The Impact of Transport Infrastructure on Land Value Using Tyne and Wear Metro As Case Study

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Synopsis

In recent years, land value capture has attracted increasing attention as a result of its potential for funding transport infrastructure. However, it is crucial to examine the evidence of the impact of transport infrastructure on land value as it is increases in land value following new transport infrastructure which predicates policies of land value capture. There has been substantial research into this issue recently in the US. But, in the UK, only a few studies have considered this subject and these studies have concentrated on London. The capital is different in many aspects from other places in the UK. Other conurbations such as Manchester, Sheffield, Tyne and Wear, etc. might be more representative for British cities. Following studies on the impact of light rail transit on property prices in Manchester and Sheffield which employed hedonic models, the Tyne and Wear Metro seems to be an appropriate case to study in the UK context using new techniques.

This paper looks at the relationship between transport infrastructure and land value using Tyne and Wear Metro as a case study to examine the impact of Tyne and Wear Metro on the value of residential properties using a new methodology. Traditional techniques to understand changes in property value such as hedonic models, which use multiple regression modelling, normally assume that the observations in the regression are independent of one another. However, the spatial autocorrelation often present within geographical data means this is unlikely to be the case. In this paper, with the accessibility information derived from the Tyne and Wear Accessibility Model and other social economic data derived from census 2001, the methodology employs a Geographically Weighted Regression model, a new approach to spatial data analysis. It works by modifying multiple regression modelling to be better suited to geographical enquiry so that property prices, in this case as the dependent variable, is then explained by a number of spatially defined factors including transport accessibility of the house location. It is hoped that the estimation of the importance of transport accessibility in determining house prices will help to identify the potential for land value capture associated with transport investment.

The results from GWR do clearly reveal a spatially varying relationship between property prices and a number of spatially defined variables. The initial results from the global regression model show that the internal factors of the property and socio-economic classification of its location are the dominant determinants of property prices while transport accessibility variables, as key components of property location reflecting land value, are significant too in determining property prices. The spatial analysis with GWR indicates that most local parameter estimates of the variables vary significantly over Tyne and Wear area. Through mapping the results of local parameter estimates from GWR, this paper concludes that public transport accessibility does affect property prices, particularly in relatively poor neighbourhoods and property value is increased in some areas as a result of being close to city centre, confirming the recent trend of gentrification following the trend of suburbanisation of the past decades.

The Impact of Transport Infrastructure on Land Value Using Tyne and Wear Metro As Case Study

In recent years, land value capture as a potential means of financing transport infrastructure has attracted increasing attention. However, it is essential to identify the relationship between transport infrastructure and land value so as to identify how much transport infrastructure contributes to land value uplift. These issues have been of interest for a long time. In the early stages, comparison methods were used to give some findings on these issues (Pickett and Perrett 1984;Cervero and Landis 1993). These were replaced by the increasing use of hedonic price methods to identify the impact of transport investment on land value. This is particularly so in the US where there have been substantial studies into this issue (Weinberger 2000; Cervero and Duncan 2002a; 2002b). In the UK, a couple of studies have employed hedonic price methodology to evaluate the impact of light rail system on house prices in Manchester (Forrest and Glen 1995) and Sheffield (Henneberry 1998).

However, in order to properly understand the relationship between transport infrastructure and land value, it is necessary to deal with spatial data. Traditional multiple regression, including hedonic models, normally assume that the observations in the regression are independent of one another. This is unlikely in spatial analysis where spatial correlation (correlation of a variable with itself through space) is likely to be present. Spatial data is of this nature likely to follow the first law of geography which is "everything is related to everything else, but near things are more related than distant things." (Tobler 1970). Thus in this paper, a new technique, Geographically Weighted Regression (GWR) which takes account of spatial autocorrelation by adding a coordinate to each point allows the gross amount of value added by transport service over space to be examined through GWR. The method is used with property prices as the dependent variable which is then explained by a number of spatially defined factors including the transport accessibility of the house location. The importance of transport accessibility will help to identify the potential for land value capture associated with transport investment.

LITERATURE REVIEW

In the literature, studies on the impact of transport infrastructure on land value mainly examine changes to property price on the basis that the location of a property reflects, to a certain degree, the value of the land on which the property sits. This section reviews results from the literature on the impact of transport infrastructure on land value before turning to the methods used to value these impacts. Transport accessibility is clearly identified as a very important factor in location and the relationship between accessibility and location is explored in the final part of this review.

