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MEASURING THE INFLUENCE OF SPATIAL CONFIGURATION ON THE HOUSING MARKET IN METROPOLITAN LONDON

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Abstract

In real estate economics, there is a lack of research in studying the relationship between the built form and economic value. Partly this is stemmed from the lack of a methodology in studying built form objectively but also in much of regional science and spatial economics discourse, a lack of consideration in the influence of urban morphological properties. In "pricing accessibility", Webster (2009) argues the need to value the built form morphology. One perspective in understanding the built environment morphology is through its spatial configuration. (Hillier and Hanson 1984) He argues this understanding can potentially lead to more efficient allocation of resources. This research thus makes use of the hedonic approach, an established methodology in environmental economics, in estimating the influence of spatial configuration on observed housing sold price. (Rosen 1974) The results from this study suggest that spatial configuration measure of accessibility such as space syntax integration and space syntax choice are significant variables influencing transaction house price both positively and negatively in London between 1995 - 2011. In comparison to both distance to CBD measures and gravitational potential measures, the result also suggests space syntax integration is an appropriate variable in hedonic models to capture accessibility effects

Keywords: *Space Syntax, accessibility, urban economics, hedonic model*

Theme: *Urban Space and Social, Economic and Cultural Phenomena*

1.0 Background

House price can be influenced from the demand side of the market, the supply side of the market, the policy regulating the market, foreign investors entering the market as well as global economic trends. In the UK, house price has risen dramatically this past 10 years disproportionately clustering around dense urban conurbations such as London. Brought forth by this growing demand is a need to better understand how the urban environment in this case accessibility, influences the housing market. Understanding the influence accessibility has on the housing market can potentially lead to more efficient allocation of resources (Webster 2009), understanding and possibly minimising the impact of gentrification (Atkinson 2004), more equitable policies and methods in public transport financing (Medda 2012) and most importantly creating better urban environments and cities.

Buyer's preferences in the housing market are often examined in regional science through two approaches; revealed preferences approach utilising empirical data or stated preferences approach using controlled experiments. Discrete choice model uses stated preference questionnaires to determine consumer residential location choice. (McFadden 1977) Hedonic approach on the other hand of which this study focuses on uses revealed preference method to estimate the implicit price of a housing characteristic from observed sold price. (Rosen 1974) Ones can think of this concept by comparing two properties holding all features of a dwelling constant in which one has one bedroom and the other has two bedrooms. The price differential between the two is equal to the implicit price of the bedroom. Court (1939) and Griliches (1967 and 1971) were one of the first authors to apply the term 'hedonic' in regression models on heterogenous commodity. The work of Rosen in 1974 described an economic model in which consumer choices over a composite good like housing amounts to choosing an optimal bundle. (Rosen 1974; Gibbons and Machin 2003) A modern review of the hedonic theory and econometric techniques can be found in Sheppard. (1998)

In the hedonic approach, estimating the marginal willingness to pay for location differentials is an extensively studied topic in urban economics. (Marhsall 1890; Von Thunen 1826; Alonso 1964; Muths 1969; Mills 1972; Fujita 1989) Empirically, it is traditionally estimated in the form of "Distance to CBD" (Alonso 1964) and more recently "Gravitational potential model" (Hansen 1949) to employment locations. This research proposes the use of accessibility measure from a spatial configuration perspective in comparison to these two accessibility measures.

Spatial configuration in this context is defined as a set of interrelationship between space in which one approach is the theory and methods of space syntax. (Hillier and Hanson 1984; Penn et al. 1998; Hillier et al. 1987; Hillier 2006) Spatial configuration measure of accessibility has been found to relate closely to various scales of movement, spatial cognition, land use, density and social interactions. (Penn et al. 1998; Peponis 1995; Hillier 1996; Penn et al. 1999) Research between spatial configuration and economic measures are sparse. The earliest research between space syntax and economics focuses on the relationship between spatial configuration and office rent in Berlin (Desyllas 2001). More recent studies focus on the relationship between spatial configuration with rateable value in London town centres (Chiaradia, Hillier, Schwander, Wedderburn 2009b) housing council tax band in both London and Cardiff (Chiaradia, Hillier, Barnes, Schwander, 2009a and 2012a; Narvaez, Penn and Griffiths, 2012) and the use of spatial configuration measures in hedonic models on housing market research for Cardiff and Nanjing. (Xiao 2012).

This research continues from previous research arguing the use of accessibility measures from a spatial configuration perspective allows for more objective analysis. Our decision in buying a house is not limited to accessibility to one set of destination but rather multiple destinations.

The originality of this research is the use of micro sold price data across time for the greater metropolitan area of London. This allows a year by year estimation on the influence of spatial configuration on house price in a global world city. Secondly, it provides an initial comparison between configuration measures of accessibility and traditional measures of accessibility. This research argues the use of configuration measure is not only an objective method and are especially important for longitudinal study where micro-data on distribution of economic activity are often incomplete, sparse in time and aggregated.

The main research questions are thus;

"What is the influence of accessibility on house price for the metropolitan area of London between 1995 – 2011 from a spatial configuration perspective?" To what extent does measure of spatial configuration compare to traditional accessibility measure?

In order to answer this research question, the paper is structured into four parts:

- the first part introduces the methodology, the hedonic framework and accessibility measures
- the second part introduce the case study of London, the house price dataset and network dataset
- the third part explores the data and describes the regression results
- Finally, we summarise and discuss some steps forward.

2.0 Methodology

In order to study the influence accessibility has on the housing market, this study will consists of two parts; an exploratory data analysis that correlates property price with four accessibility measures followed by a hedonic regression model of the dataset that includes a number of controlled variables.

2.1 Exploratory data analysis methodology

To explore the influence different measures of accessibility has on the housing market; four measures of accessibility will be correlated with the price per sqm for the metopolitan area of London between 1995 – 2011 through a bi-variate scatterplot correlation analysis where price per sqm is regressed against measures of accessibility.

$$Price\ per\ sqm = \beta_1 Accessibility + \varepsilon$$

Equation (1)

The four measures of accessibility includes distance to Central business district (CBD), gravitational potential to employment, space syntax integration, space syntax choice.

