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THE ECONOMIC VALUE OF SPATIAL NETWORK ACCESSIBILITY FOR UK CITIES:

A comparative analysis using the hedonic price approach

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ABSTRACT

Spatial network accessibility was found to be significant when associating with house prices using the hedonic price approach. These results suggest some individuals are willing to pay more for spatial isolation while some individuals will pay more for spatial co-presence. An obvious limitation of earlier research is a lack of comparative analysis between cities. Focusing on a single case study reduces the generalisability of the results and the extent to which different spatial contexts might value accessibility differently. The aim of this research was therefore to study the extent to which spatial network accessibility effects differ across cities in the UK. A hedonic price approach was used to explore the extent to which these differences are related to social-economic-mobility factors. Results show, both visually and quantitatively, the economic value of accessibility, measured using space syntax analysis, differs across geographical regions. The accessibility effect on house price ranges from strongly significant in London to insignificant in Birmingham. In general, the economic effect is weaker in smaller, more car dependent cities, with a greater proportion of the population employed in the manufacturing sector, and is stronger in cities that are denser, more walkable with greater productivity and a greater proportion of residents in the education sector. This exploration therefore suggests that the economic value placed upon urban accessibility may be related to a combination of mobility factors, its urban form and its economic profile. Finally, it appears that city productivity as measured by GVA is correlated with increased value placed upon accessibility.

KEYWORDS

Spatial networks, accessibility, hedonic price model, UK, space syntax

1. INTRODUCTION

The economic value of accessibility is an important topic in urban research. As Webster (2011) noted, if accessibility had an economic value, it could then be allocated more efficiently, costs of infrastructure could be recovered and urban designers would be able to weigh objectively between alternative designs. Webster (2011) suggests one approach in retrieving the economic value of accessibility is through the hedonic price approach. (Rosen, 1974). Applying the hedonic price approach, both spatial network accessibility (Law et al., 2013; Xiao, 2015) and land use accessibility (Shen and Karimi, 2016) were found to be significant factors associated with house prices. More simply, some individuals are willing to pay more for accessibility and some less. An obvious limitation from previous research is the focus on single case study cities. Focusing on a single case study reduces the generalisability of the results and the extent to which different spatial contexts might value accessibility differently. Do individuals in different cities value accessibility differently and importantly why might they differ? Could these differences relate to social-economic factors, mobility factors or possibly urban form factors? The aim of this research was therefore firstly to study the extent to which spatial network accessibility effects differ across cities in the UK, and secondly to explore the extent to which these differences relate to a cities' socio-economic-mobility factors. The results improve our understanding of the effects of spatial network accessibility on house price. The study employs the hedonic price approach in estimating the effects of spatial network accessibility on house price using the sold house price dataset for twenty-three cities in England.

The remainder of the paper is organised as follows: Section One introduces previous research into effects of accessibility on house prices; Section Two introduces the specification for calculating spatial network accessibility using a space syntax approach; Section Three provides details for the empirical method; Section Four introduces the case study and the dataset; Section Five reports the empirical results, Section Six discusses some of the results, drawing conclusions and reviewing the limitations of the research.

1.1 PREVIOUS LITERATURE

Following Rosen's economic framework (1974) and Ridker and Henning's empirical study (1967), the hedonic price method has become one of the most popular approachs to the valuation of intangible goods such as school quality or pollution (Black 1999; Ridker and Henning, 1967), and as inputs in land use and transportation models (Waddell, 2002; Lochl and Axhausen, 2010). The theory undermining the use of accessibility came from the concept of spatial equilibrium and its exposition through a monocentric model. Spatial equilibrium or spatial tradeoff theory originated from Von Thunen's study on the location of market places. He found agricultural activities that were most sensitive to transport costs and consuming the least land were located near the market (Von Thunen, 1826). Following this seminal work, Alonso (1964) Muth (1969) and Mills (1972) developed a related urban monocentric model to explain the centralisation of business and commercial activities where density, land rent and house price diminishes away from the centre. The model operated through a bidding process whereby the people who capitalise the most from the assets acquire the right to the land in a property market. The essence of the monocentric model is its simplicity in explaining land rent through transport cost to determine the location of residents relative to its workplaces.

Based on the monocentric model, location differential is traditionally estimated in the form of "Euclidean Distance to the Central Business District (CBD)" in hedonic price modelling (Kain and Quigley, 1970). One limitation is that this require the endogenous definition of a CBD location and that inner city decline coupled with rising suburban employment led to the diminishing influence of central places. For example, Heikkila et al (1989) found that house prices rise rather than fall with distance from the CBD in the Los Angeles Metropolitan Area. This led to the use of multiple employment accessibility models. The motivation of these approaches is that it moves away from the idea of all economic activity concentrated in a single dimensionless point to a more heterogenous distribution of employment.

A second limitation is that these geographic measures of accessibility focused less on general accessibility effects as explained by Webster (2010). This has led to interest in research from the field of space syntax which has methods to allow the quantification and valuation of general accessibility. Empirical research found significant positive associations between spatial network accessibility and council tax band in London (Chiaradia, Hillier, Barnes, Schwander, 2012a; 2012b), house price in Cardiff (Xiao et al. 2015; Narvae\ et al. 2014; Narvaez 2015), house price in Shanghai (Yao and Karimi 2015) and house price in London (Law et al. 2013). Despite the identification of associations between spatial network accessibility and house price, studies to date have focused on a single case rather than drawing on multiple cases across different cities.

Recent research suggests that the influence of accessibility can differ both geographically and across time. For example, McMillen (2003) found strong evidence in Chicago CBD where the effect of employment accessibility on house price was significant before 1980, insignificant in 1980 but significant again in 1990. This might be explained by the inversion in the social geography of residential location which appears to be taking place in a number of cities around the world (Ehrenfelt 2012). Under similar vein, Hennerberry (1997) found in the UK the effects of the new tramway in Sheffield had a stronger effect before construction than under operation. This shows the effect of a transport infrastructure project may be complex and can be capitalised during different stages of the development. The key objective of the study presented here is to test the extent to which spatial network accessibility effects exist across different cities in the UK for 2001 and 2011 house price datasets. The next section will begin by setting out the specification for the space syntax definition of spatial network accessibility and the empirical method.

2. METHOD

2.1 SPATIAL NETWORK ACCESSIBILITY

In Walter Hansen's seminal paper "How accessibility shapes land use" (Hansen, 1949), accessibility was defined as a measure of potential interactions, or relative proximity or nearness in an environment for individuals or places to all others. This study will employ the space syntax measure of integration (Hillier and Hanson, 1984; Hillier et al., 2012) also known as closeness centrality in the network science literature. For a weighted dual graph G=(V,E) where v∈V are the streets and e∈E are the junctions, Integration or Closeness C at metric radius r measures the reciprocal of the average (angular) distance between every origin i to every destination j on least angular deviation paths. More simply, the index measures the to-movement potential of a space in the system (Freeman, 1977). Empirically, closeness centrality had been found to associate positively to residential property values and commercial rent. More formally:

$$C_i(r) = \frac{N_i(r)-1}{\sum d_{ij}\,(r)} \qquad (1)$$

Where Ci denotes the closeness centrality and Ni denotes the node count and dij denotes the angular distance between every space at radius r.

2.2 EMPIRICAL METHOD

In order to test to what extent a spatial network accessibility effect exists across different cities, this research adopts a three stage empirical process. We begin first by employing a pooled hedonic price model to establish the relationship between house price and accessibility. In the second stage we employ the same hedonic price model for individual case study cities in 2011 and 2001. This will study the extent to which any accessibility effect holds across different cities in the UK. We apply clustering analysis to identify natural clusters of cities in the UK. The third stage then examines how the economic value of spatial network accessibility could possibly be related to different social, economic and mobility factors.