Impact of transport infrastructure on land value

Amongst all the studies in the US, only the studies by Landis *et al.* (1994), Lawless and Dabinett (1995) claimed no discernable effect found on residential property. Other studies give statistical evidence of residential property increase, of up to 25%, which is attributed to rail transit provision(Armstrong and Jr. 1994;Cervero and Duncan 2002;Hack 2002). Accessibility to transport has been found in Hong Kong to be an important determinant of house prices where access to minibus emerges as the most influential factor in determining house prices (So *et al.* 1997). In Japan, along the Tokaido line (near Tokyo) the value of commercial parcels of land within 50m of stations increased by 57% following the introduction of the railway line (Cervero 1998).

In the UK, the rise of housing prices in London, due to new rail transit has been dramatic. Don Riley, a south London property developer, has estimated that land values around stations on the Jubilee Line extension have increased by £13bn in total when the cost of the extension itself was only £3.5bn. Similarly, the Channel Tunnel rail link has made house prices in Stratford and east London rise significantly (Riley 2001). A recent study looking at the impact of London Jubilee Extension found positive but variable results in residential property price change (Chesterton 2002). A very early study into the impacts of the London Victoria Line showed that property values in the catchment of the line increased between 1% and 5% as compared with properties outside the catchment (Wacher 1971). The *ex post* study looking at the impact of the Croydon Tramlink did not assess changes in land use and land value (Thomas and Copley 2002).

However, apart from London, evidence of land value uplift has not been found elsewhere in the UK. The first study into the impacts of Tyne & Wear Metro revealed that there was a rise of residential housing price in two of the Metro lines but there was a fall of housing prices in the other two metro lines at the same time (TRRL 1984). A later study into the longer-term impacts of Tyne & Wear Metro failed to find statistical evidence of land value uplift resulting from the introduction of Metro (Daboudi *et al.* 1993). Similar findings were underlined in the Manchester Metrolink study (Forrest and Glen 1995) as well as the Sheffield Supertram study (Lewis 1998).

It is therefore necessary not to overstate the potential effects of transport infrastructure. Hall and Hass-Klau (1985) argue that: “transport improvements by themselves can never achieve anything; they merely facilitate urban change. It will only happen, however, if other urban policies make it do so”. In other words, transport infrastructures should be integrated with urban planning policies to help regeneration. Nevertheless, Knight (1980) pointed out that “the degree of land use impacts can be identified to be relevant to the following factors: co-ordinated land use policies, developable land, regional development trends and favourable social and physical conditions. For substantial land use impact to occur, it appears that nearly all of these factors must be favourable”. The success of London dockland’s development following the presence of Dockland light rail is a very good illustration of this.

Methods to evaluate impacts

Hedonic price methods are now the most common approach to analyse property prices so that it can be taken into account that these are a function of many variables. It has been widely considered to be the best method available to identify the effects on house prices associated with factors such as proximity to transportation facilities (Cervero and Duncan 2001). However, there are problems with how to appropriately interpret hedonic-based analyses of transport investment and, for example, Forrest and Glen (1995) and Weinberger (2001) have discussed problems in this context specifically relating to the important areas of model specification and market stability.

Methods based on simple comparisons have been employed in a number of, particularly earlier, studies (TRRL 1984;Cervero and Landis 1993;Daboudi *et al.* 1993;Pasha 1995). The price changes of houses in the catchment areas of a station are compared with the property price changes in control areas. But this method seems unable to identify the complicated features of the determination of property value which is highly multi-dimensional. Other methods such as SP surveys, qualitative analysis and projected rateable values have been brought into play in some studies as complementary ways to help better examine land value impacts.

Transport accessibility

The literature described above identifies the accessibility of a location, determined mainly by the transport system and land use pattern, as an important element of the external factors that influence house prices. It is thought that transport infrastructure impacts on property price, through this function of transport accessibility which makes the concept of transport accessibility central to this study. The term “accessibility” has been debated in the literature on the transport planning studies for some time and refers to the ease of reaching potential destination from a certain location by means of a particular transport system (Morris *et al.* 1979;Handy and Niemeier 1997;Zhu and Liu 2004;Horner and Mefford 2005).

