate distances around 1,500m. These represent plausible market reactions in light of the timeline presented in Table 1. That is, despite construction starting in 2002 (clearly removing some uncertainty about whether the renovation was to happen), it is plausible that "visual" effects capitalised to some degree in prices when the arch was raised and lit up in 2004 and the "iconic" element of the stadium materialised. The 2008 response might be interpreted as an inauguration effect.

Figure 1 suggests that, compared to the pre-construction phase, prices at close locations significantly increased by up to 15–20% on average relative to the base year (2000). Moreover, the plots point to a discontinuity in 2002, which is in line with the hypothesis that real estate markets value locational 'improvements' as soon as the respective information enters the market. Prior to 2002 there is no evident positive trend in prices of properties close to the stadium relative to those further away that could confound a DiD estimate using 2002 as an intervention date.

We next estimate post-intervention treatment effects based on equation (2), taking 2002 as the intervention date. Results, presented in Table 2, indicate that following the intervention properties closer to the stadium experienced a significantly higher appreciation compared to those at larger distances. A statistically significant increase in the value of proximate properties of about 2.7% per km (note this is $[exp(\beta) - 1] \times 100$ due to the semi-log functional form; Halvorsen and Palmquist, 1980) is estimated on average – column (1). Cumulated over the 5km impact area, this corresponds to a price increase of about 13.5% for properties adjacent to the stadium relative to otherwise comparable properties at the outer fringe of the study area.

Table 2: Post-Intervention Treatment Effects – New Wembley

	(1)	(2)	(3)	(4)
Linear Distance × *POST*	-0.027**		-0.04*	-0.026+
	(0.008)		(0.017)	(0.015)
Radius Ring$_{(0-1)km}$× *POST*		0.164*		
		(0.063)		
Radius Ring$_{(1-2)km}$× *POST*		0.064*		
		(0.025)		
Radius Ring$_{(2-3)km}$× *POST*		0.070**		
		(0.024)		
Radius Ring$_{(3-4)km}$× *POST*		0.045*		
		(0.019)		
Radius Ring$_{(4-5)km}$× *POST*		Reference		
Road Network Distance × *POST*			0.01	
			(0.013)	
Road Travel Time × *POST*				-0.001
				(0.004)
Basic Hedonic Controls	Yes	Yes	Yes	Yes
Extended Hedonic Controls	Yes	Yes	Yes	Yes
Location Controls	Yes	Yes	Yes	Yes
Gradient Effect	Yes	No	Yes	Yes
Ring Effects	No	Yes	No	No
Location Effects	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes
Observations	5,263	5,263	5,263	5,263
R^2	0.9	0.9	0.9	0.9

Notes: Dependent variable is log of purchasing price in all models. Robust standard errors (in parenthesis) are clustered on postcode groups. + significant at 10%; * significant at 5%; ** significant at 1%.

This result is roughly in line with the estimated post-intervention treatment effects based on distance rings – column (2). For the first 0–1km distance ring, our results suggest an average increase in property prices of about 17%. Note that while the estimated effects generally decrease with distance – in line with the results in column (1) – the pattern here indicates some degree of non-linearity, with properties at very close distances gaining disproportionally.

Overall, the results clearly support the existence of positive and significant stadium externalities. Given that the sports services provided by the stadium (functionality) and the transport infrastructure connecting the area remained broadly unchanged, a plausible explanation of our findings is an 'iconic' design (form) effect. We attempt to substantiate this argument to some degree by modelling the functionality effect more explicitly. Assuming the functionality effect depends on the effective accessibility to the stadium, we approximate it using two measures of actual transportation distances. These are: (a) road network distances, capturing accessibility as perceived by pedestrians and cyclists who travel at a constant speed, and (b) road travel times that incorporate different velocities for cars and buses along different types of roads (both derived using MS Mappoint 2009). We argue that by controlling for accessibility and holding the functionality effect constant, the remaining effect captured by the straight-line distance measure primarily reflects a form effect.

Table 2, columns (3) and (4), add road network distances and road travel times, respectively, along with $POST$ interaction terms to the baseline model from column (1). Our estimated baseline stadium post-intervention treatment effect remains within the same range, although its significance level is reduced in model (4). The network based treatment effects are not statistically significant. We conclude that the accessibility effect captured by these variables cannot explain the overall stadium effect, making an argument for a Wembley form effect more credible.

