

# The Relationship between Transport Accessibility and Land Value: a local model approach with Geographically Weighted Regression

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**Abstract**

1 In recent years, land value capture has attracted increasing attention as a result of its potential for funding  
 2 transport infrastructure. It is well acknowledged that transport infrastructure can improve accessibility to  
 3 employment and amenities thus one might expect that it is the part of improved accessibility that adds the value  
 4 towards land. Therefore, the issues in the relationship between transport accessibility and land value rise in  
 5 connection with the concept of land value capture.

6 This paper looks at the relationship between transport accessibility and land value with the implication of a local  
 7 model – Geographically Weighted Regression (GWR). Traditional techniques, such as hedonic models, used to  
 8 understand the attributes of land value, are global models that could be misleading in examining the spatially  
 9 varying relationships, such as transport accessibility and land value. Using Tyne and Wear Region, UK as a case  
 10 study, this paper reveals that nonstationarity existing in the relationship between transport accessibility and land  
 11 value indicates that transport accessibility may have a positive effect on land value in some areas but in others a  
 12 negative or no effect, suggesting that a uniform land value capture would be inappropriate. The use of GWR  
 13 allows such spatially varying relationships to be revealed leading to a better understanding of the factors  
 14 determining positive land value uplift and the implications of spatially-dependent transport access premiums in  
 15 housing values in the context of value capture policies.

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## INTRODUCTION

1 Land value capture is topical in the UK as a potential means of financing transport infrastructure. Transport  
2 infrastructure, especially significant transport facilities, such as highway and modern light rail systems, are  
3 believed to have improved transport accessibility greatly to services (employment and amenities). The classical  
4 urban land economics theories (1, 2, 3) indicate transport cost is an important determinant of land value. With  
5 increasing distances to the Central Business District (CBD), where employment and amenities concentrate, the  
6 land value increases as a result of the decreasing transport cost. The policy of land value capture is based on this  
7 theory and relates to capturing the increased value of land arising from improving the accessibility provided by  
8 transport facilities to services to fund or partly fund transport infrastructures. To explore the ideas behind land  
9 value capture, it is important to well understand relationships between transport accessibility and land value.

10 Classical land theories as expounded by Mills (3) is concerned with only two types of land - unimproved land  
11 which is without structures and improved land where the value includes the value of structures and other capital  
12 invested in the land. In this paper, focusing on residential land, land value is examined through improved land  
13 values in the form of house prices. However, the housing market is not as homogenous as suggested by the  
14 'improved land' of classical theories and an empirical approach needs to cater for the heterogeneous nature of  
15 the market. Typically the more sophisticated house prices analysis uses hedonic price models whereby house  
16 prices are expressed as a bundle of characteristics that households place values on, including transport  
17 accessibility (4). In a typical hedonic price model, it is assumed that the assumptions of multiple regression are  
18 observed. However, in analysis which has a spatial element, as observed in the housing market, spatial  
19 dependency between observations should be expected and this gives rise to concern of the effects of the presence  
20 of spatial autocorrelation in spatially unadjusted hedonic price models.

21 In this paper, a relatively new technique, Geographically Weighted Regression (GWR), which addresses the  
22 issue of spatial autocorrelation, is employed to examine the relationship between transport accessibility and land  
23 value aiming to make contributions to the land value capture policy discussions. By embodying spatial  
24 coordinates into the traditional global regression model, GWR provides a set of local estimates using a weighted  
25 least squares process where the weights are linked to the distance of the observation to the location of the  
26 regression point. The Tyne and Wear Metro system, located in Tyne and Wear in the north-east of England, UK  
27 is used as a case study. This Region has a population of 1.07 million (5) accommodated in five Metropolitan  
28 Districts comprising of the City of Newcastle upon Tyne, the City of Sunderland, the Borough of Gateshead, the  
29 Borough of North Tyneside and the Borough of South Tyneside.

## EXISTING LITERATURE, ITS DEFICIENCIES AND IMPLICATIONS FOR THIS STUDY

30 There are substantial studies, particularly in US, on the impact of transport investment on land value. Studies  
31 since the 1990s are summarized in Table 1. Most of literature on this topic tends to concentrate on the positive  
32 side of the results but taking a closer look shows considerable variation in the findings. First, as different  
33 approaches have been taken, the results are not comparable in terms of the unit of values used and Table 1 has  
34 tried to ameliorate this by presenting the results in terms of the percentage of average values. Second, the table  
35 identifies a somewhat surprising lack of significant results for UK studies in contrast to US studies. For example,  
36 the Jubilee Line Extension (JLE) study failed to identify any significant effect in Phase 1 using a hedonic price  
37 model and this was substituted by the adoption of an 'agents survey' in Phase 2 (6). Although this latter  
38 demonstrates positive results, the methodology is not as robust. Insignificant results in the UK might relate to  
39 difficulties of data acquisition in the UK where transaction property data are not open to researchers. The table  
40 also highlights the frequent use of hedonic price models and it is notable that the latest studies are applying  
41 hedonic price models to sub-categories of housing markets or seek to find alternative approaches to cope with  
42 the awareness of the variation that exists in the property market.