There are various approaches to accessibility measures, depending on the purpose of accessibility study. The Technical Guidance on Accessibility Planning in Local Transport Plans (DfT 2004) categorises three main types of accessibility measure: Access Measures - “one of the simplest forms of measures”, e.g. proportion of the population having access to a bus service within 10-minute walk from home; Threshold measures – “the most commonly used accessibility measure”, e.g. the threshold time series (time bands) of accessibility to a specific service or location by public transport; Continuous measures – “the most robust approach”, e.g. Hansen/gravity accessibility measures - the general accessibility to a certain service such as employment by public transport. Whilst this latter measure is perhaps the best measure since it gives the idea of the overall opportunities for one purpose for a particular location, but it should be remembered that (particularly) accessibility measures are prone to data limitations and also limitations due to methodological issues (DfT 2004).

The specification of a measure for accessibility is critical for obtaining sensible results. This is especially so when moving to the use of a lower level of data aggregation through the use of smaller zones to obtain more accurate estimates requires that more accurate data is needed as an input (Handy and Niemeier 1997). Travel time has been found significant in house location choice for all types of household (Zondag and Pieters 2005). Travel choice, engaging with definition of origins and destinations as well as the measurement of attractiveness, is very complex. In terms of the relationship of transport accessibility and land use, the jobs-housing concept has long been the centre of transport and land use studies (Ma and Banister 2005). As a result, employment is now considered as the most likely conventional destination type for an accessibility measure on the grounds that commuting is probably the most regular form of travel (Horner and Mefford 2005). For this, a continuous measure is the most robust type among three types of accessibility measure and thus a Hansen accessibility measure is used in this study. The specific measure used is the Hansen accessibility to employment (i.e. accessibility to all employment opportunities weighted by the distance to the origin) based on information provided by Newcastle City Council on behalf of the Tyne and Wear Partnership calibrated to one minute intervals.

DATA ACQUISITION

To conduct statistical analysis and to enable statistically significant results to be generated it is essential to acquire ample data. For this study this includes property prices data as well as socio-economic data and importantly, good quality transport accessibility data. Many data sources have been explored before making a decision as to how to make appropriate data acquisition for this study.

Property data

Transaction property price data are normally considered as ideal data for property related analysis on the grounds that these prices are the agreed and accepted prices by the market. In contrast, asking prices can be seen as expected prices which are valued by agencies. Whilst these reflect a market valuation, there may be some unrealistic extreme cases. In some ways, asking prices may be more appropriate for the purpose of examining the effect of external factors influencing house prices, such as transport accessibility, than transaction data as the latter may vary due to internal factors such as decoration style, garden or parking space whilst asking prices can be seen more generalised in terms of internal factors. Transaction data are unavailable in England due to confidentiality but asking prices are available and form the basis this study. Current property asking prices advertised on the internet are the source used with data being drawn from a website www.icnewcastle.co.uk which provides a service called ‘icproperty’ containing the advertisements of property selling in Tyne and Wear. The advantages of this source is that it gives sufficient information about the property and the neighbourhood environment at full postcode level to allow the study to add demographic and social-economic factors to each property.

This data has been collected at the postcode district (e.g. NE1). For each postcode district area, various numbers of advertisements, from between 50 and 200 can be found on this website every day. The advertisements update from time to time depending on sale results. As there are about 30 postcode districts in Tyne and Wea, this gives nearly 3000 properties’ asking prices. This is more than sufficient for a multiple regression analysis. One day’s worth of properties for each postcode district throughout May has been used for property data collection. The main advantage of using asking prices from the internet has been the easy access to considerable data as well as giving a sample originating from a number of major estate agencies in Tyne and Wear area rather than relying on a single agency. However, there are some obvious disadvantages of this data source. First, a great deal of manual work was involved as the information for each property needed to be exported to Excel spreadsheet one by one and then formatted manually. Second, it was impossible to keep the records of original information electronically (although a paper copy was retained) and thus much care to be taken when data were being gathered.

Accessibility and social economic data

Accessibility and social economic data are used to explain the external factors of house prices. In this study, it is essential to obtain good transport accessibility data. The transport planning team at Newcastle City Council on behalf of Tyne and Wear partnership was committed to developing a model to assess transport accessibility in Tyne and Wear region and this is an on-going project. This study uses the most comprehensive of the accessibility measures – the Hansen accessibility – a continuous measure. Whilst this is available in four forms, accessibility by public transport accessibility to employment, education, shops and health care services, this study uses the public transport accessibility to employment for reasons advanced in the literature review. For accessibility by car, data are available under three conditions of road network – congested network, half-congested network and un-congested network but only from an origin to a single point in the Network. As a Hansen type measure for car accessibility is not easily available and as this study is focussing on public transport accessibility, the data for car accessibility to Newcastle city centre (Haymarket) under a half-congested network was derived for each property location. The half-congested network is reported on the basis of giving travel times between the congested network and un-congested network (although the results of the analysis do not appear to be sensitive to which type of network being used).