The first measure is distance to CBD. This is the most common accessibility measure in hedonic models and theorised from the monocentric model of Alonso. (1964) This general form measures the metric distance (D) from each dwelling unit (i) to one employment point in space.

$$A_i = D_{ij}$$

Equation (2)

Distance to CBD is calculated from each house price point to the centroid of the segment in front of Holborn underground station which is between Bank and Westminster. A significant limitation to this specification is the assumption of a central business district location. The estimates fluctuate dependent on the location of the central business district.

The second accessibility measure is gravitational potential to employment. This measure has been recently applied in hedonic models. In geographical science, accessibility is defined as a function positively proportional to the size of activity and attraction and inversely proportional to distance or travel time in realising the opportunity. (Hansen, 1959) Gravitational potential is a variation of the traditional gravity model measuring accessibility linking household location i to a census output area employment ward j with dij as the metric distance impediment from i to j.

$$Gi = \sum_{j=1}^{n} \frac{E_j}{d_{ij}}$$

Equation (3)

A significant limitation of this specification is the use of zonal aggregated data and the lack of micro-data on exact employment location for each residence.

The third accessibility measure is space syntax integration also known as segment angular integration. (Hillier and Hanson 1984; Hillier et al. 2012) This measure previously has been found to relate closely to residential property values and office rent. (Chiaradia et al. 2009a; Desyllas 2001) Segment angular integration is a close derivative of closeness centrality in network science literature measuring the reciprocal sum of the shortest path between every origins (i) to every destination (j), i.e. the potential of movement to this street segment (Sabidussi 1966; Freeman 1977; Hillier and Iida 2005).

$$Ci = \frac{1}{\sum d_{ij}}$$

Equation (4)

Segment angular integration is calculated for each segment of the spatial network model using the computer software UCL Depthmap developed by Alasdair Turner (Turner 2001) and Tasos Varoudis (Varoudis 2012). The radius for the analysis is 24,000 metre for the street networks and 48,000 metre for the public transport network. Segment angular integration measure is defined for each house price point to its nearest segment.

The fourth accessibility measure is space syntax choice also known as segment angular choice. (Hillier and Iida 2005; Hillier et al. 2012) This measure has previously been found to relate closely to pedestrian movement, vehicular movement, retail land use, pollution and noise. Segment angular choice in space syntax is a close derivative to shortest path weighted betweenness centrality in network science literature which measure the sum of shortest paths (N) between all pairs of origins (s) and destinations (t), i.e. the potential of moving through this street segment (Freeman 1977; Brandes 1996; Hillier and Iida 2005).

$$Bi = \sum_{s \neq t} N^i{}_{st}$$

Equation (5)

Segment angular choice is calculated for each segment of the spatial network model using the computer software UCL Depthmap developed by Alasdair Turner (Turner 2001) and Tasos Varoudis (Varoudis 2012). The radius for the analysis is 24,000 metre for the street networks and 48,000 metre for the public transport network. Segment angular integration measure is defined for each house price point to its nearest segment.

2.2 Hedonic regression model

The work of Rosen in 1974 described a hedonic framework in which consumer choices over a composite good like housing amounts to choosing an optimal bundle. (Rosen 1974; Gibbons and Machin 2003) The standard empirical form of the hedonic framework is to regress Log house price against a vector of dwelling specific and location specific variables through a simple *Normal-Linear-Quadratic model (NLQ model)* using cross section data. *(Ekeland 2004)* The method of ordinary least square (OLS) is used for the estimation of the NLQ model. The implicit price for the specific location attribute can then be determined by the first order condition of this equation.

$$Log\ Price = \sum \beta_1\ Location\ variables + \sum \beta_2\ Dwelling\ variables + \varepsilon$$

Equation (6)

Early research in hedonic regression model focuses on dwelling specific variables. Cheshire and Sheppherd (1995) suggests that it is necessary to include both dwelling and location specific variables in order to get stable and reliable estimates for the two. Four candidate models are applied to test this relationship where all the variables are constant except for the accessibility variables. The first candidate model will include Distance to CBD which represents the traditional accessibility measure being applied to hedonic model. The second candidate model will include gravitational potential. The third candidate model will include space syntax integration. The fourth candidate model will include both space syntax integration and gravitational potential.

Table 1 Four candidate models

Candidate model	***Accessibility***
Candidate model 1	*Distance to CBD*
Candidate model 2	*gravitational potential*
Candidate model 3	*Space syntax integration*
Candidate model 4	*Space syntax integration + gravitational potential*

Research limitations in the specification and functional forms of hedonic models have been the source of extensive econometric research. The most important being omitted variables bias where econometric techniques are applied to more accurately estimate the implicit price of an amenity. (Black 1999) Controlling for omitted variables bias will be discussed in forthcoming publications and will not be the focus of this research. The simple specification of the hedonic

model allows for simple interpretation but it is also an empirical limitation to the research.

3.0 Case study London

In order to answer the research question, the case study of London is applied. The extent of the study area is presented in the figure below where the red line indicates borough boundaries of Greater London.