43 The hypothesis of this paper is that the use of global statistics, as used in previous studies, does not give a useful  
44 insight into issue of land value. As shown in table 1, the relationship between transport improvements and  
45 property values examined is not consistently treated because of the way in which the global statistics have been  
46 utilised and this can be misleading in the examination of spatial relationships. For example, the global statistics  
47 for England may show that the age of houses does not affect house prices significantly. But in some parts of  
48 England, old houses such as those built in Victorian times, might have character so generating higher prices than  
49 newer houses in the same area. Whereas in other urban areas, older houses built to lower standards to house  
50 workers in rapidly expanding cities in the 1850s, might be in poor condition resulting in substantially  
51

**Table 1: Summary of recent literature**

Studies	Location	Impact of	Impact on	Findings	s/ns*	Methods
Nelson (1992)(7)	Atlanta, US	Heavy Rail (HR)	Residential property (R)	+(lower income)/-(higher income)	s	N/A
Bollinger et al. (1998)(8)	Atlanta, US	HR/Highway	Office Rent	-(HR)/(Highway)	s	Hedonic Price (HP)
Gatzlaff & Smith (1993) (9)	Miami, US	HR	R	up to +5%	s/ns	Comparison / HP
Landis et al. (1994)(10)	California, US	HR/Light Rail (LR) /Highway	R	+\$2.29/m for HR, +\$2.72/m for LT, no effect for Highway	s/ns	HP
Armstrong, R. J. (1994)(11)	Boston, US	HR	R	+6.7% Communities with commuter rail compared with other communities	s	Comparison
Chen et al (1997)(12)	Portland,US	LR	R	up to +10.5%	s	HP
Cervero & Landis (1993)(13)	Washington D.C., US	HR	Commercial property (C)	+	ns	Comparison
Cervero & Duncan (2001)(14)	Santa Clara Cty, US	HR/LR	C	+120%	s	HP
Weinberger(2001)(15)	Santa Clara Cty, US	LR	Comercial Rent	+(within 0.8km)	s	HP
Hack (2002)(16)	Dallas,US	HR/LR	R	+25%	N/A	N/A
Weinstein & Clower (2002)(17)	Dallas,US	LR	R/C	+12.6%(R)/+13.2%(C)	N/A	Comparison
Cervero & Duncan (2002)(18)	San Diego Cty, US	HR/LR	C	up to +91.1%/-9.9%	s	HP to 3 types of properties
Cervero & Duncan (2002)(18)	San Diego Cty, US	HR/LR	R	up to +46.1%/-7.1%	s	HP to 3 types of properties
Cervero & Duncan (2002)(19)	Los Angeles Cty, US	HR/LR	C	up to +16.4%/-29.8%	s	HP to 3 types of properties
Cervero & Duncan (2002)(19)	Los Angeles Cty, US	HR/LR	R	up to +14.2%/-15.2%	s	HP to 3 types of properties
TRRL (1993)(20)	Tyne and Wear, UK	LR	R/C	+/-	ns	Comparison
Forrest (1995)(21)	Manchester, UK	Metro	R	up to -8.1%	s	HP
Lawless (1999)(22)	Sheffield, UK	Tram	R	-(during construction)	ns	HP
Adair et al (2002)(23)	Belfast, UK	Accessibility	R	+<2%(most models), up to +14%	s/ns	HP to sub-markets
Chesterton (2002)(6)	London, UK	LR	R/C	+	N/A	Agents Survey
RICS (2004)(24)	Croydon, UK	Tram	R/C	no discernable	ns	Kriging/IDW/GWR**

\*s/ns: significant/non-significant;

\*\*GWR was applied as an experiment with just three variables due to lack of data source.

1 lower prices than newer houses. The contrasting relationships in different areas are likely to have a cancelling  
2 effect so that on average, across England, the age of houses appears to have no impact on the house prices. This  
3 means that using a set of *local statistics*, in which data are analysed at local level, is necessary to provide more  
4 accurate results in a study linking house prices to accessibility.

5 Some studies (7, 10, 18, 19, 23) have revealed non-stationarity between different areas in the relationship  
6 between transport accessibility and land value. For example, in Atlanta, proximity to rail has a positive effect on  
7 house prices on the south side where neighbourhoods are dominated by higher income groups and negative  
8 effects were found on the north side where neighbourhoods are dominated by lower income groups (7). Such  
9 spatial nonstationarity can arise for two reasons. The first arises from model misspecification, particularly when  
10 there are missing variables arising from data unavailability or simply data that has been overlooked. Indeed,  
11 mapping local statistics can help improve the accuracy of the global model through the spatial patterns hinting  
12 to presence of omitted variables. The second cause arises from the way in which there are fundamental  
13 differences existing across space for some variables. For instance, the same 3-bedroom house is likely to be  
14 cheaper in a poorer area as compared to a richer area. This type of variation needs to be studied on the basis of  
15 demography varying over space and a better local model, such as GWR, is able to deal with this spatial non-  
16 stationarity effectively.

## 16 DATA ACQUISITION

17 Ample and accurate data are essential for conducting statistical analysis to generate statistically significant  
18 results. For the purpose of this study, house price data together with socio-economic data and importantly, good  
19 quality transport accessibility data are required. This section describes the data acquisition process for this study.