It has to be noted, however, that we found a similar pattern of results for the Arsenal case in unpublished robustness checks, even though the straight-line distance measure in that setting is unlikely to capture a form effect due to the densely built environment. An alternative explanation for the strength of the effect captured by straight-line distances might be that these could lead, in practice, to a better approximation of the accessibility (functionality) effect than transportation distances do. To the extent possible, we have tried to rule out other non-form-related effects that could have driven the estimates just presented in a number robustness-checks summarised in section 4.3.

4.2 Emirates Stadium Results

Figure 2 (left) plots the time-varying estimates for the Emirates case based again on specification (1) and distance measure X^c (i.e. the change in (log)distance to the stadium after and before the stadium's relocation). As noted in section 3.2.3, we re-estimate the model by additionally controlling for a set of consecutive 0.5km radius ring dummies (Figure 2, right) in order to separate the net effect on the neighbourhood from the effect of the relocation of the sports venue within the neighbourhood. Notice here that, compared to the case of the New Wembley, we are able to reduce the area covered by each consecutive radius ring from 1km to

0.5km here, as the Emirates area is well-populated with transactions. Both plots attribute the change in average property prices in year t relative to the base year 2000 to the experienced change in distance to the stadium as the location moved from the old stadium to the Emirates.

The plots reveal an evident trend reversion in 1999. Before 1999, properties within areas that experience an increase (decrease) in stadium proximity tend to sell at a discount (premium) compared to the reference year 2000. Starting in 1999, we observe a positive (negative) and permanent increase (decrease) in average sale prices for properties located in the same areas. This suggests an adjustment to the stadium intervention, which largely takes place between 1999 and 2001. As illustrated in Table 1, this is precisely the period when the intention to move to the new site and the final stadium plans were revealed. Hence, the intervention date suggested here by our estimates again supports the presence of anticipation effects.

Notes: Figure illustrates estimated coefficients based on specification (1) and distance measure X^c, with (right) and without (left) controlling for year-ring effects. Estimated coefficients are multiplied by (-1) so that an increase in the index reveals a positive stadium proximity effect capitalising in property prices. The vertical line depicts the last date prior to the suggested intervention date.

Figure 2: Time-varying stadium effects: Arsenal/Emirates

Based on this evidence, we set the intervention date to 1999 when estimating post-intervention treatment effects based on equation (2). Table 3, column (1), suggests that a reduction in distance to the stadium by 1% increases the price of properties by about 0.17% – a result which is in line with the presence of positive stadium externalities. This estimate is robust even after controlling for neighbourhood trends captured by a set of 0.5km year-ring cells – column (2).

So far, we have implicitly assumed that in terms of magnitude the change in stadium location caused similar effects at the sites of the old and new stadiums, despite pointing in opposite direction. While this might be a reasonable assumption for the change in access to sports services offered by the stadia, it is less plausible with respect to the alteration of the visible built environment. This is because the old structure was not entirely removed, in addition to being significantly smaller than the new stadium and hardly visible from public space. We therefore introduce two dummy variables, each determining local spheres of influence: properties now located closer to the new stadium (denoted by POS) and those now located further away (denoted by NEG). We interact each of these with the $POST$ intervention date dummy variable to capture the interaction effect. Results are presented in column (3).

Table 3: Post-Treatment Effects – Emirates

	(1)	(2)	(3)	(4)	(5)
Distance Measure $X^c \times$ $POST$	-0.166**	-0.189**			-0.19**
	(0.037)	(0.039)			(0.038)
Distance Measure$X^c \times$ $TREND$					
Distance Measure$X^c \times$ $POST$ $\times$ POS			-0.096*		
			(0.046)		
Treatment $X^c \times$ $POST$ $\times$ NEG			-0.273**		
			(0.080)		
Radius Ring$_{(0-0.5)km} \times$ $POST$				-0.076+	
				(0.04)	
Radius Ring$_{(0.5-1)km} \times$ $POST$				-0.071*	
				(0.030)	
Radius Ring$_{(1-1.5)km} \times$ $POST$				-0.030	
				(0.026)	
Radius Ring$_{(1.5-2)km} \times$ $POST$				-0.032	
				(0.025)	
Radius Ring$_{(2-2.5)km} \times$ $POST$				-0.057*	
				(0.024)	
Radius Ring$_{(2.5-3)km} \times$ $POST$				-0.042+	
				(0.024)	
Radius Ring$_{(3-3.5)km} \times$ $POST$				-0.018	
				(0.027)	
Radius Ring$_{(3.5-4)km} \times$ $POST$				-0.032	
				(0.029)	
Radius Ring$_{(4-4.5)km} \times$ $POST$				0.007	
				(0.027)	
$VIEW \times POST$					0.004
					(0.141)
Basic Hedonic Controls	Yes	Yes	Yes	Yes	Yes
Extended Hedonic Controls	Yes	Yes	Yes	Yes	Yes
Location Controls	Yes	Yes	Yes	Yes	Yes
$log\left(D_{ijz+1}\right) - log\left(D_{ijz}\right)$	Yes	Yes	Yes	No	Yes
Ring Effects	No	No	No	Yes	No
Ring $\times$ Year Effects	No	Yes	No	No	Yes
Location Effects	Yes	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes	Yes
View Dummy	No	No	No	No	Yes
Observations	9,933	9,933	9,933	9,933	9,933
R^2	0.89	0.9	0.89	0.89	0.9