2.3 HEDONIC PRICE MODEL

Rosen (1974) described the hedonic price approach, where a differentiated product such as housing is made up of "utility-bearing" characteristics including structural characteristics, neighbourhood amenity and location accessibility (Cheshire and Sheppard, 1995; Sheppard, 1999). We will adopt this method in two ways; a pooled hedonic price model and an individual-city hedonic price model.

2.4 POOLED-CITY HEDONIC PRICE MODEL

The pooled-city hedonic price model studies the effect of accessibility using a pooled-city least square dummy variable regression specification (LSDV). The standard cross section LSDV model is described in the following equation. This is estimated first for 2001 and then for 2011 datasets.

$$LogP_{ij} = \theta X_{ij} + \beta A_{ij} + \alpha D_j + e_{ij} \qquad (2)$$

Where **P** denotes the price of a property at the postcode level i, **X** represents a vector of independent controlled variables, A denotes the closeness centrality variable in the model, **D** is a city-specific dummy variable for each city **j** and **e** is the error term. The first order condition of this function is the implicit price or the economic value for the accessibility variable. This allows the property price to be decomposed into its constituents, which can be valued separately.

2.5 INDIVIDUAL-CITY HEDONIC PRICE MODEL

Instead of analysing the pooled effect of accessibility, the individual-city subset hedonic price regression model will study the effect of accessibility for each city separately. For each city, one regression would be estimated for 2001 and one would be estimated for 2011. Equation (03) shows the standard OLS regression model which is similar to the pooled regression model without the city-specific dummy variable. The beta estimates in this case the implicit price of accessibility for individual cities. There are obvious limitations concerning omitted variable bias such as the exclusion of neighbourhood amenity variables which will be discussed at the end of the paper.

$$LogP_i = \mu X_i + \beta A_i + e_i \qquad (3)$$

Where **P** denotes the price of a property at the postcode level, **X** represents a vector of independent controlled variables, A denotes the closeness centrality variable in the model, and **e** is the error term

2.6 CLUSTERING ANALYSIS

To further understand the differences between individual cities' economic value of accessibility we will explore the data to see if natural clusters exists in the data. This study will adopt one of the standard techniques, the K-means clustering technique (MacQueen 1967) which aims to partition n observations into the k clusters that minimise the differences between the implicit price of accessibility for individual cities.

2.7 SOCIO-ECONOMIC-MOBILITY EXPLORATORY ANALYSIS

After calculating the hedonic price model between cities, we will compare the beta estimates in equation (3) for each city, in order to determine the extent to which different cities value accessibility differently. We conjecture in this research that there are significant differences between cities. To further explore the plausible reason for these differences, we will statistically correlate the beta estimates with different social, economic and mobility factors for each city. The bi-variate correlation takes the following form where the beta for each city j will correlate with its respective social, economic and mobility factors.

$$Log\beta_j = \alpha LogX_j + e_j \quad (4)$$

Where **B** denotes the beta estimates for equation (3), **X** denotes the vector of social, economic and mobility factors to be tested in the study and e is the error term.

This comparison will explore plausible reasons why certain cities value accessibility more than others in the UK. The key variables include demographic factors such as size, population density and employment density, economic factors such as gross value added (GVA), Gini coefficient (a measure of inequality) and industry proportions and mobility factors such as the transport modal split.

3. CASE STUDY AND DATASETS

3.1 CASE STUDY

This study is framed within the area of England in United Kingdom focusing on its twenty largest cities. In addition, we included Milton Keynes, Oxford and Cambridge as special cases. This study uses the primary urban area from the ODPM (2006) as study area boundary for analysing

1	London	7	Leeds	13	Newcastle	19	Cambridge
2	Middlesbrough	8	Brighton	14	Oxford	20	Leicester
3	Bournemouth	9	Bradford	15	Southampton	21	Sheffield
4	Portsmouth	10	Birmingham	16	Reading	22	Bristol
5	Preston	11	Nottingham	17	Milton Keynes	23	Huddersfield
6	Liverpool	12	Manchester	18	Stoke		

Figure 1 - Case study cities.

the largest English cities. [1]Figure 1 shows the study area and the case study cities.

3.2 DATASET

In order to investigate the relation between spatial configuration and house price, three datasets have been used. This includes the house price dataset, the street network dataset and the census dataset.

3.3 HOUSE PRICE DATASET

The first data set is the sold house price dataset in the UK. It contains for each sold property its attributes such as size, dwelling type, age and tenure. The source of the data is Land Registry and Nationwide Building Society [2]. There are a total of 17,552 transactions in 2011 and 24,988 transactions in 2001 for the twenty-three cities. Table 3 shows the list of the variables included in the hedonic price model. This research has used a parsimonious set of variables which is a limitation to the study. The exclusion of neighbourhood amenity variables is an obvious limitation.

Name	Type	Data
Space Syntax Integration	Location Variables	Continuous
Dwelling type	Structural Variables	categorical
Dwelling size	Structural Variables	Continous
Age of building	Structural Variables	Ordinal
Tenure	Structural Variables	categorical
Number of bedrooms	Structural Variables	number
Case Study Cities	City-specific Variable	categorical

Table 1 - Hedonic model variables specification

Figure 2 describes house price in the UK for both 2001 and 2011 where the black line denotes the case study cities.

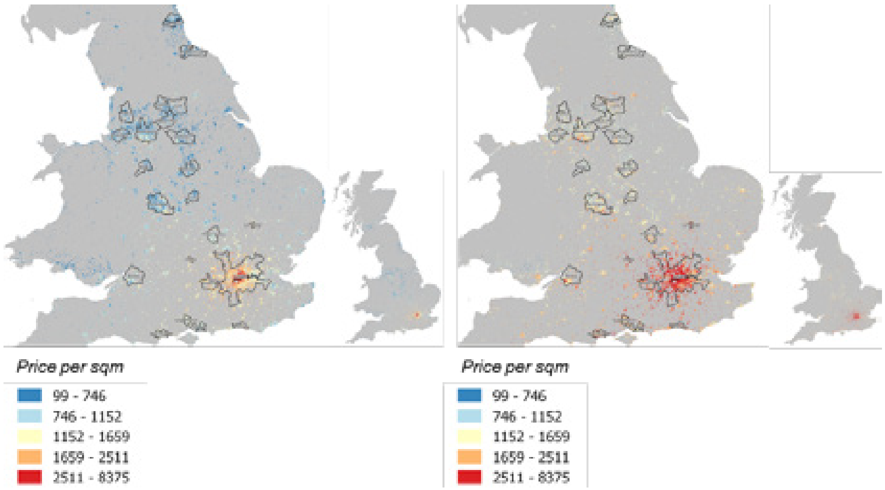

Figure 2 - UK House price GIS maps.
a. 2001 sold price | b. 2011 sold price

1 Primary Urban Areas are defined as continuous built-up areas which have a minimum size cut-off of 125,000 inhabitants in the UK. (ODPM 2006)
2 The nationwide dataset is a subset of the Open Source Land Registry dataset through a licensing agreement with London School of Economics. The origins of all data on sold house prices in United Kingdom is owned by Land Registry/Registers of Scotland © Crown copyright 2013.

3.4 STREET NETWORK DATASET

The second dataset is the spatial model of UK derived from the Ordnance Survey Meridian 2 data set in 2011 (see figure 3a). There are a total of 2,033,012 street segments in the mainland UK. Figure 3b. shows the integration values at radius 50km of the meridian line network and Figure 3c. shows a multi-scale representation of the UK integration maps. Northern Ireland has been excluded as it does not have a physical connection to mainland UK.