Social economic data like income and ethnic group were derived from census 2001 data at the level of Output Area (OA) which were created, as far as possible, by grouping together postcodes, thus allowing better integration between geographical information referenced by census and postcode geographies. On average, OAs contain between 200-400 people and between 120 and 150 households. There are approximately 3,714 OAs in Tyne & Wear. As the property data was obtained at full postcode level (containing about 2000 properties), each property was mapped at the centroid of the postcode unit and then social economic data was allocated to each property by GIS. Thus, each property data observation had all the socio-economic information associated with it.

METHODOLOGY

This study is using a new technique, the Geographically Weighted Regression (GWR) model, to evaluate the impact of transport accessibility on property prices. This GWR model is based on the traditional multiple regression model, called the "global regression model" as compared with the GWR model which takes into account of the distance between one data point and another. Consequently it is necessary to first establish the global regression model before extending the analysis further using the GWR model.

Global regression model

"Location, location and location" – the real estate industry is all about location. As a result, house prices involve not only internal factors, such as the quality of the house itself, but also external factors, such as accessibility and environment, which are highly related to location. On this basis, the house prices are defined as a function of a group of variables, which are shown below:

$$P_i = f(C, T, N) \qquad (1)$$

Where

C is a vector of characteristics of properties: type (FLAT, TERR, SEMI, DETA), number of bedrooms (BEDROOM);

T is a vector of transport accessibility: travel time to employment opportunities using a Hansen measure by public transport (PT_Han) and travel time to city centre (Haymarket) by car under half congested network - explain (Car_HCon);

N is a vector of the neighbourhood environment effects which are measured by the status of households and ethnic distribution as well as the accessibility to schools which has been identified as one of the key factors to determine the location of houses in Tyne and Wear (TRRL 1984). In this case, the status of households is captured by the top and the bottom of National Statistics Socio-economic Classification (NS-SeC): higher professional occupations (%HPROF) and long term unemployment (%UNEM). Ethnic distribution focuses on ethnic minority (%ETHNM) and accessibility to schools is to be controlled by the average point score of the nearest primary school (SP_AVE). The average point score for each school is calculated by allocating points to each pupil's exam results in statutory tests and dividing this total by the number of eligible pupils in each subject (DFES 2004).

The variation in property prices in the data set, based on equation (1), is given by the following global regression model.

$$P_i = \alpha_0 + \alpha_1 TERR_i + \alpha_2 SEMI_i + \alpha_3 DETA_i + \alpha_4 BEDROOM_i + \alpha_5 SP\_AVE_i + \alpha_6 \%ETHNM_i + \alpha_7 \%HPROF_i + \alpha_8 \%UNEM_i + \alpha_9 CAR\_HCon_i + \alpha_{10} PT\_Han_i \quad (2)$$

where

P_i is the price in pounds sterling at which a house asked to be sold;

FLAT, TERR, SEMI and DETA is a set of dummy variables that depict the type of property as shown below and where the estimated coefficient $\hat{\alpha}_i$ measures the shift in the intercept from each dummy variable relative to the excluded variable in the model (in this case the property type of flat).

FLAT is 1 if the property is a flat/apartment, 0 otherwise; TERR is 1 if the property is terraced, 0 otherwise;

SEMI is 1 if the property is a semi-detached, 0 otherwise; DETA is 1 if the property is detached, 0 otherwise.

BEDROOM is the number of bedrooms in the property;

SCH_APS is the average point score of the primary school in 2003 nearest to the house, derived from the performance statistics (DFES 2004);

%UNEM is the percentage of long term unemployment in the census 2001 output area in which the house is located;

%HPROF is the percentage of higher professionals, including large employers and highest managerial occupations and higher professional occupations, in the census 2001 output area in which the house is located;

%ETHNM is the percentage of ethnic minority in the census 2001 output area in which the house is located;

CAR_HCon is the car travel time (minutes) to measure the accessibility to the city centre (the point of Haymarket metro station chosen) by car using a half congested network level;

PT_Han is the public transport travel time (minutes) to measure accessibility to employment by public transport (including metro and bus) using hansen method.