### 21 House price data

22 In house price related data analysis, transaction house price data are normally sought as these are the proven  
23 prices by the market in contrast to asking prices which are expected prices based on the valuation by agencies .  
24 However, there is evidence that the asking house price and the transaction house price are highly correlated with  
25 sales price achieved being above 93% on average of the asking price in UK housing market since 2002 (25). In  
26 May 2004, when the data for this study were collected, the transaction house price achieved was 98.6% of the  
27 asking price in the North region (25). Therefore, it is possible to examine the determinants of house prices by  
28 looking at asking prices without significant error. Asking price data for properties are available and are used in  
29 this study because transaction data are unavailable in England either due to confidentiality issues or available  
30 only with limited information about the property characteristics.

31 At the time of data collection for this study, a website [www.icnewcastle.co.uk](http://www.icnewcastle.co.uk) advertised properties for sale in  
32 Tyne and Wear Region with sufficient information on property characteristics. With the information of full  
33 postcode unit (e.g. NE1 7RU), the data for this study was collected at the full postcode district (e.g. NE1) level  
34 for which various numbers of advertisements, between 50 and 200, can be found on this website every day. The  
35 main advantage of this internet data source is the easy access to considerable data provided by a number of  
36 major estate agencies in Tyne and Wear in contrast to needing to rely on a single agency, normally covering a  
37 local area. This data source provided 2855 records that could be linked to the Output Area (OA) for census data  
38 OAs are the smallest unit for UK 2001 Census output data and are formed by grouping together full postcodes.  
39 OAs are designed to have similar population sizes and social homogeneity by reference to the characteristics of  
40 actual Census data using a recommended size of 125 households.

### 41 Neighbourhood environment data

42 Neighbourhood environment data including, social economic data, such as household status in relation to  
43 household income and ethnic group, as well as environment data, like schooling environment, is required to try  
44 and explain the external factors of house prices other than transport accessibility. In this study, household status  
45 is captured by “Higher managerial and professional occupations” and “Long term unemployed” which are found  
46 in one of the widely-used standard socio-economic classifications in the UK (National Statistics Socio-economic  
47 Classification (NS-SeC)). Ethnic distribution focuses on ethnic minority households and excludes white and  
48 mixed households. NS-SeC and ethnic data were extracted from UK 2001 census data at OA.

Proximity to good schools has been identified as one of the key factors to determine the choice in location of houses in Tyne and Wear (26). This is confirmed by other empirical studies (27, 28, 29) although whether primary school quality or secondary school quality adds more to house price seems to vary from city to city (28). Therefore, the environment data in this study uses the appropriate average point score in school performance league table published annually by the Department for Education and Skills to reflect the quality of school amenities (30).

### Accessibility data

Accessibility of a location, determined mainly by the transport system and land use pattern, is an important element of the external factors that influence house prices. The term “accessibility” has long been used in the literature on the transport planning studies. In very general term, it refers to the ease of reaching potential destination from a certain location by means of a particular transport system (31). There are various approaches to accessibility measures, depending on the purpose of accessibility study. Continuous measures – Hansen/gravity accessibility measures have been considered as the most robust approach which measures the general accessibility to a certain service such as employment by public transport (32). The Hansen method is particularly suitable for measuring accessibility to for example, employment as job opportunities are likely to be proportional to the size or number of potential people. In contrast, the accessibility to some services, for example education, need to be measured in a different way, using the nearest destination as the potential opportunity for accessibility measurement since, in principal, every child at certain age, is regarded as living in the catchment area of the nearest school.

Accessibility within the Region of Tyne and Wear is being modelled by Newcastle City Council, on behalf of the Tyne and Wear Partnership. At the time of this study, this modelling produced travel time as an accessibility measurement, using both closest or weighted Hansen methods for public transport (hourly between 0700 and 2300) and for car travel at different road states (capacity speed/half-capacity speed/full speed) to a number of services, such as large employers/food/hospital/primary education, etc, calibrated at one minute intervals. Public transport accessibility is calculated on the bus and metro timetable, rather than the actual running service thus assuming that all bus and metro services run on schedule. Car accessibility was calculated using the highway speed using an algorithm of minimum path build. Origins and destinations are based on bus stops located in the OAs.

The closest method for public transport to education is calculated as simply the travel time to the nearest school; the weighted Hansen accessibility measure is more complicated, calculated by reference to a gravity-based formulation as follows:

$$t_i = \ln \left\{ \frac{\sum_{j=1}^J A_j \exp(-\lambda t_{ij})}{\sum_{j=1}^J A_j} \right\} / (-\lambda) \quad (1)$$

where  $t_i$  is travel time in zone  $i$  ( $OA_i$ );  $j$  indexes available destination zones reachable from zone  $i$ ;  $A_j$  is the number of jobs at zone  $j$  accessible to large employers;  $\lambda$  is a deterrence parameter consistent the trip distribution and  $t_{ij}$  gives overall travel time from zone  $i$  to zone  $j$  (both journey time and walking to/from bus stops).

Public transport accessibility in this model considers metro and bus as a single public transport network making it impossible to separate metro from bus accessibility. As metro is a significant transport facility in part of the case-study Region, the effect of metro accessibility on house prices is explored by a simple measure which identifies whether a property has good access to metro station within walking distance which is interpreted as within 500 metres of the the property. This has been achieved by setting up a buffer of 500 metres around each Metro stations with GIS. There are few empirical studies on walking distances to and from light rail transit stations but a study (33) based on a survey in the city of Calgary, Canada, which indicates that average walking distance to light rail stations is 326 metres in the CBD area or 649 metres in the suburban area. Consequently 500 metres is felt to be an appropriate walking distance to a Tyne and Wear Metro station.