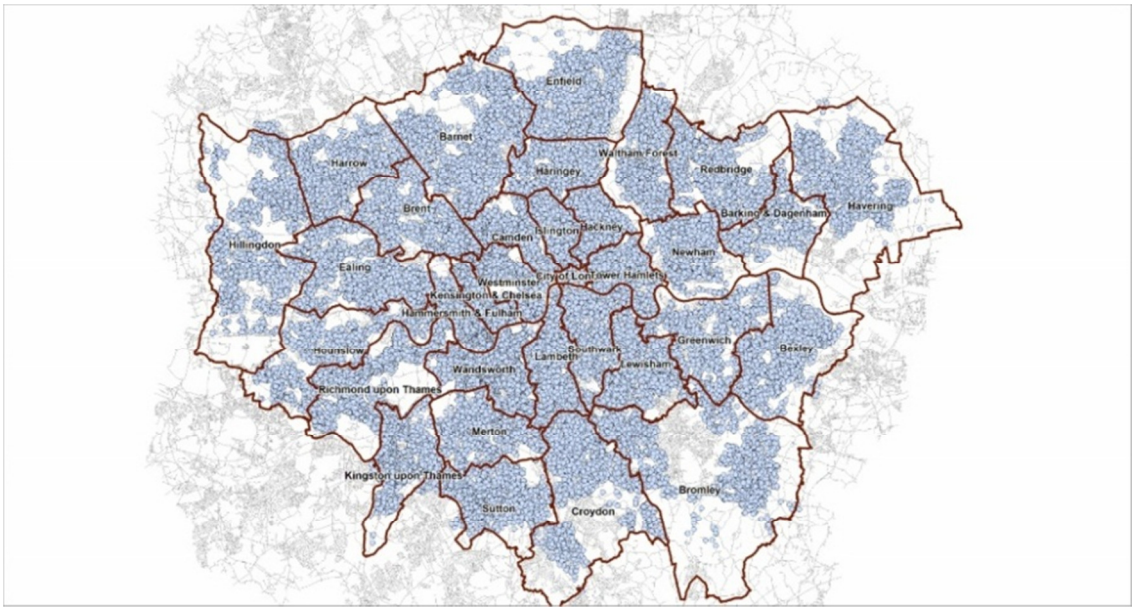

Figure 1 Extent of study area

3.1 Residential house price dataset

Residential sold house price is defined as the property value dataset for this study. The source of the data comes from Zoopla [1], Land Registry [2] and Nationwide Building Society [3]. The dataset includes; transaction price between the vendor and the buyer in GBP, dwelling size in square metre, date of transaction, address in postcode, dwelling type separated into flat or house, tenure separated into leasehold or freehold, number of bedrooms and number of bathrooms. The figure below describes house price in London between 1995 and 2011 where average house price rose more than 4 times from less than £80,000GBP (£800/sqm) to over £350,000(£3,500/sqm) in the last 15 years. The standard deviation of the house price has similarly increased fourfold from £300/sqm to £1,400/sqm. The histogram on the right shows the long tail distribution of house price across time with the majority of house sold in the low to medium house price quantiles and a minority of house sold in the upper house price quantiles.

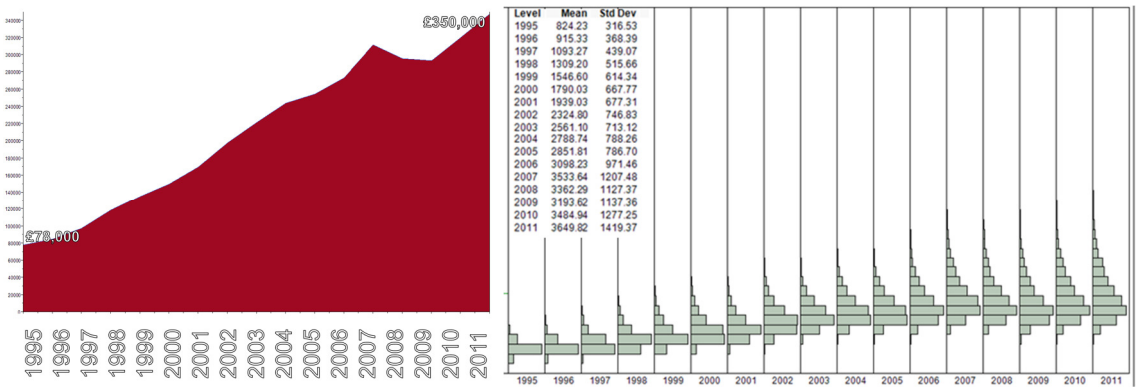

Figure 2
Left Average house price in Metropolitan London between 1995 - 2011
Right Histograms of house price in Metropolitan London between 1995 - 2011

3.1.1 Descriptive statistics City-wide House price

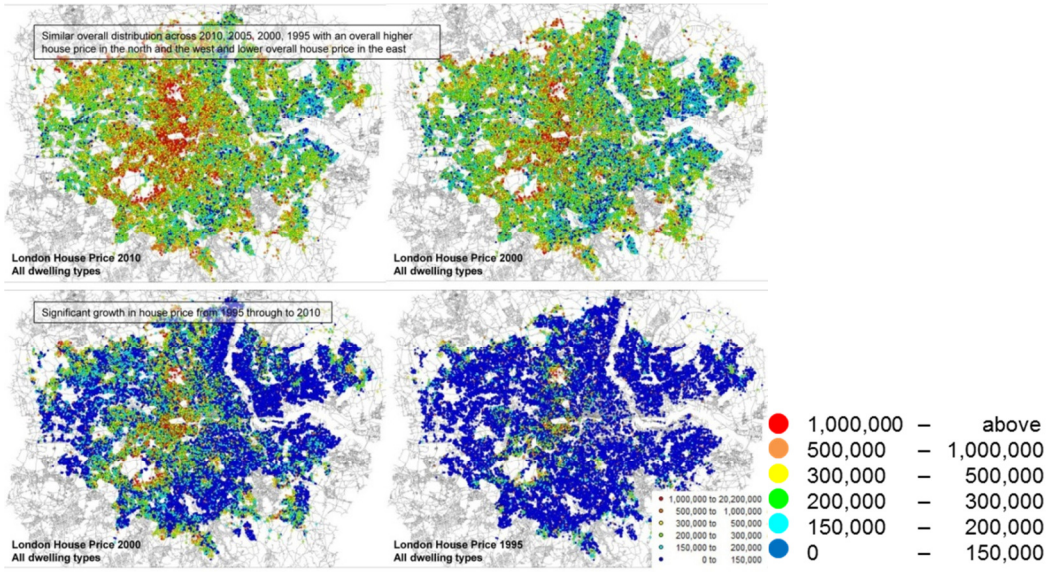

Figure 3 London house price for 2010, 2005, 2000, 1995 in same price range showing the increase in house price across space and time

The above figure describes overall house price in Greater London for the four time periods of 1995, 2000, 2005 and 2010 visualised in post code level where red denote property price above £1,000,000 and blue denote property price below £150,000. The same ranges are used to illustrate the house price differences for the four time periods. A key observation from the temporal distribution is the dramatic increase in house price over time for the same location. The persistency in high house price areas contributes to the lock-in effect of neighbourhood preference in the housing market of London. Geographically higher house prices are clustered near the centre of the city and in traditionally affluent areas such as Hampstead, Richmond, Kensington and Chelsea which are also in proximity to Royal Parks. Lower house prices are clustered in less central areas at Tottenham, Lower Edmonton and Dagenham which are in proximity to less integrated open space such as the Lee Valley regional park and industrial land uses. This description corresponds to previous research and suggests the influence of centrality, attractive green space, proximity to retail land use and school quality on house price.