Notes: Dependent variable is log of purchasing price in all models. Robust standard errors (in parenthesis) are clustered on postcode groups. + significant at 10%; * significant at 5%; ** significant at 1%.

We find consistent post-intervention treatment effects within the catchment areas of the new as well as the old site. Notably, the magnitude of the adjustment is relatively smaller for the new than the old stadium. This may be due to the positive effects around the Emirates being partially cancelled-out by negative externalities linked to the much increased stadium capacity, such as more congestion, noise and crime.

In order to test for a significant *net* effect in the neighbourhood we replace the (log)change in distance to the stadium (X^c) with a consecutive set of 0.5 km rings (measure X^b) – column (4). Recall that for the Emirates case, these rings denote areas based on the minimum distance to *either* the Emirates *or* the old stadium. Compared to the case of the New Wembley, we find considerably smaller post-intervention treatment effects, which also point into the opposite direction. The areas within 1km of either of the two stadia experience a significant decline in property prices relative to more distant areas, although the estimated coefficient corresponding to the innermost 0–0.5km radius ring is only statistically significant at the 10% level.

One of the ambitions of this study is to disentangle stadium functionality effects (inherent to their function as sports venues) from design effects that emerge from the visual appearance (form) of the structure. The absence of iconic elements, a prominent architect, or particular architectural ambitions makes an amenity effect less likely in the case of the Emirates. Still, the new stadium represents a large and dominating structure that changes the visual setting in the neighbourhood. No matter in what direction, visual effects should be more localised than for the New Wembley as the surrounding Emirates neighbourhood is quite densely developed and the stadium does not feature an iconic element that could be widely visible from a certain distance. It is relatively difficult in practice to perfectly identify properties with a direct view to the stadium. Backed up by an inspection of the site, our approach makes use of the boundaries of postcode N7 7JD, which defines a sparsely developed strip of land in between two railway lines from which the stadium is relatively clearly visible. To allow for second row effects, we extend the postcode area by 100m into all directions and define a dummy variable ($VIEW$) for all properties falling into this area. This variable is then interacted with the $POST$ intervention period to isolate changes in prices following the stadium intervention that are specific to the view area. Results do not support a statistically significant view effect, nor affect the coefficient of the stadium's post-intervention treatment variable – column (5). We experimented with various distance thresholds greater than 100m to account for a potential second row effect, none of which altered this result. We note, however, that relatively few transactions took place within this small area, which must affect the estimation precision (28 in total, 11 of which occurred in the $POST$ period).

Taken together, our results point to a shift of demand occurring within the neighbourhood at a very micro-level. Net effects to the broader neighbourhood are either very small, or even negative. These results are consistent with countervailing externalities occurring at different distances. Positive effects related to an upgrade in terms of neighbourhood image or an emotional attachment to the venue and the home team seem to dominate at close distances, while negative externalities potentially related to congestion, noise and crime dominate at intermediate distances. Note that the new stadium has a much increased capacity, with correspondingly larger disamenity effects related to spectators that pass through the area on their way to/from the stadium, or stay within the neighbourhood after matches. At the same time the structure of the stadium does not offer a visual amenity to the same degree as that of other ambitiously designed arenas.