### ANALYSIS AND RESULTS

This study is using GWR to examine the relationship between transport accessibility and land value. GWR is based on a global regression model (a hedonic price model) which is then modified by GWR to calibrate local

regression parameters by weighting the distance between one data point and another through the coordinates of data.

### Global regression model

There have been numerous studies on housing market using hedonic price modeling to estimate house prices. In order to identify the main characteristics that house buyers have placed value on, Sirmans et.al (34) have reviewed 125 studies in the US published in the last decade that have used hedonic price modeling. This review found a large number of characteristics have been included in hedonic price models. The most frequently included characteristics are plot size, square feet, age, the number of stories, the number of bathrooms, the number of rooms, the number of bedrooms, fireplace, central air-conditioning, basement, garage, deck, pool, brick exterior, distance to CBD, time-on-the-market and a time trend. However, problems with model specification can often be observed and this seems to be the main issue in hedonic price modeling since there is a lack of agreement on the most appropriate functional form and the choice of the best regression (15, 21, 34). Nevertheless, the GWR approach requires the specification of a global model at its start and this is equivalent to a hedonic price model.

The hedonic price method hypothesises house prices as a function of a bundle of attributes, which can be thought of being made up of two parts: internal factors and external factors. Internal factors consist of house features, such as the type of house and the number of bedrooms, whereas external factors embrace the factors of transport accessibility and the environment of the neighbourhood. Consequently, house prices can be seen as a function of a group of variables contained by three vectors:

$$P_i = f(H, N, T) \quad (2)$$

Where

H is a vector of house features including: the type of property (FLAT, TERR, SEMI, DETA), number of bedrooms (BEDROOM) and interaction terms of type and bedrooms (FLATBED, TERRBED, SEMIBED, DETABED);

N is a vector of the neighbourhood environment including: two classifications of NS-SeC (HPROF, UNEMP), ethnic minority group (ETHNM) and the average point score for secondary school (EDU13PT);

T is a vector of transport accessibility including: travel time to secondary school by public transport at peak hour (PT08E13), travel time to employment by car with capacity speed (CARCEMP) and the proximity to metro stations (INMSCA).

The description of these variables is given below in Table 2. These specific variables modifies equation (2) to equation (3) below:

$$P_i = \alpha_0 + \alpha_1 \text{FLAT}_i + \alpha_2 \text{TERR}_i + \alpha_3 \text{DETA}_i + \alpha_4 \text{FLATBED}_i + \alpha_5 \text{TERRBED}_i + \alpha_6 \text{DETABED}_i + \alpha_7 \text{BEDROOM}_i + \alpha_8 \text{EDU13PT}_i + \alpha_9 \% \text{ETHNM}_i + \alpha_{10} \% \text{HPROF}_i + \alpha_{11} \% \text{UNEM}_i + \alpha_{12} \text{PT08E13}_i + \alpha_{13} \text{CARCEMP}_i + \alpha_{14} \text{INMSCA}_i \quad (3)$$

In the context of the UK, in terms of the internal attributes, the floor area, the age of the building and the number of bathroom have been found as important determinant variables other than the number of bedroom (35). However, constrained by data availability, the 14 variables included in the model, as shown above, were chosen. To avoid multicollinearity, transport accessibility variables have been considered as a pair of public transport to secondary schools and car accessibility to large employers, which have been identified as the best explanatory variables. In addition, correlation analysis has shown insignificant correlation between the explanatory variables with the exception of high but expected correlation between the interaction terms \*\*\*BED and the associated type variables FLAT, TERR, SEMI, DETA respectively. In addition, scatter plots of the dependent variable against each of independent variable suggest a linear regression model is suitable for this study.

### Geographically Weighted Regression model

Geographically Weighted Regression (GWR) is a relatively new technique for exploratory spatial data analysis developed by Fotheringham *et al.* (35). In traditional multiple regression it is assumed that the relationship to be modelled holds everywhere in the study area. However, this is not necessarily the case for house prices as spatial data is likely to be autocorrelated. Spatial autocorrelation may occur in two different forms: one is concerned with spatial dependency and the other form is spatial error dependence relating to spatial heterogeneity, namely

spatial nonstationarity, and misspecification. Misspecification always relates to the process of model establishment leaving little that can be done through an improvements of the technique. However, spatial dependency and spatial nonstationarity have been the major challenges in spatial data analysis. Indeed, GWR not only can deal with spatial dependency by taking into account of geographical location in intercepts, but also tackles spatial nonstationarity by accounting for coordinates in parameter estimates. There is evidence that GWR can reduce the residuals more substantially as compared to models containing an autoregressive term because of the way that spatial varying relationships are modelled through geographically varying parameter estimates rather than through the error term (35). Nevertheless, GWR can be seen as an alternative to, and one which is perhaps more intuitive than, spatial regression modelling.