Geographically Weighted Regression (GWR)

Geographically Weighted Regression (GWR) is a new technique for exploratory spatial data analysis developed by Fotheringham *et al.* (2002). 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 due to the likely autocorrelation of spatial data and can be revealed by mapping the residuals. Many different methods have been tried to tackle this problem in geographical analysis. GWR models such geographical relationships by taking into account of coordinates of the dependent variable. The traditional regression model with one predictor variable can be written as:

$$y_i = \beta_0 + \Sigma_k \beta_k x_{ik} + \varepsilon_i \quad (3)$$

Considering location of data points with coordinates (u_i,v_i), (3) could be rewritten as:

$$y_i = \beta_0(u_i,v_i) + \Sigma_k \beta_k (u_i,v_i) x_{ik} + \varepsilon_i \quad (4)$$

This can be then fitted by using the least squares method to give an estimate of the parameters at the location (u_i, v_i) and a predicted value. In GWR, data nearer to (u_i, v_i) is weighted more heavily than data further away. By this geographically weighted calibration, estimates of the parameters can be made for each data point with coordinates, which then can be mapped.

Expectations of the results

From the global regression model, the estimated parameters for variables TERR, SEMI, DETA, BEDROOM, SP_AVE and %HPROF are expected to be positive ($\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_7 > 0$) and %ETHNM, %UNEM, CAR_HCon and PT_Han are expected to be negative ($\alpha_6, \alpha_8, \alpha_9, \alpha_{10} < 0$) as positive/negative relationships of the property prices and these variables are expected.

One of the advantages of GWR model is the ability to examine the spatial variability of independent variables included as explanatory variables. Some independent variables therefore might be non-significant at the 5% level in the global regression model which hides the spatial variability but might vary significantly over the geographical area and be revealed by significant local parameters by the GWR modelling. It is expected that mapping the estimated parameters for public transport accessibility to employment, using the results of the local estimates from GWR, will show these distributed in accordance with public transport facilities, such as bus stops and metro stations, and the estimated parameters for car accessibility to city centre are expected to show a relationship with good road access, such as arterial roads.

ANALYSIS

The research is on going to find the best equation and this paper is based on sample data for Tyne and Wear area with NE postcode areas (this therefore excludes the parts of Sunderland area with SR postcodes). Two sets of results are shown below which emerge after using GWR 3.0 software. The first part shows the results from the global regression analysis, showing parameter estimates and their standard errors from the global model fitted to the data. The second part shows the results from spatial analysis with diagnostic for the GWR estimation. More importantly, the parameter estimates and other diagnostics, along with other referenced data, can be mapped through GIS so that the spatial variation can be seen clearly.

The results from Global regression model

Through calibrating the global regression model, the results of global regression parameters can be obtained. The diagnostic information suggests that 59% of the total variation in house prices is explained by the model (adjusted R^2) which is a reasonable fit given the cross-section nature of the data. The results of global regression parameters (Table 1) are shown below:

Table 1: Results of global regression parameters

PARAMETER	ESTIMATE	T
INTERCEPT	64650.09	3.37 **
TERR	7295.38	1.96 *
SEMI	24919.00	6.56 **
DETA	73828.57	17.19 **
BEDROOM	32835.91	22.59 **
SP_AVE	-699.69	-1.30 non-sig.
%ETHNM	-390.55	-1.49 non-sig.
%HPROF	5147.81	26.15 **
%UNEM	-3647.25	-3.61 **
CAR_HCON	1515.30	5.98 **
PT_HAN	-1903.60	-5.69 **

** = significant at 1% level for one tailed tests
* = significant at 5% level for one tailed tests

The results of global regression parameters (Table 1) contain the name of the variable whose parameter is being estimated, the estimate of the parameter, and the t statistic for the null hypothesis H_0: α=0. The alternative hypothesis is either H_1: α>0 or α<0 as explained above and the level of significance for rejecting H_0 in a one tailed test. The interpretation here, for the example of the number of bedrooms in a property, is that an increase in one bedroom will lead to £32835 increase in house price on average, holding everything else constant. The t-value is 22.59 demonstrating that this global regression parameter – BEDROOM is significant greater than zero at a 5% level of significance. This result confirms the expectation of the parameter for bedrooms mentioned above. However, some results of the global regression parameters are either non-significant at 5% level or do not comply with the expectation above when significant.