4.3 Robustness Checks

Our DiD estimation assumes that the stadium is the only intervention taking place in the area and that the control group is not affected by it, but would otherwise follow the same trend and therefore provides a compelling counterfactual. We have further assumed that the sample of observed property transactions is representative. As with most applications of experimental methodologies to quasi-experimental real-world settings (natural experiments), these assumptions cannot be satisfied by appropriate design *ex-ante* to the experiment. Instead, researchers must evaluate whether the natural experiment satisfies the criteria *ex-post*. Our time-variant estimates (a) suggest that there are no positive pre-trends that would confound the DiD estimates, (b) help identify the most likely intervention date in an environment where the intervention date is uncertain, and (c) indicate that there are no major interventions at *other* points in time other than the intervention dates identified.

Our methodology, however, offers no protection against other events that affect the treatment group but not the control group and occur at the *same* time with the stadium treatment. It is empirically challenging to control for all possible factors that could have affected property prices in our treatment areas. To the best of our knowledge we address at least the most obvious candidates in a series of robustness checks. We have also evaluated that the control groups themselves were not affected by the new stadia and that our results are not driven by sample selection. The reader is referred to Ahlfeldt and Kavetsos (2011) for relevant graphical illustrations and empirical results not reported in this section for brevity.

(a) Brent Council regeneration plans (Wembley): As previously mentioned, one of the selection criteria for both stadia was the absence of *major* alternative projects, such as infrastructure improvements and other urban interventions, within the time span of our sample that could potentially drive our estimated results. Note though that Brent Council (the borough hosting Wembley Stadium) released a detailed regeneration masterplan in 2004 involving the construction of new housing and office space units, as well as the renovation of existing transport infrastructure (e.g. of proximate tube stations, bicycle and pedestrian walkways, improvement in lighting, bus stops, etc). Although the regeneration plan was not implemented until its final revision in 2009, which is out of our sample, we test here the possible impact the announcement of these plans in 2004 might have had on property prices. This is achieved by introducing three dummy variables, each denoting various regeneration areas/stages. We additionally control for regeneration spillover effects up to 1km around the boundaries of the actual regeneration plan (Rossi-Hansberg et al., 2010). These variables are then interacted with post-2004 year dum-

mies to estimate post-announcement treatment effects in these areas. Results are presented in Table 4, column (1). Note that there are zero transactions observed in the 'stage 1' and 'masterplan' regeneration areas post-2004. The remaining regeneration-related coefficients are statistically insignificant. Notably though, the post-intervention stadium distance, although marginally reduced, is still statistically significant at the 1% level.

(b) View effects (Emirates): From the results presented so far no considerable view effects seem to be evident for the conventionally designed Emirates stadium. Of course, modelling view effects precisely is by no means a trivial task, as these will vary with the height of surrounding buildings. Flats in high-rise buildings could realise particularly high premiums and – if the distribution of such buildings is correlated with our main stadium distance variable – drive the estimated stadium effect, even though the average view effect is statistically insignificant. While there is probably no perfect solution to this problem as we cannot observe the storey of a property, we distinguish between flats and other types of properties, since properties in high-rise residential buildings fall into the 'flat' category. We subsequently interact the view dummy with the flats dummy, and then interact the resulting variable with the $POST$ period dummy. Table 4, column (2), suggests that none of the view coefficients are statistically significant, while the stadium estimate remains almost unaffected.

(c) Congestion effects (Emirates): The change in location from the old to the new Emirates Stadium, albeit within the same neighbourhood, plausibly affects the pathways which spectators use when walking from underground stations to the stadium, and vice versa. The change in usual pedestrian walkways may affect the attractiveness of specific streets in either direction, depending on whether negative effects from congestion or positive effects from increased spending of fans dominate. We attempt to identify the most obvious pathway from/to the Emirates and compare it to the most obvious pathway from/to the old stadium. To reach the Emirates the most likely pathways used are Hornsey Road and Drayton Park for fans exiting from Holloway Road and Arsenal underground stations, respectively. To reach the old stadium, fans exiting from Arsenal station would most probably walk along Avenell Road, Gillespie Road (up to Avenell Road), and Highbury Hill (up to Aubert Park). Based on these paths, we analyse property prices in these specific areas the same way as performed for the view effect. Results are presented in Table 4, columns (3). Column (4) estimates the congestion effects while allowing for different distance to stadium effects in the two spheres of influence around the old and the new site (as in Table 3, column (3)).