In contrast to hedonic price models, assuming that all the assumptions of multiple regression are met, the local estimators provided by GWR are not best linear unbiased estimators (BLUE estimators). In identifying local estimators, GWR trades bias against efficiency of estimators in taking account of the spatial autocorrelation. This means that the traditional model of multiple regression (4) is re-written as (5) so that fitting using the least squares method gives an estimate of the parameters at the location  $(u_i, v_i)$ . The GWR does this by weighting the data nearer to  $(u_i, v_i)$  more heavily than data further away. By this geographically weighted calibration, estimates of the parameters are made for each data point with coordinates, which is then mapped for interpretation.

$$y_i = \beta_0 + \sum_k \beta_k x_{ik} + \varepsilon_i \quad (4)$$

$$y_i = \beta_0(u_i, v_i) + \sum_k \beta_k(u_i, v_i) x_{ik} + \varepsilon_i \quad (5)$$

### Global regression parameters

The results of global regression parameters are shown in Table 2 which contains the description of the variable whose parameter is being estimated, the estimate of the parameter, the t statistic and whether outcome matches expectations. The interpretation here, for the example of the average performance points of the closest secondary school (EDU13PT), is that an increase in one point will lead to £950 increase in house price on average, holding everything else constant. The t-value is 5.12 demonstrating that this global regression parameter – EDU13PT is greater than zero at a 5% level of significance.

In this global regression model, the internal factors are considered to combine the types of house with number of bedrooms so the results are the price per bedroom for each type of house. As the variable SEMIBED was dropped, the estimate for BEDROOM  $\alpha_4$  (35098) in fact represents the price for one bedroom of semi-detached house. The estimate for FLATBED  $\alpha_{12}$  means the value for one bedroom of flat compared to semi-detached house and similarly for a terraced or detached house. The value of one additional bedroom of flat/terraced/detached is then given by adding  $\alpha_4$  and  $\alpha_{12} / \alpha_{13} / \alpha_{14}$  as a result one additional bedroom of flat/terraced/detached is worth £18966/£37234/£47700 respectively. Some results, such as for EDU13PT, confirm the expectation of the parameters mentioned above. However, some results of the global regression parameters are either non-significant at 5% level or reverse to the expectation above where significant and this is shown in Table 2 above.

For the internal factors, FLATBED and TERRBED were expected to have less value than SEMIBED while DETABED was thought to be more expensive than SEMIBED. With respect to the socio-economic factors, %ETHNM and %UNEM were expected to decrease the property value however only %UNEM is significant in the global regression. %HPROF and having a better school nearby would be expected to lift property value and this is the case for both %HPROF and EDU13PT variable. So we can see that, in the global regression model, the factors of high professional and unemployment reflecting household status does, as expected, significantly contribute positively and negatively to property value respectively.

In terms of car and public transport accessibility, more travel time means worse accessibility so, the alternative hypothesis  $H_1$  for these parameters are expected to be negative: thus one more minute of public transport/car travel time (worse public transport accessibility to secondary schools and car accessibility to larger employers) would lead to lower property prices, i.e. better accessibility would increase house value. Whilst  $H_1$  is confirmed for the public transport variable PT08E13 at 5% level, for the car variable CARCEMP,  $H_0$  must be accepted. These results tell us that, in general term, a house with better accessibility (one minute less) to secondary schools by public transport can add £1046 to house value whereas, for cars, one minute closer to larger employers will



reduce £749 house value. INMSCA is significant at a 1% level, suggesting that, in accordance with expectation, a house within 500 metres of a metro station is worth £10407 more than a house more than 500 metres away.

**Table 2: Global regression statistics and ANOVA table**

<i>Variable</i>	<i>Estimate</i>	<i>T value</i>	<i>Outcome Matches Expectations (Agree ✓/ Disagree ×)</i>
<b>Property Attributes</b>			
FLAT (1=yes; 0=no)	15197.95	1.44	N/A
TERR (1=yes; 0=no) (Terraced property)	-24762.75	-2.57 **	N/A
DETA (1=yes; 0=no) (Detached propoerty)	5089.74	0.43	N/A
# FLATBED = FLAT * BEDROOMS	-16132.52	-4.02 **	✓
# TERRBED = TERR * BEDROOMS	2135.57	0.67	×
# DETABED = DETA * BEDROOMS	12601.54	3.47 **	✓
BEDROOM: total number on the house	35098.76	13.57 **	✓
<b>Neighbourhood Attributes</b>			
EDU13PT: the average point score of the secondary school in 2003 nearest to the house	950.15	5.12 **	✓
%ETHNM: % of ethnic minority in OA	121.86	0.54	×
%HPROF: % of higher professional occupations in OA	5179.36	27.82 **	✓
%UNEM: % of long term unemployment in OA	-4290.68	-5.30 **	✓
<b>Accessibility</b>			
PT08E13: public transport travel time (minutes) to secondary school at peak hour (8:00am)	-1046.96	-3.62 **	✓
CARCEMP: car travel time (minutes) with capacity speed to employment	749.51	3.87 **	×
INMSCA: within 500 metres of metro station catchment area (1=yes; 0=no)	10407.59	3.76 **	✓
<b>Summary statistics</b>			
No. Observations = 2837 (18 outliers have been identified and removed)			
Dependent mean = 159915			
R-Squared = 0.60 (GWR: 0.73)			
<b>ANOVA</b>			
	<i>Sum of Squares</i>	<i>Degrees of Freedom</i>	<i>F value</i>
OLS reiduals	7754132163030.3	15.00	
GWR improvement	2960569139200.0	258.29	
GWR residuals	4793563120640.3	2563.71	6.13

\*\* = significant at 1% level for a one tailed test;

# FLATBED, TERRBED, SEMIBED and DETABED is a set of interaction terms: the gradient of the relationship between house price and bedroom is given by adding the estimate  $\alpha_7$  and  $\alpha_4/\alpha_5/\alpha_6$  and the intercept is given by adding the estimate  $\alpha_0$  and  $\alpha_1/\alpha_2/\alpha_3$ .