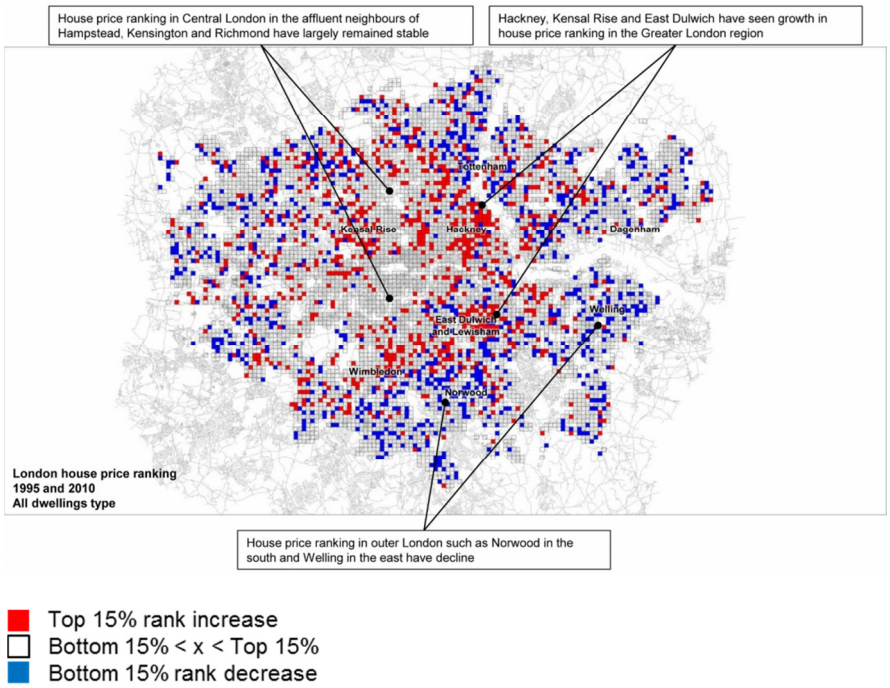

Figure 4 London house price ranking difference between 1995 and 2010

The above figure describes the differences in ranking for the Greater London region aggregated in 400 metre x 400 metre cells between 1995 and 2010. Red cells describe areas that are in the top 15% rank increases. Blue cells describe areas that are in the bottom 15% rank decreases. White cells describe areas that did not experience significant changes. The result suggests areas such as Hackney and Dalston in East London, Kensal Rise, Wimbledon, Brixton and Dulwich have increased significantly in ranking between 1995 and 2010 and that house price ranking in outer London such as Norwood in the south and Welling in the east have declined. These descriptive results points to increase in demand of central areas between 1995 – 2010.

3.2 Spatial network data

In order to measure the impact spatial configuration has on property values, a spatial network model has been constructed within the M25. A spatial network model of Greater London has been constructed using network layers including the London street segment network and London Underground, London Overground and Docklands Light Rail network. The methodology in constructing the street and rail segment model extends from a previous study on the construction of the London bi-modal segment model. (Law, Chiaradia and Schwander 2012) The coupling method of the street and the tube model is still in its infancy in space syntax research and will require future research. The rationale in the use of the street and rail segment model is attributed to an overall better fit when comparing to a street only model.

The basis of the London strategic street segment network has been provided by Space Syntax Limited (Space Syntax Limited, 2013) and uses the Ordnance Survey Integrated Transport Network (ITN) as a base. [4] The London Underground network is constructed by modelling straight lines between all pairs of connected London Underground, Overground and Docklands Light Rail Station. The London Underground, London Overground and Dockland Lightrail network are then connected to the street model at the location of the station through a perpendicular link which accounts for the cost between the street and the station. (Law, Chiaradia and Schwander 2012)

Table 2 London street-tube segment model specification for 1995 and 2011

Spatial network model	London street network	London underground and Railway 1995	Jubilee Line extension 1999	London overground East London Line Phase 1 2010	London Docklands Light rail stage two extension 1999	London Docklands Light rail stage three extension 2005
1995	Y	Y	N	N	N	N
2000	Y	Y	Y	N	Y	N
2005	Y	Y	Y	N	Y	Y
2011	Y	Y	Y	Y	Y	Y

Four spatial model; 1995, 2000, 2005 and 2011 are constructed as specified in the table above of which the street network remains constant and the only differences in the four network model is its changes in its rail network. The figure below compares space syntax integration measure (equation4) of London in 1995 (left), space syntax integration in 2011 (middle) and a difference map between two. (right) Difference map are calculated by differencing between space syntax integration in 2011 from space syntax integration in 1995 for the same segment in the two periods. The space syntax integration map (Fig.6) are visualised using the colour spectrum: red for high accessibility through to orange, yellow, green and blue for areas with low accessibility. The space syntax integration difference map are visualised using the colour spectrum: red for greater increase in accessibility through to white for areas with lesser increase. Significant increase in space syntax integration values can be observed between the two time periods. To allow for comparable interpretation, only the 2011 spatial model has been applied to the hedonic analysis to ensure estimates are comparable between the years.