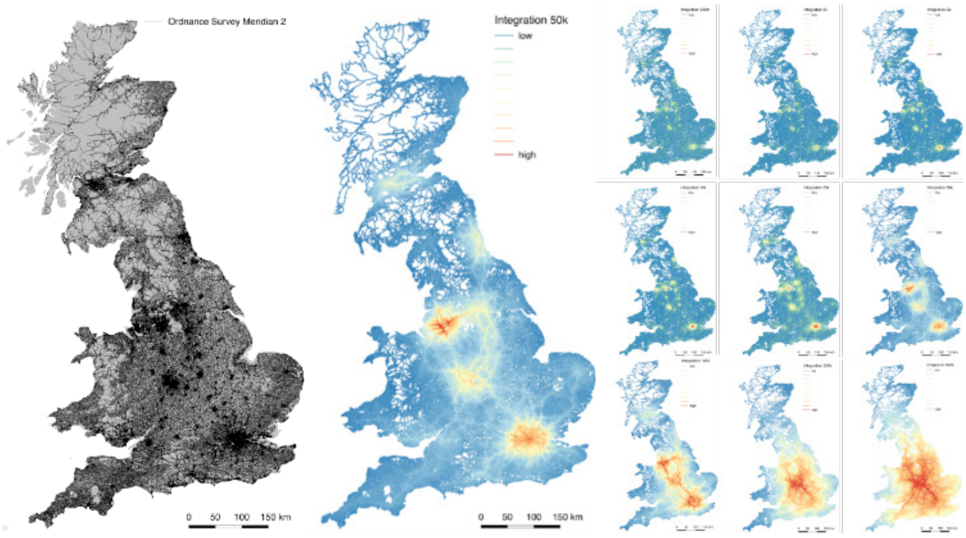

Figure 3- a. UK meridian line street network. | b. UK Integration at radius 20km. | c. UK Integration maps for different radii. Diagram produced in Law and Versluis (2015).

3.5 CITIES DATASET

The third dataset is the cities dataset that came primarily from two sources, namely the census dataset produced by the Office of National Statistics (ONS) and the Centre for Cities dataset (Centre for Cities, 2016). Table 02 describes statistically these various datasets at the city level. This includes size, population, employment, travel to work mode and employment statistics. This dataset will mainly be used for the city comparison analysis.

		2001			
Statistic	**Description**	**Mean**	**St. Dev.**	**Min**	**Max**
area	city area	48,303	59,483	4,069	302,988
pop	population	925,696	1,698,462	108,863	8,389,587
emp	employment	413,817	789,998	49,251	3,921,586
Pop_den	population density	17.9	7.5	6.7	29.4
Emp_den	employment density	8	3.4	3.4	13.2
age_0_19	population age 0-19	25.3	1.9	21.6	29
age_30_44	population age 30-44	22.3	1.2	20.2	25.4
age_45_64	population age 45-64	22.3	1.6	17.8	24.6
age_65_	population age 65+	15.1	2.3	10.3	22.5

2001					
Statistic	**Description**	**Mean**	**St. Dev.**	**Min**	**Max**
Gini_13	Gini coefficient 2013[3]	0.4	0.02	0.4	0.5
GVA_pw11	GVA per worker 2011[4]	48,006	8,004	40,923	69,227
Ind_per	manufacturing jobs percentage	8.2	3.6	2.6	17.2
Fin_per	finance jobs percentage	0.03	0.01	0.01	0.1
Edu_per	education jobs percentage	0.1	0.02	0.04	0.1
walk_per	walk percentage	10.7	2	6.9	15.5
PT_per	public transport percentage	14.8	7	6.4	38.5
car_per	private car percentage	62	9	41.8	72.7
non_car_per	non-private car percentage	30.1	8.9	18.7	49.5
area	city area	48,209	59,325	4,068	302,052
pop	population	1,015,765	1,918,236	123,867	9,480,417
emp	employment	476,259	938,059	59,437	4,656,358
Pop_den	population density	19.5	8.4	7.7	33.3
Emp_den	employment density	9.1	4	3.8	15.4
age_0_19	population age 0-19	24.4	1.8	20.9	28.8
age_20_29	population age 20-29	16.3	3.4	12.8	26.1
age_30_44	population age 30-44	20.8	1.6	18.7	24.9
age_45_64	population age 45-64	23.7	2.1	18.2	26.6
age_65_	population age 65+	14.7	2.3	11	21.7
Gini_13	Gini coefficient 2013	0.4	0.02	0.4	0.5
GVA_pw11	GVA per worker 2011	48,006	8,004	40,923	69,227
Ind_per	manufacturing jobs percentage	8.2	3.6	2.6	17.2
Fin_per	finance jobs percentage	0.04	0.02	0.02	0.1
Edu_per	education jobs percentage	0.1	0.02	0.1	0.1
walk_per	walk percentage	11.1	2.6	7.1	17.5
PT_per	public transport percentage	14.9	8.1	7.4	44.6
car_per	private car percentage	60.1	11.8	33.5	74.3
non_car_per	non-private car percentage	31.2	11.1	18.5	56.8

Table 2 - Descriptive statistics for ONS population, travel-to-work and employment dataset

3 We do not have the GINI coefficient data at the city level for 2001 and 2011. We have thus used the 2013 data for both regression model.

4 We do not have the Gross value added data (GVA) at the city level for 2001. We have thus used the 2011 data for both regression model.

The figures below describe visually the population and employment density mapped in GIS from light red to red and workplace density mapped in GIS from light blue to blue for each local authority in the UK. Population and employment density scales linearly to spatial network accessibility which suggest spatial network centrality can act as a proxy for employment accessibility in the UK context.

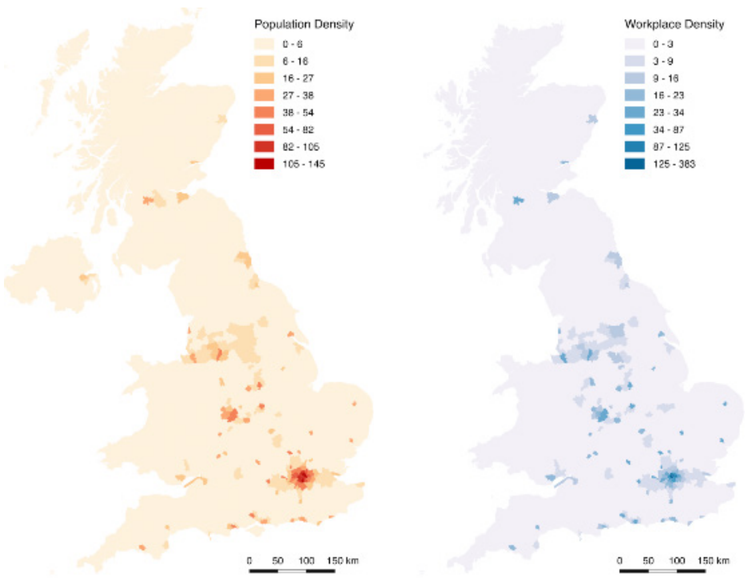

Figure 4 - a. Population density in the UK. | b. Workplace density in the UK.

4. RESULTS

This section summarises the empirical results for the three sections namely the pooled-city hedonic price model, the individual-city hedonic price model and the cities comparison analysis.

4.1 POOLED-CITY HEDONIC PRICE MODEL RESULTS

We start by examining the overall relations between accessibility and house price for the twenty-three case study cities in a pooled-regression model. The hedonic price model is estimated as a pooled-city least square dummy variable regression model (LSDV). Figure 1 illustrates on the left spatial network integration at 20km radius (R20k) and on the right house price per sqm. Visually, there are obvious similarities between city-scale space syntax integration and house price per sqm. This is logical as spaces with greater centrality have greater numbers of jobs leading to higher wages and hence higher house prices. We note only the transactions within the twenty-three primary urban area boundaries were considered in the model. The reason is that accessibility is likely to exhibit a different effect for small cities and rural areas.