### GWR estimation

The GWR model provides diagnostic information including an ANOVA which tests the null hypothesis that the GWR model has no improvement over a global model. These are shown in Table 2 where the F test suggests that the GWR model has a significant improvement over the global model for this study. In addition, from the summary statistics in Table 2, it can be seen that the adjusted  $R^2$  has increased from 0.60 to 0.73 implying that the GWR model gives a better explanation, after taking into account degrees of freedom.

As identified above, GWR gives the ability to examine spatial variability hidden in a global regression model. All the local parameter estimates can be mapped but, due to space limitations, this paper concentrates on transport accessibility variables – PT08E13, CARCEMP and INMSCA. These parameter estimates are mapped

in Figures 1–3 by inverse distance weighted interpolation with GIS. The best interpretation comes from maps of local parameter estimates alongside the maps of local t- value since the local t- values maps exhibit the local significance that accounts for the local varying estimate errors. However, to make best use of space, the parameter estimates maps are shown incorporated with t- values maps. In the case of PT08E13 and CARCEMP, the value of parameter estimates is classified by four bands in accordance to the t- value. In the case of INMSCA, the parameter value is classified by five bands with an additional band for 0-1 in order to identify the areas where a local regression is problematic because the value of the dummy variables are all zero (all properties are some distance from the metro). In addition, in all maps the global value is set as one band to show the difference between global parameters and local parameters. As a result, there are five bands for the value of parameter estimates in Figure 1 and 2 and six bands in Figure 3. In all three Figures, the lightest areas and darkest areas are significant but with the lightest areas exhibiting positive house premiums and the darkest negative house premiums.