From these estimates, a remarkable increase in prices of about 30% is evident for areas that were, but no longer are, heavily used by spectators (column 3 and 4). There is also evidence for negative effects (about 12%) along roads where the respective frequency increased (column 4). These findings are in line with previous studies that inferred to the existence of localised congestion externalities, but were not able to model them explicitly (Ahlfeldt and Maennig, 2009, 2010a).

Table 4: Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)
	Wembley	Emirates	Emirates	Emirates	Emirates	Wembley
Linear Distance × *POST*	-0.025**					-0.041**
	(0.009)					(0.009)
Distance Measure X^c× *POST*		-0.191**	-0.184**		-0.190**	
		(0.039)	(0.039)		(0.039)	
Distance Measure X^c× *POST* × *POS*				-0.092*		
				(0.045)		
Distance Measure X^c× *POST* × *NEG*				-0.264**		
				(0.079)		
Stage 1 Regeneration × *POST*	0					
	(0)					
Masterplan Regeneration × *POST*	0					
	(0)					
Regeneration × *POST*	0.057					
	(0.039)					
Regeneration Buffer (1 km) × *POST*	0.017					
	(0.023)					
VIEW × *POST*		-0.037				
		(0.247)				
VIEW × *POST* × *FLAT*		0.072				
		(0.253)				
Spectator Decr. × *POST*			0.295*	0.307+		
			(0.141)	(0.179)		
Spectator Incr. × *POST*			-0.1	-0.130*		
			(0.079)	(0.059)		
Stadium Distance × Performance Rank					0.012	-0.003*
					(0.01)	(0.001)
Basic Hedonic Controls	Yes	Yes	Yes	Yes	Yes	Yes
Extended Hedonic Controls	Yes	Yes	Yes	Yes	Yes	Yes
Location Controls	Yes	Yes	Yes	Yes	Yes	Yes
$log\left(D_{ijz+1}\right) - log\left(D_{ijz}\right)$	No	Yes	Yes	Yes	Yes	No
Distance to Wembley	Yes	No	No	No	No	Yes
Ring × Year Effects	No	Yes	Yes	Yes	Yes	No
Location Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes
Regeneration Dummies	Yes	No	No	No	No	No
View Dummy	No	Yes	No	No	No	No
View × *Flat*	No	Yes	No	No	No	No
Spectator Increase	No	No	Yes	Yes	No	No
Spectator Decrease	No	No	Yes	Yes	No	No
Observations	5,263	9,933	9,933	9,933	9,933	5,263
R^2	0.901	0.897	0.897	0.895	0.897	0.901

Notes: Dependent variable is log of purchasing price in all models. Robust standard errors (in parenthesis) are clustered on postcode groups. + significant at 10%; * significant at 5%; ** significant at 1%.

(d) Team performance (Emirates & Wembley): If team performance is correlated with a

move into a new stadium the estimated stadium effects could be affected. To test this hypothesis we introduce an interactive term of distance to the stadium with the rank Arsenal FC hold at the end of a respective Premier League season.

Note that in creating this variable we again use the minimum distance of a property to *either* the former *or* the new stadium, as the distance component is meant to be constant in postcodes over time so that the only variation over time results from changes in team performance. For New Wembley, the traditional venue of the English national football team, we control for performance effects in the same way using annual ranking averages retrieved by the FIFA world rankings.

Table 4 column (5), indicates that team performance does not exhibit a statistically significant effect on the stadium proximity effect for the Emirates case, which might be partially due to the relatively stable performance of the club over our study period. The Wembley results – column (6) – hold some surprise as the estimated coefficient of the performance-stadium distance interactive variable comes out statistically significant, but with a negative sign. At the same time, however, the estimated stadium effect increases from close to 3% to more than 4%. Overall, the stadium coefficients of primary interest remain fairly robust in both cases even after controlling for performance.

(e) Spill-over effects (Emirates & Wembley): We further evaluate whether the 5km margin, as suggested by the existing literature, is an appropriate control area. We perform separate DiD estimations for both stadia comparing how property prices inside and outside the 5km radius ring evolve following the identified stadium intervention dates. In each case, we separately compare 250m or 500m radius rings inside and outside the 5km margin. None of the resulting four DiD estimates are statistically different from zero. We conclude that spillover effects beyond our study areas are not a major concern.

(f) Data source (Emirates & Wembley): Finally, we have replicated the main analysis of section 3.2 with the Land Registry data, which offers the entire population of transactions at the cost of limited detail in property characteristics. The results support those presented here.