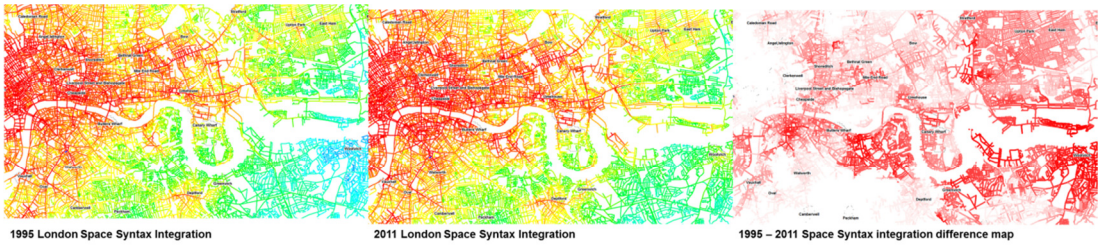

Figure 6
Left Space Syntax Integration 1995
Centre Space Syntax segment angular integration 2011
Right Space Syntax Difference map between 1995 and 2011

Limitations of the dataset include the use of a simplified street network dataset that was not objectively simplified, modified and modelled across the city. Another limitation is the exclusion of public transport network such as the bus network and an over simplification of a multi-modal transport model which excludes trip assignment and mode choice selection. All of these limitations are recommended to be addressed in future researches.

4.0 Exploratory data analysis between house price and accessibility overtime

Before employing the hedonic regression model on house price, house price per square metre and log house price per square metre are plotted against space syntax integration, space syntax integration + space syntax choice measure, gravitational potential measure and distance to CBD measure for exploratory data analysis.

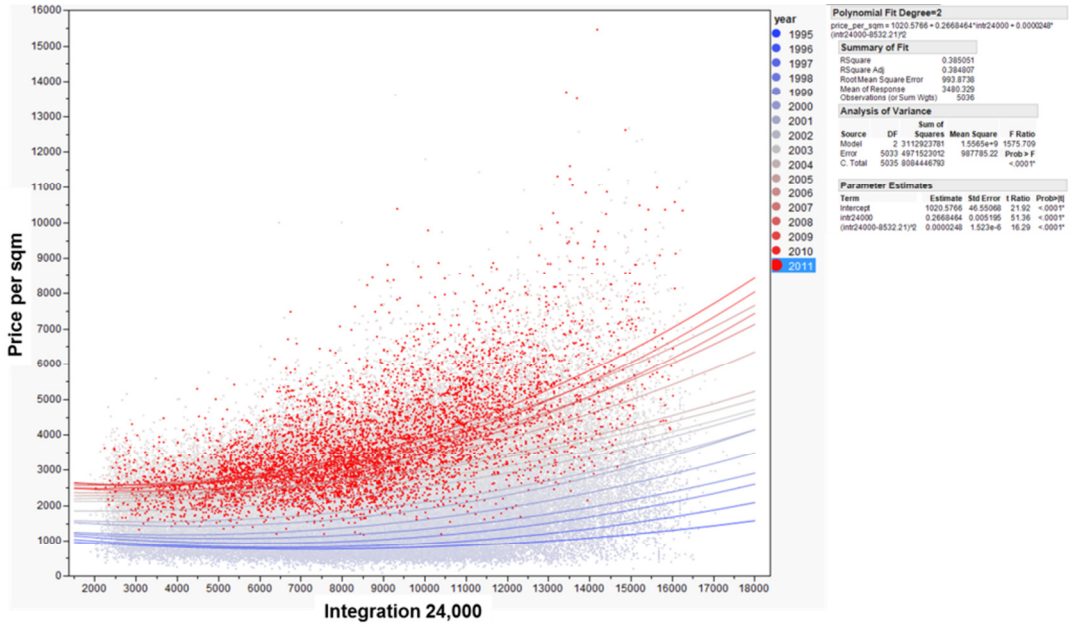

Figure 7 Scatterplot between Price per sqm and integration 24,000

The table above illustrates the scatterplot with price per square metre (sqm) on the y-axis and space syntax integration on the x-axis. The colour of the dot indicates the year of the transaction and the colour of the line is the fitted line for the specific year. In this case red dot indicates 2011 house price and red line indicates the fitted line for 2011. The result suggests a positive relationship between price per sqm and integration, where space syntax integration explains nearly 40% of the variation in price per sqm in London for 2011. Interpreting the beta coefficients, one standard deviation of space syntax integration radius is equal to 0.50+ standard deviation differences in price per sqm. The result suggests space syntax integration is a highly significant variable in explaining house price per sqm. The results are inconsistent across time. In 1995, less than 10% of the variation in price per sqm can be explained by space syntax integration. While in 2000, 30% of the variation in price per sqm can be explained by space syntax integration. Similar results are achieved with the log price per sqm plot. The result suggests an increasing importance of centrality in the metropolitan areas of London after 1999.