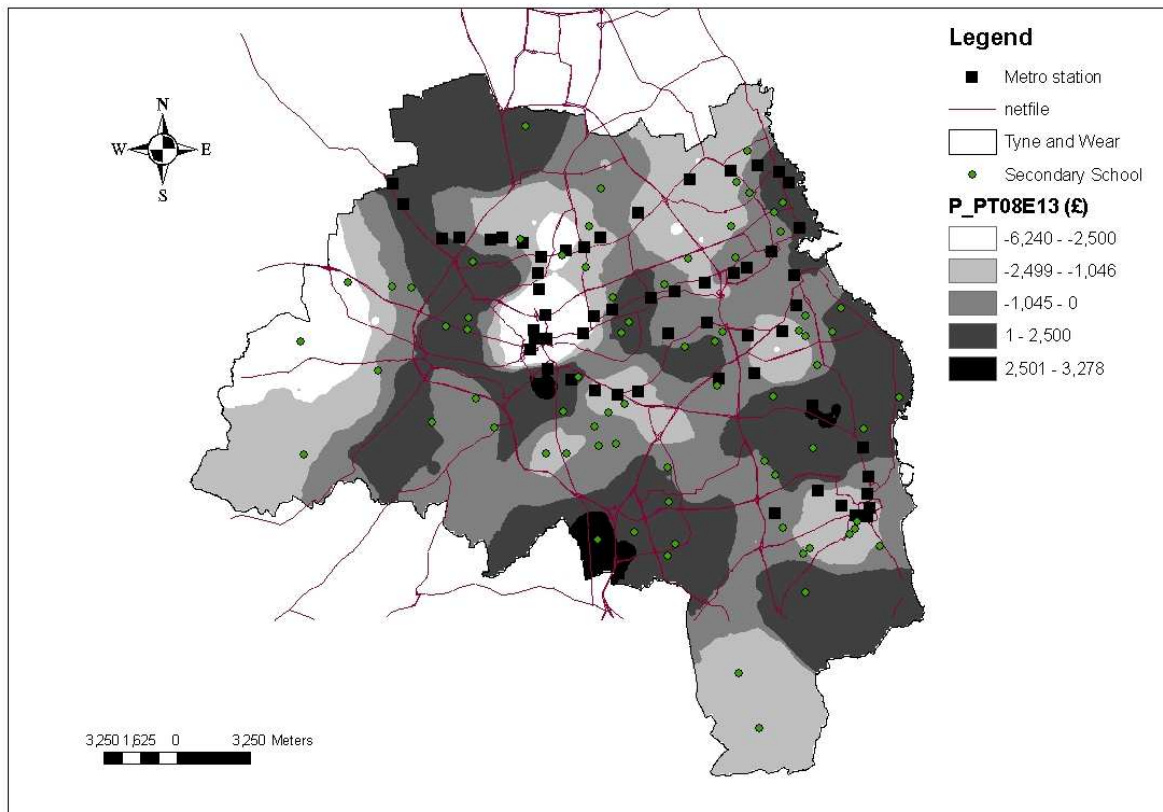


Figure 1: map of parameter estimates associated with variable PT08E13

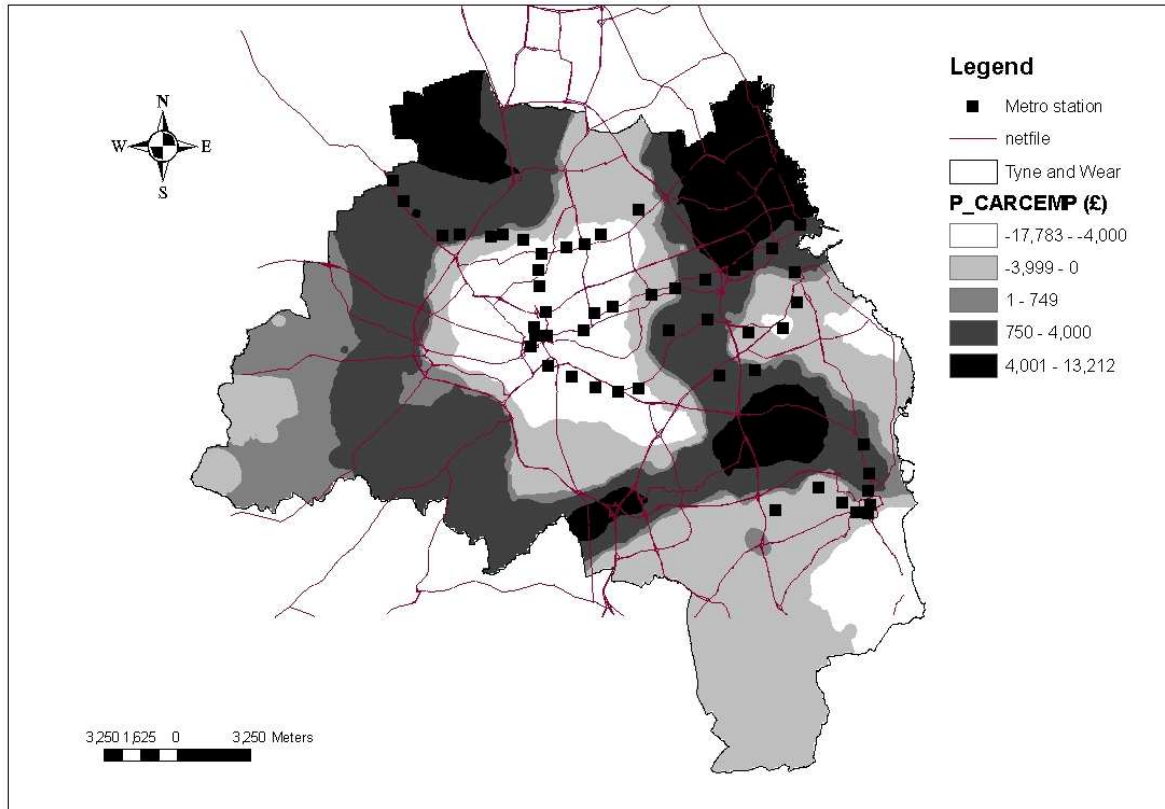


Figure 2: map of parameter estimates associated with variable CARCEMP

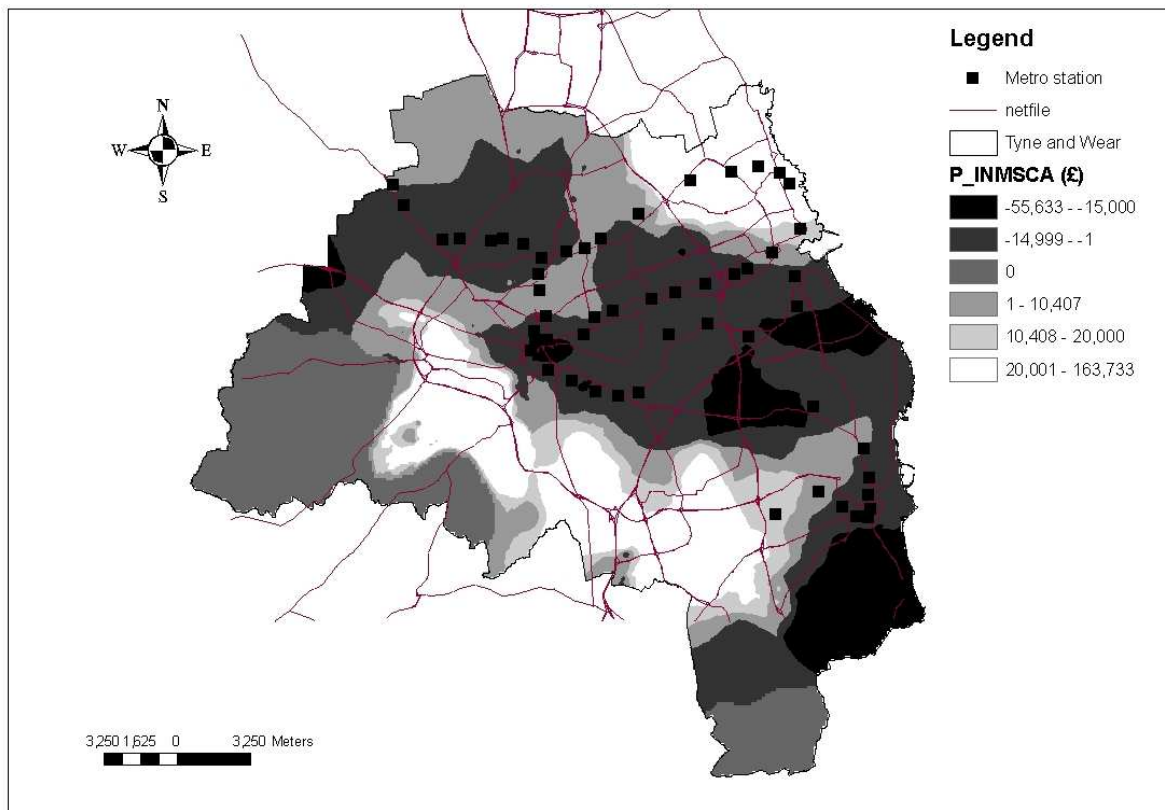


Figure 3: map of parameter estimates associated with variable INMSCA

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1 It is clear from the maps that the parameters demonstrate considerable spatial variation. Although globally better  
2 public transport accessibility to secondary schools can add significant value to house price, from Figure 1, it can  
3 be seen that, in most of the Region, the two variables appear to be unrelated. Only two areas - the west end of  
4 Tyne and Wear Region and Newcastle central area emerge with such relationship with value added from £2500  
5 to £6240. In the west end, bus access to secondary schools is associated with the positive premiums whilst in the  
6 other area public transport accessibility seems to be positively capitalised in relation to the metro access to  
7 secondary schools for pupils. As can be seen, the value of global parameter (£1046) is not in any of the  
8 significant value categories. As a global average value, it is also not indicative of the local value for most  
9 households.

10 The results from global regression show better car accessibility to large employers reduce house value. Figure 2,  
11 shows that there are some areas where better car accessibility can add value from £4000 up to £17783. In  
12 particular, a large area in the centre of Tyne and Wear where the negative relationship confirms the latest trend  
13 of gentrification in the UK (36). The northwest area with positive relationship between car travel time to large  
14 employers is hypothesised to have other stronger environment feature, such as nice countryside landscape, which  
15 contribute more strongly to property value than proximity to employment by car. The northeast area with a high  
16 positive relationship is thought partly to be the result of proximity to a seaside amenity and partly to be caused  
17 by the attractiveness of metro access to employment. The reason behind this positive relationship in the southeast  
18 area needs to be identified with more detailed socio economic information in further study.

19 In contrast to the global value of £10407.59 as the premium of being within 500 metres metro station catchment  
20 area, such positive premium does not occur in most areas in the Region as shown by Figure 3. This suggests the  
21 global model has overestimated the value associated with metro access for most houses. The south and the  
22 southwest of Tyne and Wear, where the estimate values are 0 as these areas are so far away from metro network  
23 that they are not accounted for in comparable areas by the local model. Two locations, where proximity to a  
24 metro station has a significant negative effect on house prices, relate to city centre properties located adjacent to  
25 metro lines which may acquire a negative effect from this proximity. Two areas exhibit significant positive  
26 premiums. The area to the southwest of Tyne and Wear is not located in any relevant the catchment areas of  