5 Concluding Remarks

This study contributes to the emerging literature on the impact of neighbourhood consumption amenities, and more specifically of sports stadiums, on property prices, as well as to the broader discussion on whether expenditures on the construction and modernisation of large-scale professional sports facilities can be justified on the grounds of significant neighbourhood spillovers. We investigate two of the largest stadium projects of the recent decade, the New Wembley and the Emirates Stadium in London. The selection of stadia is motivated by case-specific particularities that help separate form (i.e. design) and functionality effects, and isolate stadium effects from correlated neighbourhood effects and trends.

For the New Wembley we find a significant increase in property prices close to the stadium of up to 15%, which gradually decreases in distance to the stadium. The magnitude of the effect is roughly in line with results from previous studies. The New Wembley replaced a pre-existing stadium of about the similar size with the same functionality. Many of the external functionality effects, including positive effects related to civic pride and emotional attachments, as well as potential negative externalities arising from increased noise, crime and congestion, are thus held constant. Given its distinctive design and prominent architects, these findings are in line with an 'iconic' design effect which has recently been found for the case of historic residential buildings. The distinctive iconic element of the new stadium – a widely visible arch of roughly 130m high – can also explain the presence of significant stadium effects at relatively more distant properties.

The relocation of the Arsenal home venue to the Emirates Stadium provides micro-level variation in distance to the stadium over time, which we use to disentangle stadium effects from correlated neighbourhood effects and trends. We find a robust increase in property prices where distance to the stadium location is reduced – a result in line with positive (net) externalities. Our results indicate a 1.7% increase in property prices for a 10% decrease in distance to the stadium. Moreover, we find that price adjustments are considerably larger, although less abrupt, in areas that experience an increase in stadium distance. No view effects could be associated with the Emirates, which is perhaps not as surprising since, compared to the New Wembley, the Emirates is a much more conventionally-designed stadium. Given that the old structure was not removed but modernised, these effects point to the existence of (a) significant effects related to the functionality of the stadium, and (b) a negative externality that partially cancels out positive effects and may be related to the increased capacity and presumably increased noise, crime and congestion effects. A negative externality emerging from spectators going to/from the stadium could be identified using the change in their typical walkways after the stadium had been moved, confirming that stadia are not only associated with positive, but also negative neighbourhood externalities.

A further contribution compared to previous studies is that we explicitly address the open question related to the timing of the intervention, which is crucial for subsequently deriving average stadium post-intervention treatment effects. One strand of research assumes immediate price reactions occur when new information enters the market (e.g. McMillen and McDonald, 2004). Another view is that prices re-adjust after an improvement has actually taken place (e.g. Gibbons and Machin, 2005). Given the large nature of stadium projects and the correspondingly strong signal associated with their announcements, we expect capitalisation effects to commence when the critical information enters the market. This is confirmed in our estimation of time-varying stadium effects.

Aggregating the identified property market reactions based on the estimated marginal effects and the adjusted mean property prices at output area yields substantial monetised estimates. For all three stadium locations, the estimated change in aggregated value amounts to about £1.91 billion for the New Wembley and £1.04 billion for the Emirates, which is however accompanied by a reduction of £1.41 billion around the old Arsenal stadium, leaving a negative net effect to the neighbourhood (see Ahlfeldt and Kavetsos, 2011, for a background regarding these estimates). These estimates are large even compared to the construction cost of the New Wembley (£1.4 billion including expenditures on infrastructure and financing).

Our findings open an avenue for potential policy recommendations. If stadiums impact positively on the intrinsic value of a neighbourhood, then the expectation that stadium (re)development projects will contribute to the neighbourhood (re)vitalisation may be justified, especially if a comprehensive urban and building design quality is used. A critical question, however, is who should pay for the incremental cost related to good design which benefits the neighbourhood but not the owner of a stadium. Given that it is difficult to convince a profit-maximising agent to undertake private investments to benefit the public, commitment of public funds may become necessary; though in that case a distributional conflict arises if costs are spread equally across taxpayers but benefits are only capitalised locally. Moreover, renters will usually be more than compensated for the benefits by increases in rent levels (Ahlfeldt, 2011a), leaving local owners, occupiers and landlords as the effective profiteers, which further increases inequality. These are concerns that more generally apply to a wider range of local policies, including transport facilities, public spaces or any other infrastructures, which are difficult to address in practice. One way would be to levy compensations, in the case of owner-occupied buildings, possibly after a property is sold or inherited – although heavy opposition should be expected. These concerns are obviously not raised to dismiss any approach to neighbourhood revitalisation policies in general, and stadium related ones in particular, but to raise awareness of the potential distributional consequences.