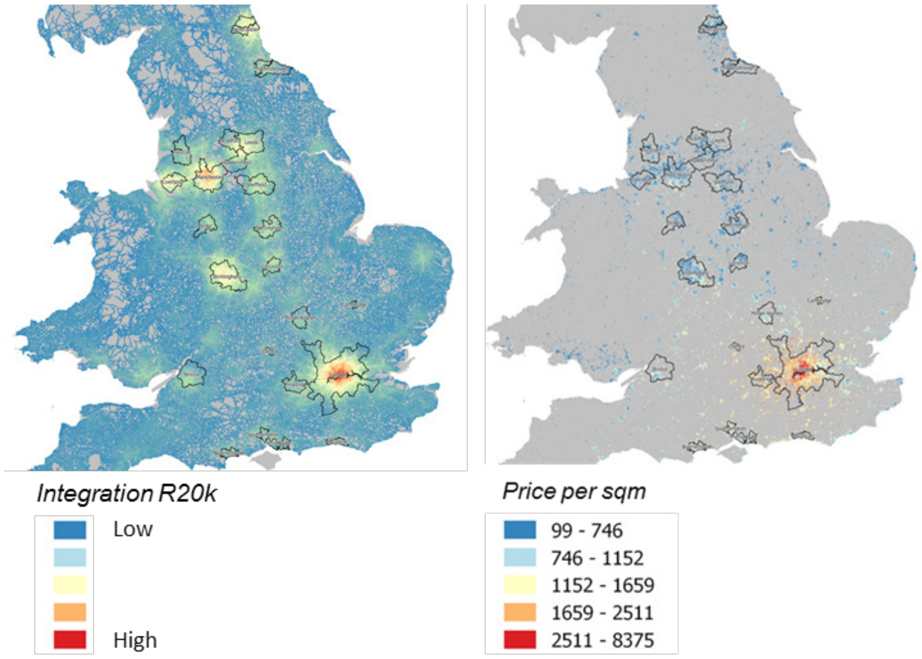

Figure 5 - Integration and House Price.

The pooled hedonic price model achieved a significant R2 of 74% for both 2001 and 2011. See Table 03 and Table 04. Space Syntax integration R20k was a significant variable in both time periods and the implicit prices for spatial network accessibility rose from 0.15 in 2001 to 0.21 in 2011. This finding is like previous research (Law et al. 2013), where the value of centrality has been found to be dynamic over time and where there appears to be a resurgence of central places in recent years.

2011 model	estimates	std error	t ratio	prob>t
Intercept	9.596	0.046	209.48	<.0001
Type[Conv Flat]	0.057	0.019	2.95	0.0031
Type[Conv Maisonette]	-0.349	0.11	-3.17	0.0015
Type[Detached]	0.193	0.019	10.38	<.0001
Type[Detached-bungalow]	0.264	0.022	12.19	<.0001
Type[PB Flat]	-0.066	0.019	-3.55	0.0004
Type[PB Maisonette]	-0.194	0.072	-2.68	0.0074
Type[Semi-bungalow]	0.124	0.023	5.43	<.0001
Type[Semi-detached]	0.029	0.018	1.61	0.1083
tenure[Freehold]	-0.016	0.006	-2.54	0.0112
Bedrooms	0.054	0.004	12.66	<.0001
Floor size	0.007	0	69.9	<.0001
Age	0.001	0	9.15	<.0001
Integration R20,000m	0.214	0.006	36.37	<.0001
Case Study[Birmingham]	-0.252	0.008	-30.07	<.0001
Case Study[Bournemouth]	0.246	0.013	19.19	<.0001
Case Study[Bradford]	-0.255	0.02	-13.01	<.0001
Case Study[Brighton]	0.451	0.013	33.64	<.0001
Case Study[Bristol]	0.137	0.01	13.33	<.0001
Case Study[Cambridge]	0.689	0.026	26.15	<.0001
Case Study[Huddersfield]	-0.277	0.019	-14.29	<.0001
Case Study[Leeds]	-0.174	0.013	-13.19	<.0001
Case Study[Leicester]	-0.19	0.015	-12.5	<.0001
Case Study[Liverpool]	-0.403	0.016	-24.63	<.0001
Case Study[London]	0.483	0.006	82.19	<.0001
Case Study[Manchester]	-0.259	0.01	-25.6	<.0001
Case Study[Middlesbrough]	-0.244	0.018	-13.27	<.0001
Case Study[Milton Keynes]	0.136	0.016	8.42	<.0001
Case Study[Newcastle]	-0.332	0.012	-26.64	<.0001
Case Study[Nottingham]	-0.297	0.013	-22.14	<.0001
Case Study[Oxford]	0.689	0.026	26.58	<.0001
Case Study[Portsmouth]	0.167	0.012	13.95	<.0001
Case Study[Preston]	-0.229	0.018	-12.76	<.0001
Case Study[Reading]	0.396	0.011	34.76	<.0001
Case Study[Sheffield]	-0.25	0.014	-17.79	<.0001
Case Study[Southampton]	0.175	0.014	12.59	<.0001
R2	0.74		F-ratio	1424.35
R2 Adj	0.739		Prob>F	<.0001
RMSE	0.276			
Observations	17552			

Table 3 - Pooled hedonic price model results 2011.

2001 model	estimates	std error	t ratio	prob>t
Intercept	9.602	0.053	181.87	<.0001
Type[Conv Flat]	-0.029	0.034	-0.85	0.397
Type[Conv Maisonette]	0.49	0.262	1.87	0.061
Type[Detached]	0.082	0.034	2.42	0.016
Type[Detached-bungalow]	0.216	0.036	6.04	<.0001
Type[PB Flat]	-0.197	0.034	-5.82	<.0001
Type[PB Maisonette]	-0.225	0.051	-4.45	<.0001
Type[Semi-bungalow]	0.04	0.036	1.12	0.262
Type[Semi-detached]	-0.114	0.033	-3.39	0.001
tenure[Freehold]	0.025	0.004	6.24	<.0001
bedrooms	0.056	0.004	14.63	<.0001
Floor size	0.007	0	73.53	<.0001
Age	-0.001	0	-8.83	<.0001
Integration R20,000m	0.147	0.006	25.37	<.0001
Case Study[Birmingham]	-0.212	0.007	-29.95	<.0001
Case Study[Bournemouth]	0.246	0.012	21.22	<.0001
Case Study[Bradford]	-0.416	0.015	-27.89	<.0001
Case Study[Brighton]	0.494	0.013	38.15	<.0001
Case Study[Bristol]	0.181	0.009	19.24	<.0001
Case Study[Cambridge]	0.681	0.024	28.27	<.0001
Case Study[Huddersfield]	-0.403	0.016	-24.78	<.0001
Case Study[Leeds]	-0.183	0.014	-12.96	<.0001
Case Study[Leicester]	-0.204	0.012	-17	<.0001
Case Study[Liverpool]	-0.444	0.012	-35.61	<.0001
Case Study[London]	0.586	0.006	105.16	<.0001
Case Study[Manchester]	-0.23	0.008	-27.51	<.0001
Case Study[Middlesbrough]	-0.423	0.014	-29.76	<.0001
Case Study[Milton Keynes]	0.187	0.013	14.59	<.0001
Case Study[Newcastle]	-0.367	0.011	-34.16	<.0001
Case Study[Nottingham]	-0.286	0.011	-26.22	<.0001
Case Study[Oxford]	0.752	0.027	27.91	<.0001
Case Study[Portsmouth]	0.256	0.011	24.26	<.0001
Case Study[Preston]	-0.245	0.013	-19.04	<.0001
Case Study[Reading]	0.588	0.01	59.75	<.0001
Case Study[Sheffield]	-0.356	0.012	-30.26	<.0001
Case Study[Southampton]	0.258	0.012	21.65	<.0001
R2	0.74		F-ratio	2028.226
R2 Adj	0.74		Prob>F	<.0001
RMSE	0.294			
Observations	24988			

Table 4 - Pooled hedonic price model results 2001.