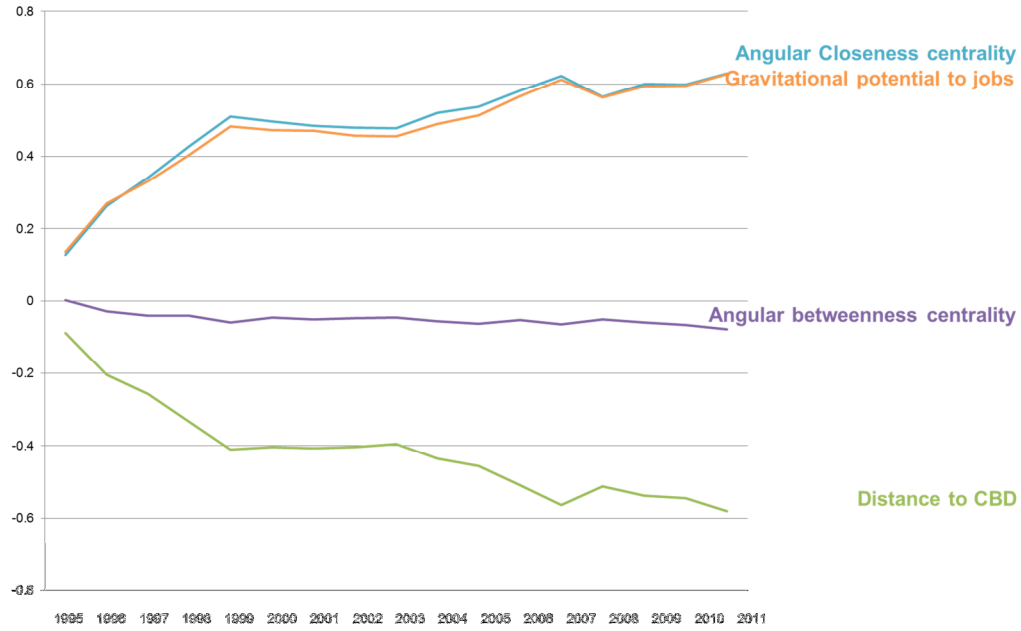

Figure 8 Beta coefficient comparison between gravitational potential, space syntax integration, space syntax choice

The figure above describes on the Y axis the beta coefficients for the four accessibility measures across time and on the X axis the year of the analysis. The result suggests that space syntax angular integration and gravitation potential to employment achieve a similar beta (0.50) after 1999 and rising steadily after. The results suggest one standard deviation increase in space syntax integration or gravitational potential to employment approximate to half a standard deviation increase in house price during the period between1999-2011. Distance to Central Business District achieves a similar coefficient expectedly in the opposite direction. Space syntax choice achieves a negative coefficient consistently between the time period suggesting high space syntax choice results in lower house price. The negative influence of choice can be attributed to negative externality of high through movement such as noise and pollution. Different radiuses of integration and choice have been correlated with house price. Lower correlation was achieved with lower radius of the accessibility measures suggesting global accessibility explains more variation in house price than local accessibility.

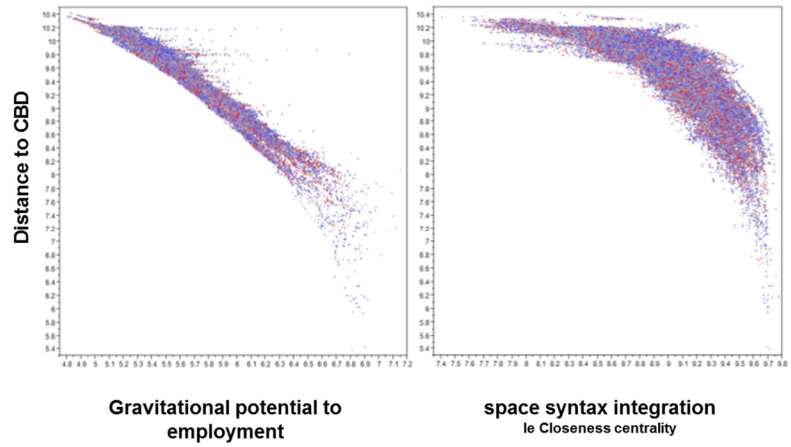

Figure 9 Log Distance to CBD vs Log gravitational potential and Log angular closeness centrality scatterplot reveals strong relationship between the accessibility indicator

The figure above describes a scatterplot between Log distance to CBD on the Y axis, Log gravitational potential and Log Space Syntax integration on the X axis. The scatterplot reveals a strong association between the three accessibility measures.

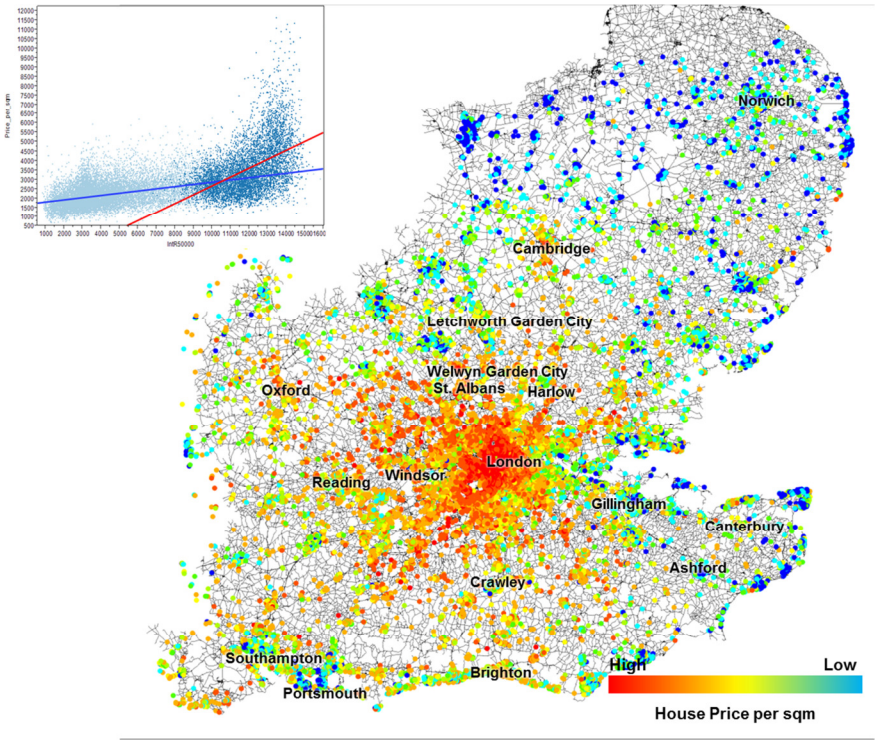

Figure 10 Greater Southeast House price per sqm

Lastly, the figure above illustrates house price per square metre for the Greater Southeast region in England with a scatterplot between space syntax integration at radius 50,000 metre and house price per sqm. This exploratory analysis uses the Greater South East segment model as provided by space syntax limited. (Space Syntax Limited 2013) Thescatterplot reveals intra-metropolitan differences between London indicated by the red fitted line and non-London indicated by light blue fitted line. The result reinforces the relationship between accessibility and property value both at the metropolitan scale and intra-metropolitan scale.