Interpretation on global regression results

To see if the results confirm the expectations mentioned above or not, Table 2 below displays a comparison between outcomes and expectations. It shows the alternative hypothesis, each parameter (as discussed above), the sign of the estimated parameter and, where the parameter is significantly different from zero, whether the outcome matches a priori expectations.

Table 2: Outcomes and expectations

VARIABLES	H_1	ESTIMATED PARAMETERS ($\hat{\alpha}_i$)	OUTCOME MATCHES EXPECTATIONS (AGREE √)
TERR	$\alpha_1>0$	+	√
SEMI	$\alpha_2>0$	+	√
DETA	$\alpha_3>0$	+	√
BEDROOM	$\alpha_4>0$	+	√
SP_AVE	$\boldsymbol{\alpha_5>0}$	**-**	**non-sig. at 5% level**
%ETHNM	$\boldsymbol{\alpha_6<0}$	**-**	**non-sig. at 5% level**
%HPROF	$\alpha_7>0$	+	√
%UNEM	$\alpha_8<0$	-	√
CAR_HCON	$\boldsymbol{\alpha_9<0}$	**+**	
PT_HAN	$\alpha_{10}<0$	-	√

First of all, considering the impact of the internal factors including the types of property and number of bedrooms in this global regression model, in this table, $\hat{a}_1$, $\hat{a}_2$ and $\hat{a}_3$ are the global parameter associated with type of terraced, semi-detached and detach property respectively compared to flat. They were all expected to give greater value to properties than a flat. Also, it was expected the more bedrooms the higher value and this is clearly a statistically significant result. From Table 1, it can be seen that, globally, a terraced property adds £7295 more value than a flat and a semi-detached or a detached property adds even more value at £24919 or £73828 respectively. Similarly, one additional bedroom increases a property price by £32835 on a global basis.

With respect to the socio-economic factors, %ETHNM and %UNEM were expected to decrease the property value but only %UNEM is significant in the global regression. %HPROF and having a better school nearby would be expected to lift property value and whilst this is the case for %HPROF variable (+5147 - significant at 5% level), the SP_AVE variable is not significantly greater than zero at a 5% level. So in the global regression model, the factors of high professional and unemployment reflecting income do, as expected, significantly contribute positively and negatively to property value respectively. However, factors such as school performance points and percentage of ethnic minority do not appear to contribute significantly to the explanation at a 5% level of significance.

In terms of both 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 car/public transport travel time (worse car accessibility to city centre and public transport accessibility to employment opportunities) would lead to lower property prices, i.e. better accessibility would increase property value. Whilst H_1 is confirmed for the public transport variable PT_Han at 5% level, for the car variable CAR_HCon, H_0 must be accepted. These results tell us that a property with better accessibility to employment opportunities by public transport have increase in value for about £1900. For cars, in general terms, the worse the accessibility to city centre, in ierms of being further away from town, the higher the property price and this gives evidence for the trend of suburbanisation happened in the UK in the past decades. The value for car accessibility does not change much whether this or the full or un-congested network figures is used.

In summary, of the ten variables incorporated in equation (2), the outcomes of seven variables, including all the internal factors (TERR, SEMI, DETA, BEDROOM) and socio-economic classification factors (% HPROF, %UEM) and public transport accessibility variable (PT_Han), appear to agree with the expectations. Two other variables, the socio-economic variables (SP_AVE and %ETHNM) relating to school quality and percentage of ethnic minority, are insignificant and car accessibility (CAR_HCon) does not have the outcome supporting the initial expectations. The next section discusses the impact of spatial analysis in this context.

GWR estimation

The information for the GWR estimation shows that the adjusted coefficient of determination (adjusted R^2) has increased from 0.592 to 0.822 and the Akaike Information Criterion in the global model is reduced from 46778.67 to 45946.44 implying that the GWR model gives a better explanation, after taking into account degrees of freedom.

As identified above, one of the advantages of GWR is the ability to examine spatial variability hidden in a global regression model. Property prices are very likely to vary over different geographical areas. Based on a Monte Carlo significance test procedure, the GWR software can examine the significance of the spatial variability of parameters identified in the local parameter estimates. The results of this Monte Carlo significance test (Table 3) demonstrate that, apart from the results for the variables TERR and DETA, there is significant variation in the local parameter estimates for the remaining eight variables. However, in this paper, the focus is on transport accessibility variables and the variables that did not appear to match the expectations in the global regression model as shown in bold in Table 3. Thus, the results of local parameter estimates from GWR for the three variables - SP_AVE, %ETHNM and CAR_HCon plus variable PT_Han will be mapped in the next section to examine their spatial variation.