4.2 INDIVIDUAL-CITY HEDONIC PRICE MODEL RESULTS

The second step is to look at the individual-city hedonic price model. Similarly, we zoom in and visualise the results. Figure 06 shows house price per sqm in 2011, on the right, and space syntax integration, on the left, in London, Bristol, Manchester and Birmingham. For both London and Bristol, the results show association between house price and centrality. For both Manchester and Birmingham, the result shows dissociation between house price and centrality.

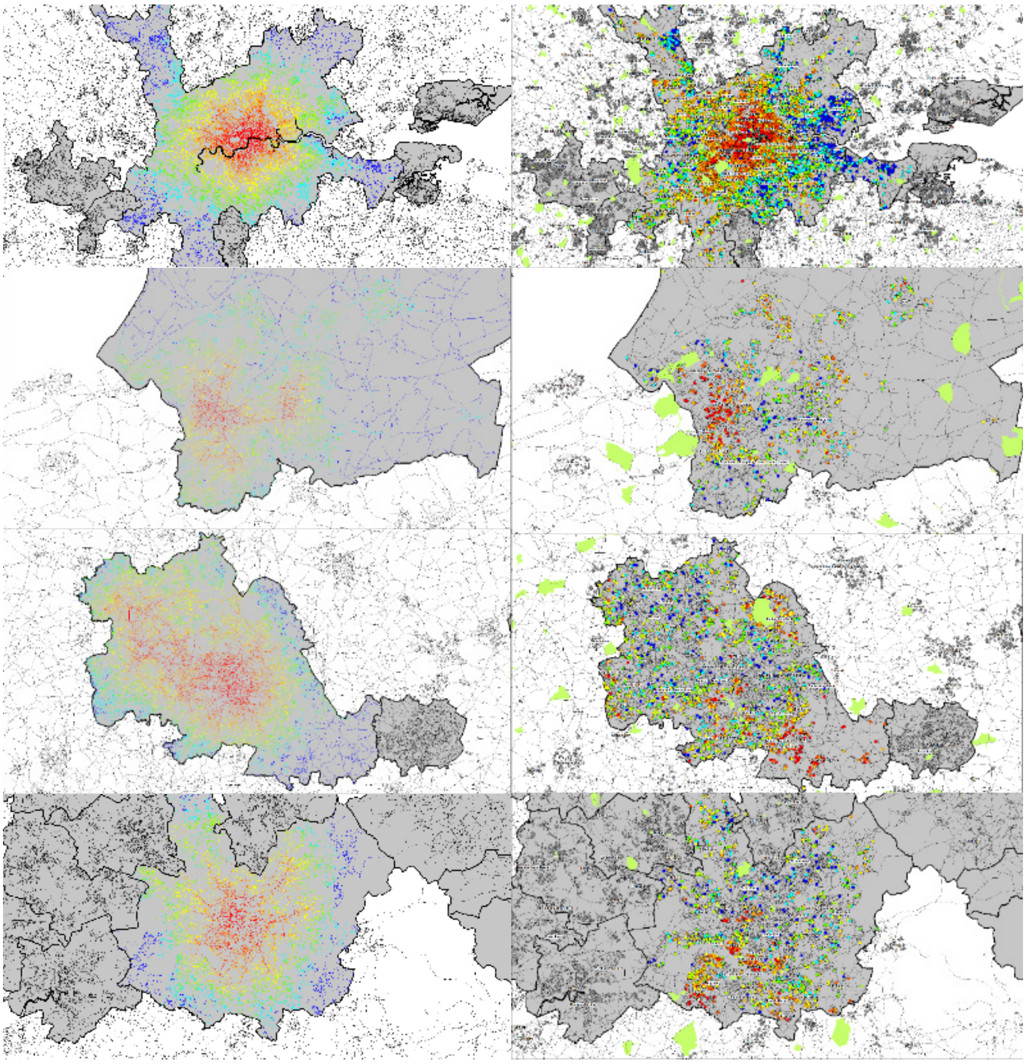

Figure 6 - a. London | b. Bristol | c. Birmingham | d. Manchester

The regression results show the implicit price for street network accessibility differs significantly across cities. See Table 05. The accessibility effect on house price ranges from 0.6 in London to nearly 0 for Manchester as reflected in the visualisation. Cities such as Bristol, Brighton and Oxford have comparatively higher implicit prices while cities such as Birmingham Leeds, Leicester, Southampton, Preston and Milton Keynes have negative implicit prices for both years. There are cities that have low or negative implicit prices in 2001 but became positive in 2011 such as Liverpool signifying a recentralisation.

Beta	2001	2011
London	0.5	0.6
Birmingham	-0.013	-0.094
Manchester	-0.09	0.005
Newcastle	0.084	0.043
Sheffield	0.029	0.04
Liverpool	-0.006	0.022
Leeds	-0.065	-0.065
Bristol	0.129	0.149
Nottingham	0.261	0.166
Bradford	-0.26	-0.044
Leicester	-0.146	-0.034
Middlesbrough	-0.013	-0.111
Portsmouth	0.122	0.016
Reading	0.113	0.038
Huddersfield	-0.14	0.024
Bournemouth	0.13	-0.056
Stoke	0.26	-0.097
Southampton	-0.064	-0.034
Preston	-0.069	-0.023
Brighton	0.38	0.38
Milton Keynes	-0.12	-0.003
Oxford	0.95	0.77
Cambridge	0.52	0.38

Table 5 - Implicit prices of accessibility for individual cities in the UK.

4.3 CLUSTERING ANALYSIS

To further analyse the implicit price difference between individual cities in the UK, we apply clustering analysis on the economic value of accessibility to see if natural clusters are formed. We employ the k-means clustering algorithm here. Figure 7a is the screeplot which shows the within group sum of squares plotted in the y-axis and the number of clusters in the x-axis. The result shows clearly the most optimal number of natural cluster is 3 .

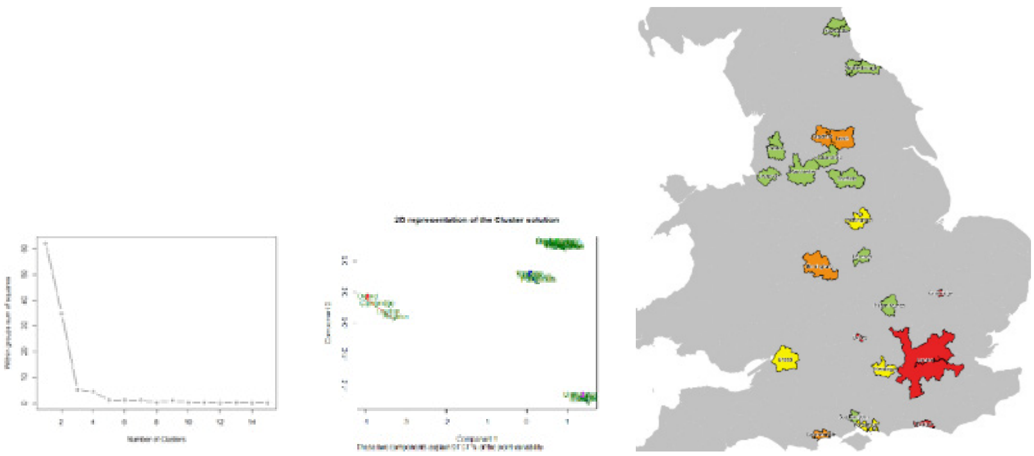

Figure 7 - a. Scree plot. | b. Cluster plot. | c. Economic value of accessibility classification (k=4).

Figure 7b is the cluster plot which shows the scatterplot between the first two principle components of the data. The result shows that there are three natural clusters in the data. It also shows the cluster in the upper-right quadrant can be separated into two sub-clusters. This research will therefore visualise the K=4 solution.