27 metro stations and in the northeast of the Region, Whitley Bay, the closeness of metro stations raises the prices  
28 of properties by over £20000.

## 29 DISCUSSION AND CONCLUSION

30 From the Tyne and Wear case study, it can be seen that the relationship between transport accessibility and land  
31 value is fairly complicated and greatly varied over space. Two causes for such spatial nonstationarity have been  
32 identified. The first, that of missing variables which has been addressed in this study to the extent that data are  
33 available. Better data, especially data relating to floor area or the number of bathrooms (so further distinguishing  
34 a property's internal factors) could make the results more robust and is a limitation of this study. Some of the  
35 variables, such as proximity to seaside, proximity to metro line, etc. that have been identified through the maps  
36 of local parameters, are being considered for in the ongoing study. The second cause, that of fundamental  
37 differences existing over space for some relationships has been clearly addressed by the use of GWR in this  
38 study by showing, for example, that public transport accessibility adds to house price in some areas but not  
39 others and this is consistent with spatial variations uncovered in the literature.

40 The global regression model offers the basis for explaining variation in house prices with the additional results  
41 from GWR clearly revealing a spatially varying relationship between house prices and transport accessibility  
42 variables. Based on the results from global regression model, there is strong evidence that proximity to metro  
43 stations can uplift house price significantly and better public transport accessibility to secondary schools also can  
44 add significant value to house whereas the closer to larger employers by car, the lower value of house price.  
45 Taking a closer look by using GWR model, one can find the relationships are not stationary in connection with  
46 neighbourhood features which seem in some cases to obscure possible benefit from transport accessibility as  
47 translated into house prices to various degree.

48 This empirical work suggests that the local model approach with GWR is appropriate to examine the  
49 relationship between transport accessibility and land value. The existence of nonstationarity between transport  
50 accessibility and land value means that transport accessibility may have a positive effect on land value in some  
51 areas but in others a negative or zero effect. Neighbourhood features may help explain such variation but this  
52 means a uniform land value capture policy would be inappropriate. Therefore, great care should be taken in the

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consideration of a policy of land value capture for the funding of transport infrastructure. The way forward is to understand better the factors which determine positive land value uplift and the approach, shown in this paper, using GWR, is a good way to identify such spatially varying relationship so as to produce rational predictors associated with transport investment to the relevant land.

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