As with most quasi-experimental research, the credibility of our findings is subject to the appropriateness of the identifying assumptions. One particular concern is that our treatment estimates could be affected by other events that occur at the same time as our identified intervention dates and whose impact is spatially correlated with distance to the stadiums analysed. While the estimated stadium effects are robust to the inclusion of controls for regeneration policies and team performance, it is difficult to control for all (unobserved) factors in a natural experiment. Another limitation is that the 'iconic' design effect of the New Wembley cannot be modelled directly and inference is only possible on the basis of being arguably the most plausible factor remaining after excluding alternatives. Finally, it is important to note that the aggregated effects discussed above should be interpreted as local WTP rather than a global welfare effect, since the preferences of the local marginal buyers do not necessarily generalise beyond our study areas. More generally, our results suggest that the impact stadia deliver to their neighbourhood depends on the mix of the various external effects they provide, which differ from case to case. More research would be desirable to affirm the identified channels of stadium impact, especially regarding the 'iconic' design effect, which the quantitative literature has just started to investigate.

Notwithstanding these issues, our results are suggestive of functionality effects directly related not only to the function (access to sports services), but also the form (architectural design) of a stadium. On the one hand 'iconic' designs may induce a visual amenity and utility effect. On the other hand such a formal vocabulary, by promoting the identification of spectators and fans with 'their' stadium, may also amplify functionality effects. In any case, our results support the potential of stadium projects to increase the attractiveness of local areas and suggest that architecture can increase that potential.

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References

Ahlfeldt, G.M. (2011a) Blessing or Curse? Appreciation, amenities and resistance to urban renewal. *Regional Science and Urban Economics*, 41(1), 32-45.

Ahlfeldt, G.M. (2011b) The train has left the station: Do markets value inter-city access to intra-city rail lines? *German Economic Review*, 12(3), 312-335.

Ahlfeldt, G.M. and Kavetsos, G. (2011) Form or function? The impact of new football stadia on property prices in London. Discussion paper 87, Spatial Economics Research Centre, London School of Economics.
www.spatialeconomics.ac.uk/textonly/serc/publications/download/sercdp0087.pdf.

Ahlfeldt, G.M. and Maennig, W. (2009) Arenas, arena architecture and the impact of location desirability: The case of 'Olympic arenas' in Prenzlauer Berg, Berlin. *Urban Studies*, 46(7), 1343-1362.

Ahlfeldt, G.M. and Maennig, W. (2010a) Impact of sports arenas on land values: Evidence from Berlin. *The Annals of Regional Science*, 44(2), 205-227.

Ahlfeldt, G.M. and Maennig, W. (2010b) Stadium architecture and urban development from the perspective of urban economics. *International Journal of Urban and Regional Research*, 34(3), 629-646.

Ahlfeldt, G.M. and Maennig, W. (2012) Voting on a NIMBY facility: Proximity cost of an 'iconic' stadium. *Urban Affairs Review*, 48(2), 205-237.

Ahlfeldt, G.M. and Mastro, A. (in press). Valuing Iconic Design: Frank Lloyd Wright Architecture in Oak Park, Illinois. *Housing Studies.*

Alexander, D.L., Kern, W., and Neill, J. (2000) Valuing the consumption benefits from professional sports franchises. *Journal of Urban Economics*, 48(2), 321-337.

Angrist, J.D. and Pischke, J.S. (2009) Mostly Harmless Econometrics: An Empiricist's Companion: Princeton University Press.

Baum-Snow, N. and Kahn, M.E. (2000) The effects of new public projects to expand urban rail transit. *Journal of Public Economics*, 77(2), 241-263.

Bertrand, M., Duflo, E. and Mullainathan, S. (2004) How much should we trust differences-in-differences estimates? *Quarterly Journal of Economics*, 119(1), 249-275.

Bowes, D.R. and Ihlanfeldt, K.R. (2001) Identifying the Impacts of Rail Transit Stations on Residential Property Values. *Journal of Urban Economics*, 50(1), 1-25.