Figure 7c shows the geographical distribution of the four clusters. The red cluster which contains London, Brighton, Cambridge and have generally the highest economic value for accessibility. The yellow cluster which contains Bristol, Reading and Nottingham have lower economic value for accessibility. The green cluster which contains Manchester, Sheffield and Newcastle have near zero value for accessibility. The orange cluster which contains Birmingham, Leeds and Bournemouth have negative economic value for accessibility. These differences can possibly be attributed to a number of socio-economic-physical factors. For example, the cities with the highest economic value of accessibility such as Cambridge and Oxford have generally a higher proportion employed in the education sector, a walkable historic core and an economy strongly tied to London. At the other end of the spectrum, the cities with low and negative economic value of accessibility such as Leeds, Birmingham and Manchester are all located in the north that were heavily dependent on the industrial sector in the past. These results show clear differences between the north and the south and a clear pattern of geographical clustering. The next section will explore these differences against various socio-economic factors.

4.4 SOCIO-ECONOMIC-MOBILITY FACTOR ANALYSIS RESULT

In order to explore the difference between cities, this research examines how a city's economic value of accessibility co-varies with different social, economic and mobility characteristics. Figure 08 illustrates the scatterplot between the beta estimates on the Y-axis and each population variable on the X-axis. The result shows there is generally a poor relationship between a city's economic value of accessibility and its size, its population and its employment. However there appears to be a significant positive relationship between a city's economic value of accessibility to its population and employment density and demographics. The result shows a denser city appears to give a greater economic value to accessibility than a sparser city. The result also shows a city with greater proportion aged between 20-29 appears to give a greater economic value to accessibility than a city with greater proportion aged below 20 or above 45.

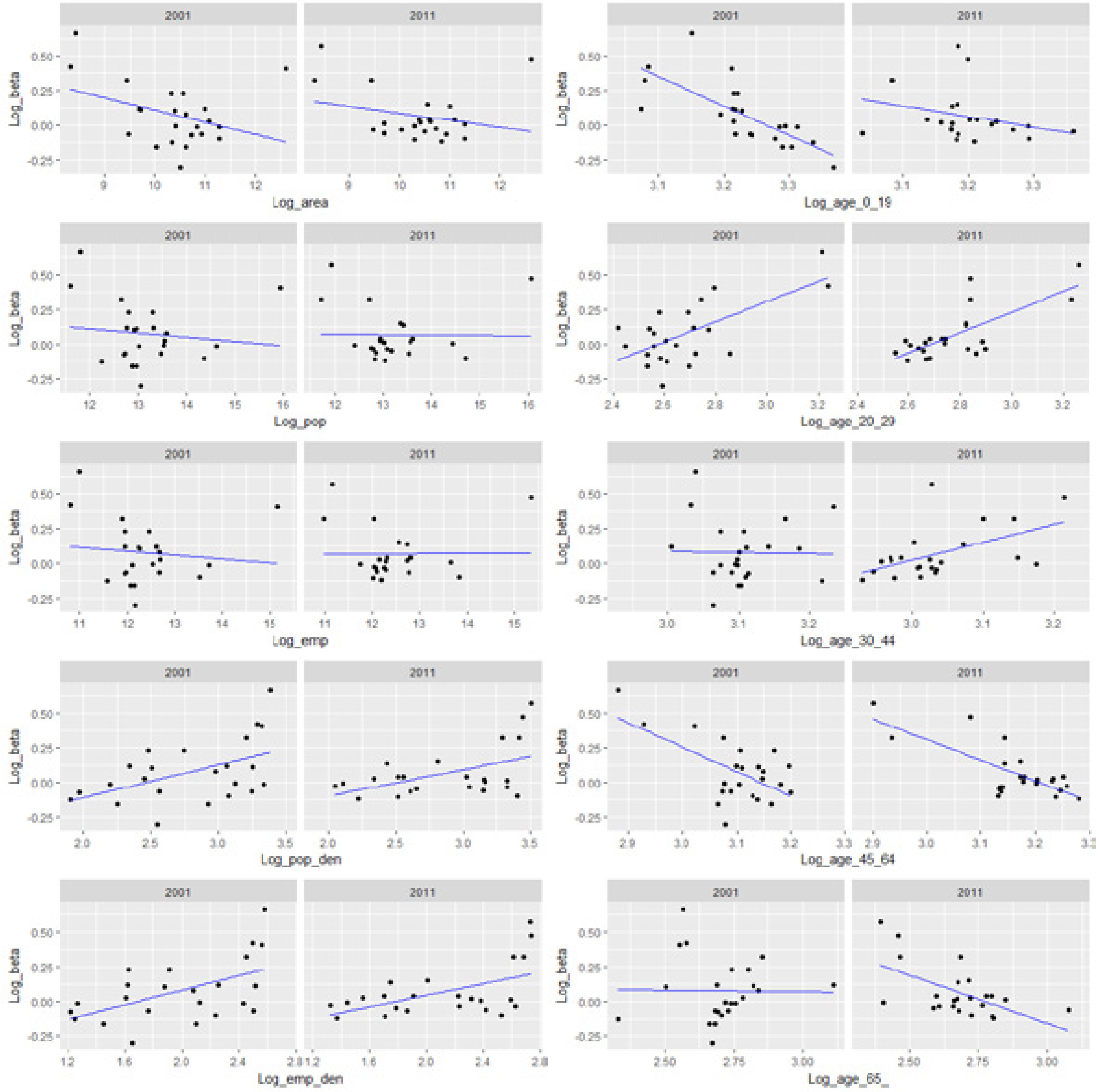

Figure 8 - Scatterplot between Beta estimates on the Y-axis and Population variables on the X-axis.

Looking to mobility factors, figure 9 illustrates the scatterplot between the beta estimates on the Y-axis for each mobility variable on the X-axis. The result shows that there is a stronger relationship between a city's economic value of accessibility and different mobility factors. In this case a more car dependent city has lower economic value of accessibility and vice versa, a more walkable city has higher economic value of accessibility.

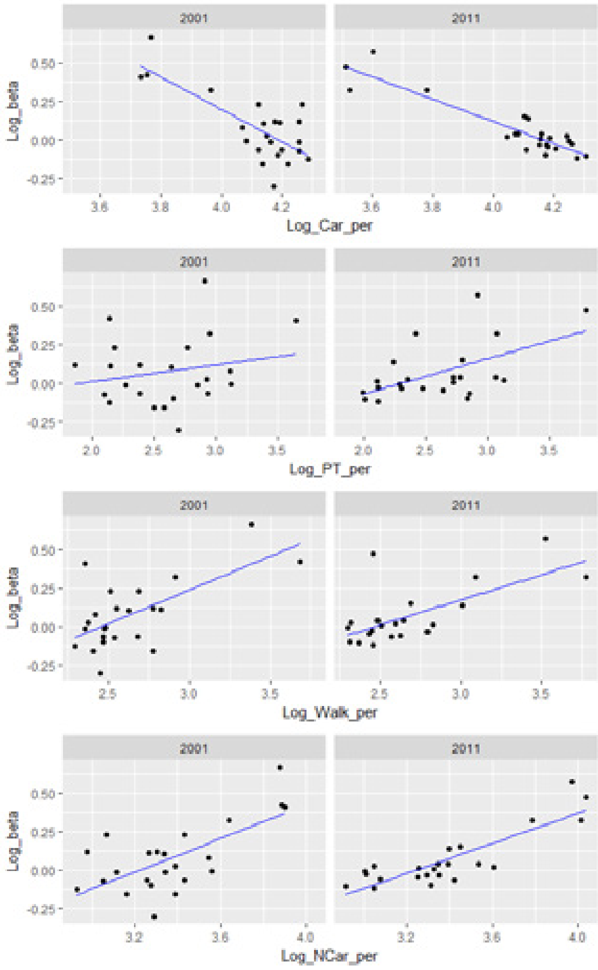

Figure 9 - Scatterplot between Beta estimates on the Y-axis and Mobility variables on the X-axis.