4.1 Hedonic regression model results

In this section, the standard Normal-Linear-Quadratic regression model (NLQ) is applied to house price in London (Ekeland 2002) where Log of house price for each year is regressed against a set of location specified variables and dwelling specific variables plus a random stochastic component. The method of ordinary least square (OLS) is used for the estimation of the NLQ model where standard assumptions on normality and collinearity are applied.

$$Log\ Price = \sum \beta_1\ Location\ variables + \sum \beta_2\ Dwelling\ variables + \varepsilon$$

Equation (7)

Dwelling specific and location specific variables included in the hedonic regression model are listed below. Dwelling specific variables include dwelling type; 0 indicate flat and 1 indicate house, tenure type; 0 indicate leasehold and 1 indicate freehold and dwelling size. Location specific variables include distance to CBD, space syntax segment angular integration, space

syntax segment angular choiceat radius, gravitational potential to employment, retail land use within 800 metre, distance to royal parks $_2$, top secondary school as indicated by average A level scores $_3$ within 800metre. These controlled variables are included as suggested from previous hedonic research. (Cheshire and Sheppherd 1995; Sirmans et al. 2006; Smith 2010; Gibbons and Machin 2003; Gibbons and Machin 2008; Ahlfeldt 2011)

Table 3 Hedonic model variables specification

Dwelling specific variables	***Location specific variables***
Flat / house	*Distance to CBD*
Leasehold / freehold	*Space syntax integration*
Dwelling size	*Space syntax choice*
	Gravitational potential to employment
	Active land use within 800m
	Distance to Royal Parks$_1$
	Average A-Level scores$_2$ within 800 metres

The table below summarises the four candidate cross section regression model between house price for 2011 with the set of dwelling specific and location specific variables. All four models achieve a high overall fit where 70% of the variation in house price can be explained by the regression model.

Table 4 Regression results

	estimates	lower 95%	Upper 95%	t-ratio	Prob>t	Std Beta
Intercept	12.16590317	12.13045825	12.2013481	672.86	<.0001	0.000
Floor size	0.008977584	0.00869886	0.009256307	63.14	<.0001	0.769
Floor size^2	-1.76E-05	-0.00002044	-1.47E-05	-12.04	<.0001	-0.117
Dummy_house_type[0]	0.088621901	0.070482411	0.106761391	9.58	<.0001	0.085
tenure[Freehold]	0.026585921	0.016782601	0.036389242	5.32	<.0001	0.056
Distance to CBD	-2.22E-05	-2.40E-05	-2.05E-05	-25.2	<.0001	-0.298
Distance to CBD^2	5.39E-10	3.38E-10	7.39E-10	5.26	<.0001	0.048
Distance to Royal Park	-2.03E-05	-2.21E-05	-1.84E-05	-21.78	<.0001	-0.232
Distance to Royal Park^2	2.02E-09	1.76E-09	2.29E-09	15.04	<.0001	0.143
Active_800	0.000105329	8.46088E-05	0.000126054	9.96	<.0001	0.088
Avg_Alevel_800	7.19665E-05	5.52435E-05	8.86874E-05	8.44	<.0001	0.060

Rsquare	69.80%
Adj Rsquare	69.74%
Root of mean square	0.2567
Mean of response	12.64
AIC	736.758
BIC	817.336

Candidate model 1

	estimates	lower 95%	Upper 95%	t-ratio	Prob>t	Std Beta
Intercept	11.363832	11.312238	11.415427	431.77	<.0001	0.000
Floor size	0.008937	0.008662	0.0092121	63.7	<.0001	0.766
Floor size^2	-1.78E-05	-2.06E-05	-1.494E-05	-12.34	<.0001	-0.118
Dummy_house_type[0]	-0.0501732	-0.0591529	-0.0411936	-10.95	<.0001	-0.096
tenure[Freehold]	0.0297091	0.0200319	0.0393864	6.02	<.0001	0.063
Gravity model to employment	0.0018347	0.0017079	0.0019616	28.35	<.0001	0.424
Gravity model to employment^2	-3.63E-06	-4.05E-06	-3.22E-06	-17.14	<.0001	-0.219
Distance to Royal Park	-1.68E-05	-1.87E-05	-1.49E-05	-17.45	<.0001	-0.192
Distance to Royal Park^2	2.13E-09	1.90E-09	2.36E-09	18.39	<.0001	0.151
Active_800	0.0001605	0.000132	0.0001891	11.02	<.0001	0.134
Avg_Alevel_800	6.226E-05	4.575E-05	7.878E-05	7.39	<.0001	0.052

Rsquare	70.57%
Adj Rsquare	70.52%
Root of mean square	0.2534
Mean of response	12.64
AIC	578.611
BIC	659.191

Candidate model 2

	estimates	lower 95%	Upper 95%	t-ratio	Prob>|t|	Std Beta
Intercept	11.430848	11.383084	11.478613	469.14	<.0001	0.000
Floor size	0.0090613	0.0087873	0.0093354	64.82	<.0001	0.776
Floor size^2	-1.79E-05	-2.08E-05	-1.512E-05	-12.46	<.0001	-0.119
Dummy_house_type[0]	-0.0417029	-0.0505695	-0.0328364	-9.22	<.0001	-0.060
tenure[Freehold]	0.0260726	0.0164547	0.0356905	5.31	<.0001	0.055
Integration R24000	5.487E-05	5.115E-05	5.86E-05	28.88	<.0001	0.319
Integration R24000^2	-5.45E-10	-1.37E-09	2.83E-10	-1.29	0.1967	-0.011
Distance to Royal Park	-2.07E-05	-2.247E-05	-1.90E-05	-23.53	<.0001	-0.238
Distance to Royal Park^2	2.31E-09	2.08E-09	2.55E-09	19.1	<.0001	0.164
Active_800	9.692E-05	7.577E-05	0.0001181	8.98	<.0001	0.081
Avg_Alevel_800	6.079E-05	4.422E-05	7.736E-05	7.19	<.0001	0.051

Rsquare	70.60%
Adj Rsquare	70.56%
Root of mean square	0.2532
Mean of response	12.64
AIC	570.443
BIC	651.024