Black, S. (1999) Do better schools matter? Parental valuation of elementary education. *Quarterly Journal of Economics*, 114(2), 577-599.

Carlino, G. and Coulson, N. (2004) Compensation differentials and the social benefits of the NFL. *Journal of Urban Economics*, 56(1), 25-50.

Cellini, S.R., Ferreira, F., and Rothstein, J. (2010) The value of school facility investments: Evidence from a dynamic regression discontinuity design. *The Quarterly Journal of Economics*, 125(1), 215-261.

Clapp, J.M., Nanda, A., Ross, S.L. (2008) Which school attributes matter? The influence of school district performance and demographic composition on property values. *Journal of Urban Economics*, 63 (2), 451-466.

Coates, D. and Humphreys, B. (2006) Proximity benefits and voting on stadium and arena subsidies. *Journal of Urban Economics*, 59(2), 285-299.

Dehring, C., Depken, C., and Ward, M. (2007) The impact of stadium announcements on residential property values: Evidence from a natural experiment in Dallas-Fort Worth. *Contemporary Economic Policy*, 25(4), 627-638.

Dehring, C., Depken, C., and Ward, M. (2008) A direct test of the homevoter hypothesis. *Journal of Urban Economics*, 64(1), 155-170.

Feng, X. and Humphreys, B. (2008) Assessing the economic impact of sports facilities on residential property values: A spatial hedonic approach. International Association of Sports Economists, Working Paper 0812.
http://ideas.repec.org/p/spe/wpaper/0812.html.

Fischel, F.A. (2001) The Homevoter Hypothesis.Cambridge, MA.: Harvard University Press.

Florida, R., Mellander, C., and Stolarick, K. (2011) Beautiful places: The role of perceived aesthetic beauty in community satisfaction. *Regional Studies*, 45(1), 33-48.

Gibbons, S. (2004) The costs of urban property crime. *Economic Journal*, 114, F441-F463.

Gibbons, S. and Machin, S. (2005) Valuing rail access using transport innovations. *Journal of Urban Economics*, 57(1), 148-169.

Gibbons, S. and Machin, S. (2006) Paying for primary schools: Admission constraints, school popularity or congestion? *Economic Journal*, 116, C77-C92.

Glaeser, E. L., Kolko, J., and Saiz, A. (2001). Consumer city. *Journal of Economic Geography*, 1(1), 27-50.

Halvorsen, R. and Palmquist, R. (1980) The interpretation of dummy variables in semilogarithmic equations. *American Economic Review*, 70(3), 474-475.

Jim, C.Y. and Chen, W.Y. (2009) Value of scenic views: Hedonic assessment of private housing in Hong Kong. *Landscape and Urban Planning*, 91(4), 226-234.

Kavetsos, G. (2012) The impact of the London Olympics announcement on property prices. *Urban Studies*, 49(7), 1453-1470.

Lynch, A.K. and Rasmussen, D.W. (2001) Measuring the Impact of Crime on House Prices. *Applied Economics*, 33(15), 1981-1989.

McMillen, D.P. and McDonald, J.F. (2004) Reaction of house prices to a new rapid transit line: *Chicago's* Midway Line, 1983-1999. *Real Estate Economics*, 32(3), 463-486.

Nelson, J.P. (2004) Meta-Analysis of Airport Noise and Hedonic Property Values: Problems and Prospects. *Journal of Transport Economics & Policy*, 38(1), 1-28.

Rosen, S. (1974) Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. *Journal of Political Economy*, *82*(1), 34-55.

Rossi-Hansberg, E., Sarte, P-D., and Owens, R. (2010) Housing externalities. *Journal of Political Economy*, 118(3), 485-535.

Siegfried, J. and Zimbalist, A. (2000) The economics of sports facilities and their communities. *Journal of Economic Perspectives*, 14(3), 95-114.

Sirmans, G., Macpherson, D., and Zietz, E. (2005) The composition of hedonic pricing models. *Journal of Real Estate Literature*, 13(1), 3-43.

Tiebout, C. (1956) A Pure Theory of Local Expenditures. *Journal of Political Economy*, 64(5), 416-424.

Tomkins, J., Topham, N., Twomey, J. and Ward, R. (1998) Noise versus access: The impact of an airport in an urban property market. *Urban Studies*, 35(2), 243-258.

Tu, C. (2005) How does a new sports stadium affect housing values? The case of FedEx Field. *Land Economics*, 81(3), 379-395.