Lastly, figure 10 illustrates the scatterplots between the beta estimates on the Y-axis and economic variables on the X-axis. The result shows there is generally a consistent relationship between a city's economic factor and a city's economic value of accessibility. For example, a city's inequality (gini coefficient) and productivity (GVA) correlates positively with higher economic value of accessibility. A consistent relationship was also found between the city's key sector of employment and the economic value of accessibility. For example, a greater proportion of the jobs employed in the education sector correlates positively with higher economic value of accessibility. Conversely, a greater proportion of the jobs employed in the manufacturing sector correlates negatively with higher economic value of accessibility. However, there is an inconsistent relationship between a city's proportion of jobs employed in the financial sector relative to its economic value of accessibility. In 2001 there was a negative association between a city's proportion of jobs employed in the financial sector relative to its economic value of accessibility. This association was reversed in 2011. Further research is needed to explore in more detail and to further disaggregate employment data to gain a better sense of the relationship between the economic value of accessibility and the economic performance of cities.

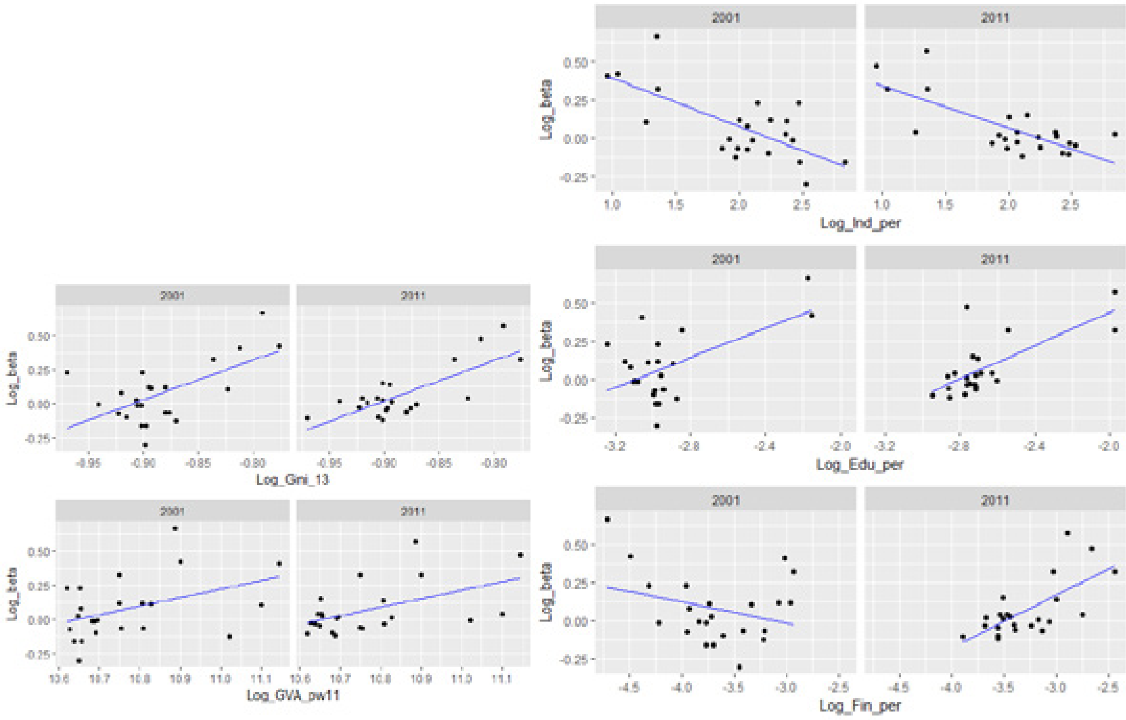

Figure 10 - Scatterplot between Beta estimates on the Y-axis and Economic variables on the X-axis.

Table 06 summarises the goodness of fit and significance between a city's economic value of accessibility and each of the social, economic and mobility variables explored for 2011, 2001 and combined. For brevity, the full regression results are not fully reported. In general, the mobility patterns were most strongly related to a city's economic value of accessibility followed by the proportion of jobs employed in the manufacturing sector, demographics and the gini coefficient. Put simply, the result suggests that a denser, more productive and less car dependent city with greater proportion employed in the education sector and greater proportion aged between 20-29 is likely to value accessibility more.

	var	Description	All R2	All Sig	2001 R2	2001 Sig	2011 R2	2011 Sig
Population	area	Area	10%	neg	14%	neg	7%	insig
	pop	Population	1%	insig	2%	insig	0%	insig
	emp	Employment	0%	insig	1%	insig	0%	insig
	Pop_den	pop density	24%	pos	25%	pos	24%	pos
	Emp_den	emp density	27%	pos	29%	pos	28%	pos
	age_0_19	pop age 0-19	28%	neg	55%	neg	9%	insig
	age_20_29	pop age 20-29	44%	pos	43%	pos	53%	pos
	age_30_44	pop age 30-44	6%	insig	0%	insig	28%	pos
	age_45_64	pop age 45-64	40%	neg	37%	neg	56%	neg
	age_65_	pop age 65+	7%	neg	0%	insig	34%	neg
Economic	Gini_13	Gini coefficient	45%	pos	37%	pos	57%	pos
	GVA_pw11	Gross Value Area per worker	21%	pos	18%	pos	27%	pos
	Ind_per	Full-time in manufacturing sector	51%	neg	49%	neg	55%	neg
	Fin_per	Full-time in financial sector	0%	insig	9%	insig	47%	pos
	Edu_per	Full-time in education sector	30%	pos	32%	pos	51%	pos
Mobility	walk_per	travel to work by walk (%)	42%	pos	42%	pos	44%	pos
	PT_per	travel to work by public transport (%)	13%	pos	4%	insig	30%	pos
	car_per	travel to work by car (%)	65%	neg	57%	neg	84%	neg
	non_car_per	travel to work by non-car (%)	56%	pos	45%	pos	73%	pos

Table 6 - Correlation coefficient

5. DISCUSSION

Extending from previous research, this research has shown firstly that spatial network accessibility is a significant variable when associating with house price using the pooled-city regression model. The overall implicit price of accessibility for the 23 case study cities in England increased from 0.14 in 2001 to 0.21 in 2011 which confirms the overall recentralisation trend for cities in the UK (Ehrenhalt 2012). The result from the individual-city regression model shown that spatial network accessibility is a significant variable for some of the cities, but not all. It shows the complexity of the housing market where different househol ds under different local conditions and economic structures might value differing levels of accessibility. This supports the general consensus that housing research needs to be conducted under different contexts and at different points in time. Clustering analysis shows cities in the south and especially near London placed higher economic value on accessibility as compared to the cities in the north. These results suggest housing location preferences have a clear geographical clustering, in this case between the north and the south.

Furthermore, the cities where accessibility was significantly positively valued appeared to be denser, more walkable, with greater productivity and greater proportions employed in the education sector and greater proportions aged between 20-29. Conversely, the cities where accessibility was insignificant appeared to be less dense, more car dependent, with lower productivity and with greater proportions employed in the manufacturing sector and greater proportions aged below 20 or above 45 [age<20, age>45]. These results can be interpreted from a number of points of view. On the one hand, cities that are smaller and more car dependent might be less affected by distance and so households would value accessibility less. On the other hand, larger cities with greater productivity that are less reliant on manufacturing industry could diversify into sectors such as the creative, technological and education sectors that benefit from greater agglomeration and so households might give greater value to accessibility. This could also be related to demographics. A population that has children might be expected to value accessibility to schools more, and a population that are seeking employment opportunities might value accessibility to social networks and jobs more.

However, these effects are complex and conditional. Even for cities that were significant, the effects seem to be greater for larger cities such as London than smaller cities such as Cambridge and Oxford. While cities such as Milton Keynes with great proportions employed in the business sector gave a lower economic value to accessibility. This might be attributed to its urban form which is highly car-dependent and unwalkable. This research therefore suggests that the economic value of residential accessibility is related to a combination of a city's mobility factors, its urban form and its economic profile. This clearly requires further research and a more detailed analysis of individual cases to elucidate the exact mechanisms at play, however it is clear that the single monocentric model, and its underpinning assumption of a spatial equilibrium is subject to further research.