Candidate model 3

	estimates	lower 95%	Upper 95%	t-ratio	Prob>|t|	Std Beta
Intercept	11.391568	11.341496	11.44164	445.99	<.0001	0.000
Floor size	0.0090315	0.0087577	0.0093053	64.67	<.0001	0.774
Floor size^2	-1.78E-05	-2.06E-05	-1.49E-05	-12.36	<.0001	-0.118
Dummy_house_type[0]	-4.31E-02	-5.20E-02	-3.42E-02	-9.53	<.0001	-0.082
tenure[Freehold]	0.0281123	0.0184806	0.0377441	5.72	<.0001	0.059
Integration R24000	4.562E-05	4.043E-05	5.08E-05	17.26	<.0001	0.265
Integration R24000^2	-1.25E-09	-2.12E-09	-3.76E-10	-2.81	0.005	-0.025
Distance to Royal Park	-1.907E-05	-2.09E-05	-1.72E-05	-20.27	<.0001	-0.219
Distance to Royal Park^2	2.25E-09	2.01E-09	2.48E-09	18.46	<.0001	0.159
Active_800	6.54E-05	4.09E-05	8.98E-05	5.24	<.0001	0.055
Avg_Alevel_800	5.931E-05	4.277E-05	7.586E-05	7.03	<.0001	0.050
Gravity model to employment	4.21E-04	2.57E-04	5.86E-04	5.03	<.0001	0.097

Rsquare	70.72%
Adj Rsquare	70.68%
Root of mean square	0.2527
Mean of response	12.64
AIC	547.197
BIC	634.488

Candidate model 4

Candidate models	Rsquare	Adj Rsquare	Root of mean square	Mean of response	AIC	BIC
Candidate model 1	69.80%	69.74%	0.2567	12.64	736.758	817.336
Candidate model 2	70.57%	70.52%	0.2534	12.64	578.611	659.191
Candidate model 3	70.60%	70.56%	0.2532	12.64	570.443	651.024
Candidate model 4	70.72%	70.68%	0.2527	12.64	547.197	634.488

Dwelling specific variables such as floor size, dwelling type and tenure are all significant variables that influences house price positively. Floor size is expectedly the most significant variable in explaining house price. Location specific variables such as space syntax segment angular integration, gravitational potential to employment, distance to CBD, active land use within 800 metre and access to top secondary school as measured by average A-level score within 800 metre are all significant and positive variables.

The significance of distance to CBD, space syntax integration and gravitational potential in candidate model 1, model 2 and model 3 suggest accessibility is significant after controlling for both dwelling and other location specific variables corresponding to previous research. Candidate model 3 with space syntax integration achieves a better fit in comparison to candidate model 1 with distance to CBD and candidate model 2 with gravitational potential. The result suggests that space syntax integration is as good a variable as both distance to CBD and gravitational potential in hedonic model. Candidate model 4 with both space syntax integration and gravitational potential achieves the highest overall fit. Controlling for employment accessibility, the significance of space syntax segment angular integration reveals the importance in accounting for non-employment related accessibility. Space syntax segment angular choice and distance to Royal Parks are significant and negative variables. The significance of global space syntax choice suggests the potential negative externalities from pollution and noise that result from locating in an area with high through movement. The significance of both distance to royal parks confirms previous research on the importance of green space in the London submarket (Smith 2010). The significance of the average A-level score also confirms previous research (Gibbons 2009).These results confirm previous hedonic research and space syntax research (Chiaradia 2012; Yang 2012). These initial results need further tests for verification.

5.0 Conclusion and steps forward

To summarise, spatial configuration measure of accessibility such as space syntax integration and space syntax choice are significant variables influencing transaction house price both positively and negatively in London between 1995 - 2011. The results confirm and extend previously established relationship between spatial configuration parameters and property values (Deysellas 2000; Chiaradia et al. 2011; Yang 2012). In addition, space syntax accessibility measures provide an objective method to measure accessibility that requires less information on land use than traditional distance to CBD measure. This is especially useful in longitudinal study where micro economic distribution data is sparse, incomplete or aggregated. The increasing influence of accessibility on house price after 1999 suggests the increase in demand for centrality. These inconsistencies signify influences not accountable for in the model.

The results from the hedonic regression model suggests dwelling specific variables such as floor size, dwelling type, and age of building are all significant variables that influences house price positively where floor size is expectedly the most significant variable confirming previous hedonic research. (Cheshire and Sheppard 1995) Location specific variables such as distance to CBD, space syntax segment angular integration, gravitational potential to employment, active land use within 800 metre and access to top secondary school as measured by average A-level score within 800 metre, space syntax choice, distance to royal parks are all significant variables. The result suggests that space syntax integration is as good a variable as both distance to CBD and gravitational potential in hedonic model without the need to specify employment location. Controlling for employment accessibility, the significance of space syntax segment angular integration also reveals the importance in accounting for non-employment related accessibility. The negative significance of global space syntax choice suggests the potential negative externalities from pollution and noise in an area with high through movement. These results require further verification. Future researches are needed to focus on comparing hedonic model across different cities and resolution, both at the regional scale and at the neighbourhood scale. More importantly there is a need to focus on the identification of the causal influence of accessibility through experiments and econometric techniques.

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Notes

1 Zoopla is a property company that provides property information such as sold house price holding over 27 million residential properties in UK

2 The origins of all data on sold house prices in United Kingdom is owned by Land Registry/Registers of Scotland © Crown copyright 2013.

3 The nationwide dataset is a subset of the Land Registry dataset which includes more detail attributes.

4 The procedure of creating the pedestrian spatial network layer includes manual editing, node reduction, network simplification and lane reduction using various tools within GIS packages.

5 Eight royal parks within London are possessions of the Crown. They include Green Park, Greenwich Park, Hyde Park, Kensington Gardens, Regent's Park, Richmond Park, St. James's Park

6 A-Level scores (General Certificate of Education Advanced Level) is an academic qualification offered by educational institutions in England, Wales and Northern Ireland to students completing secondary or pre-university education.

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