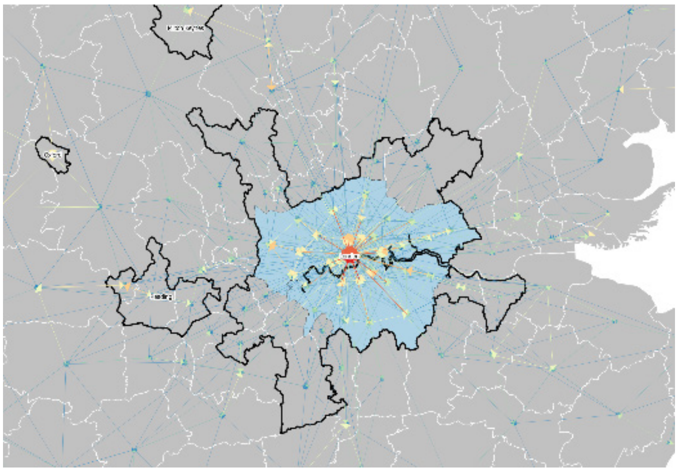

Figure 11 - Commuting patterns of Greater London overlaid with PUA boundary and GLA boundary.

There are a number of limitations to the current research. Firstly, this research selected a pre-existing primary urban area (PUA) boundary which is based on a resident threshold. The problem of this approach is the boundary can exclude areas that are within the functional boundary of the city but it may also include areas that are outside the functional boundary. Figure 11 shows this clearly where the PUA boundary in the black outline does not match either the political boundary of London in blue nor the commuting patterns overlaid on top. One approach would be to test the stability of the hedonic price model by adopting different urban area boundaries. Secondly, this research suffers from obvious omitted variable bias such as access to schools and access to parks, both of which have found to be implicated (Law et al 2013). A check was done in London and found that the exclusion of the neighbourhood amenity variables, such as access to shops, parks and school quality could underestimate the economic value of spatial network accessibility on house price, but the variable was still highly significant. These additional factors need to be included in future research studies. Thirdly, the simplicity of the specification needs to be addressed in future research. For example, the OLS regression specification is likely to suffer from both spatial autocorrelations and omitted variable bias leading to an over-estimation on the effect of accessibility. Future research requires a more robust empirical design. Finally, the economic value of accessibility might be related to differing demand from different housing submarkets. As a result, future research should consider disaggregating the data further by different submarkets to explore the relationship between the economic value of accessibility and socio-economic-mobility factors.

Finally, this research shows that on average spatial network accessibility is a significant variable when associating with house price variations. However, this relation is more complex than previously thought with some cities showing a significant association and others not. There are clear patterns where some clusters of cities placed greater economic value on accessibility and some clusters placed less. An initial exploration shows cities that value central places more tend to be denser, more productive, had greater proportion employed in the education sector and, most importantly, were less car dependent. This shows urban form factors that influence walkability and density are central to the economic value placed on accessibility, as well as city productivity.

REFERENCES

Ahlfeldt, G. (2010) If Alonso was right: Modeling Accessibility and Explaining the Residential Land Gradient. Journal of Regional Science

Alonso, W. (1964) Location and Land Use: Toward a general Theory of Land Rent. Cambridge, Massachusetts: Harvard University Press.

Black, S.E., (1999) "Do Better Schools Matter? Parental Valuation of Elementary Education," Quarterly Journal of Economics 114(2): 577-599.

Chiaradia, A.J., Hillier, B., Barnes, Y. and Schwander, C. (2012). Compositional and urban form effects in centres in Greater London. Urban Design and Planning: Proceedings of the Institution of Civil Engineers 165 (1) , pp. 21-42.10.1680/udap.2012.165.1.21

Cheshire, P.C., and S. Sheppard, (1995) 'On the Price of Land and the Value of Amenities', Economica, 62, 247-267.

Ehrenhalt, Alan (2012). The Great Inversion and the Future of the American City. New York: Knopf.

Freeman, L.C. (1977) A set of measures of centrality based on betweenness, Sociometry 40, 35-41. pp. 37. Lehigh University.

Hansen, W. G., (1959) How accessibility shapes land use. Journal of the American Institute of Planners, 25.

Heikkila, E., Gordon, P., Kim, J.I., Peiser, R.B., Richardson, H.W., Dale-Johnson, D., (1989). What happened to the CBD–distance gradient?: land values in a policentric city. Environment and Planning 21, 221–232.

Hillier, B. and Hanson, J. (1984). The social logic of space. Cambridge, MA: Cambridge University Press.

Hillier, B., Yang, T., Turner, A., (2012). Normalising least angle choice in Depthmap - and how it opens up new perspectives on the global and local analysis of city space. JOSS 2012 P155-193

Hillier, B. (2006). Space is the machine. Cambridge, MA: Cambridge University Press.

Kain, J.F. , Quigley, J.M. (1970) Measuring the value of housing quality, Journal of the American Statistical Association 65 (440) (1970) 532–548.

Law, S., Karimi, K., Penn, A., Chiaradia, A. J. (2013)., Measuring the influence of spatial configuration on the housing market in metropolitan London. Published in: Kim,Y.O.,Park, H.T.and Seo,K. W. (eds.),Proceedings of the Ninth International Space Syntax Symposium,Seoul: Sejong University, Article 121.

Löchl, M. , Axhausen, K.W. (2010) Modelling hedonic residential rents for land use and transport simulation while considering spatial effects The Journal of Transport and Land Use, Volume 3, 2010, pp. 39–63

J. B. MacQueen (1967), Some Methods for classification and Analysis of Multivariate Observations, Proceedings of 5-th Berkeley Symposium on Mathematical Statistics and Probability, Berkeley, University of California Press, 1:281-297

McMillen, D.P. (2003). The return of centralization to Chicago: using repeat sales to identify changes in house price distance gradients, Regional Science and Urban Economics, Volume 33, Issue 3, May 2003, Pages 287-304

Mills, S.E., (1972) Studies in the Structure of the Urban Economy. Baltimore: Johns Hopkins Press.

Muth, R., (1969) Cities and Housing. Chicago: University of Chicago Press.

Office of the Deputy Prime Minister (2006). State of the Cities Vol.1 – A research study. ODPM Publications.

Narvaez Zertuche, L. P. (2015). Architecture, Economy and Space: A study on the socio-economics of urban form in Cardiff, UK(Doctoral dissertation). UCL.

Narvaez Zertuche, L.P., Penn, A., & Griffiths, S. (2014). The Social and Economic Significance of Urban Form: A Configurative Thinking Using Bid Rent Theory. International Seminar of Urban Form and European Association for Architectural Education, 551-558. doi:10.3233/978-1-61499-365-0-558

Ridker, R.G. and Henning, J.A. (1967) 'The Determinants of Residential Property Values With Special Reference to Air Pollution', Review of Economics and Statistics 49,246--257.

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

Sabidussi, G. (1966) The centrality index of a graph. Psychometrika 31, 581–603.

Shen, Y., & Karimi, K. (2016). Urban function connectivity: Characterisation of functional

urban streets with social media check-in data. Cities, 55, 9–21.

Waddell, P. (2002) UrbanSim: Modeling Urban Development for Land Use, Transportation and Environmental Planning, Journal of the American Planning Association, 68(3), pp. 297-314.

Webster C, (2010). "Pricing accessibility: urban morphology, design and missing markets" Progress in Planning 73 77–111

Von Thunen, J. (1826) Isolated State: An English Edition of Der isolierte Staat (translated by Wartenberg C and Hall P). Pergamon Press, Oxford, UK.

Xiao, Y., Webster, C., Orford, S. (2015) Urban Configuration, Accessibility, and Property Prices: A Case study of Cardiff, Wales. Environment and Planning B: Planning and Design. 2015. Vol.42, Pages 1-22.