Table 3: The results of Monte Carlo significance test

PARAMETER	P-VALUE	SIGNIFICANCE LEVEL
INTERCEPT	0.00	***
TERR	0.19	non-sig.
SEMI	0.01	**
DETA	0.31	non-sig.
BEDROOM	0.00	***
SP_AVE [1]	0.00	***
PCTETHNM [1]	0.00	***
PCTHPROF	0.00	***
PCTUNEM	0.00	***
CAR_HCON	0.00	***
PT_HAN	0.00	***

*** = significant at 0.1% level
** = significant at 1% level
1. but not significant in the global regression

Mapping the local estimates

All the local estimates can be mapped but, due to space limitations, this paper will concentrate on four variables for the reasons mentioned above. Local estimates associated with PT_Han, CAR_HCon, SP_AVE and %ETHNM are shown in Figures 1 – 4 below. In all cases, the point symbols are proportional circles classified by four bands with smaller circles for negative values and larger circles for positive values. Also, the points lie at the properties which were positioned at the geographic centroids of the full postcode area. It is clear from the maps that the parameters demonstrate considerable spatial variation.

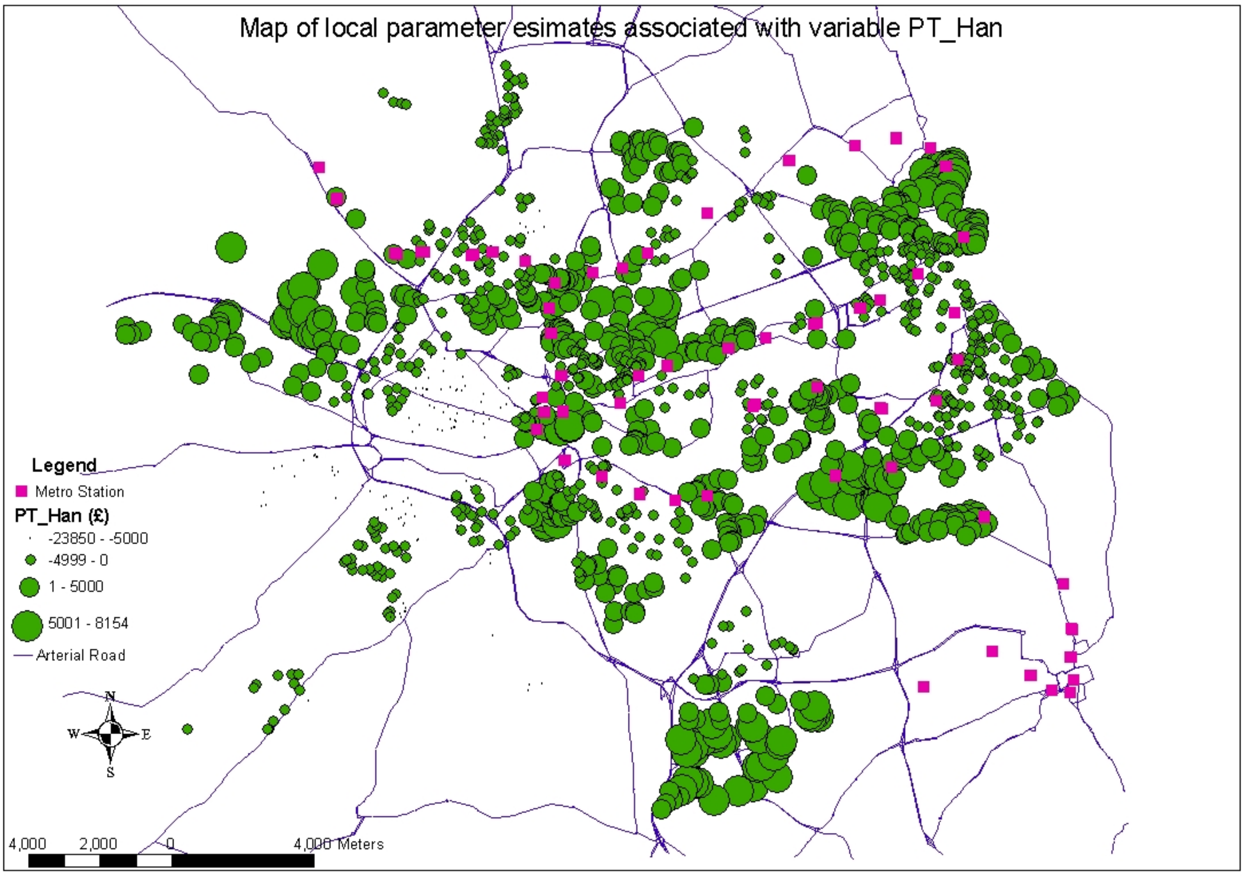

Figure 1: Map of the local parameter estimates associated with the variable PT_Han

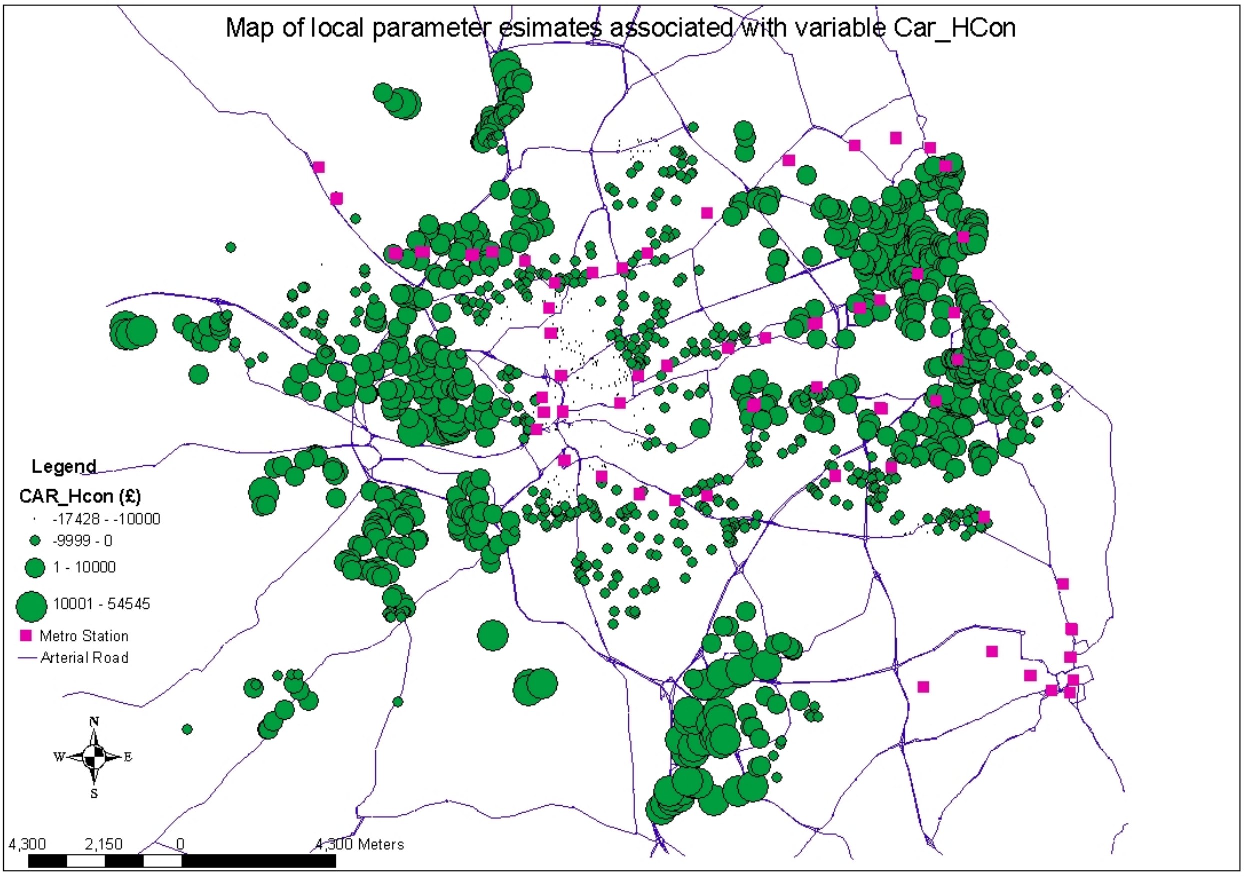

Figure 2: Map of the local parameter estimates associated with the variable Car_HCon

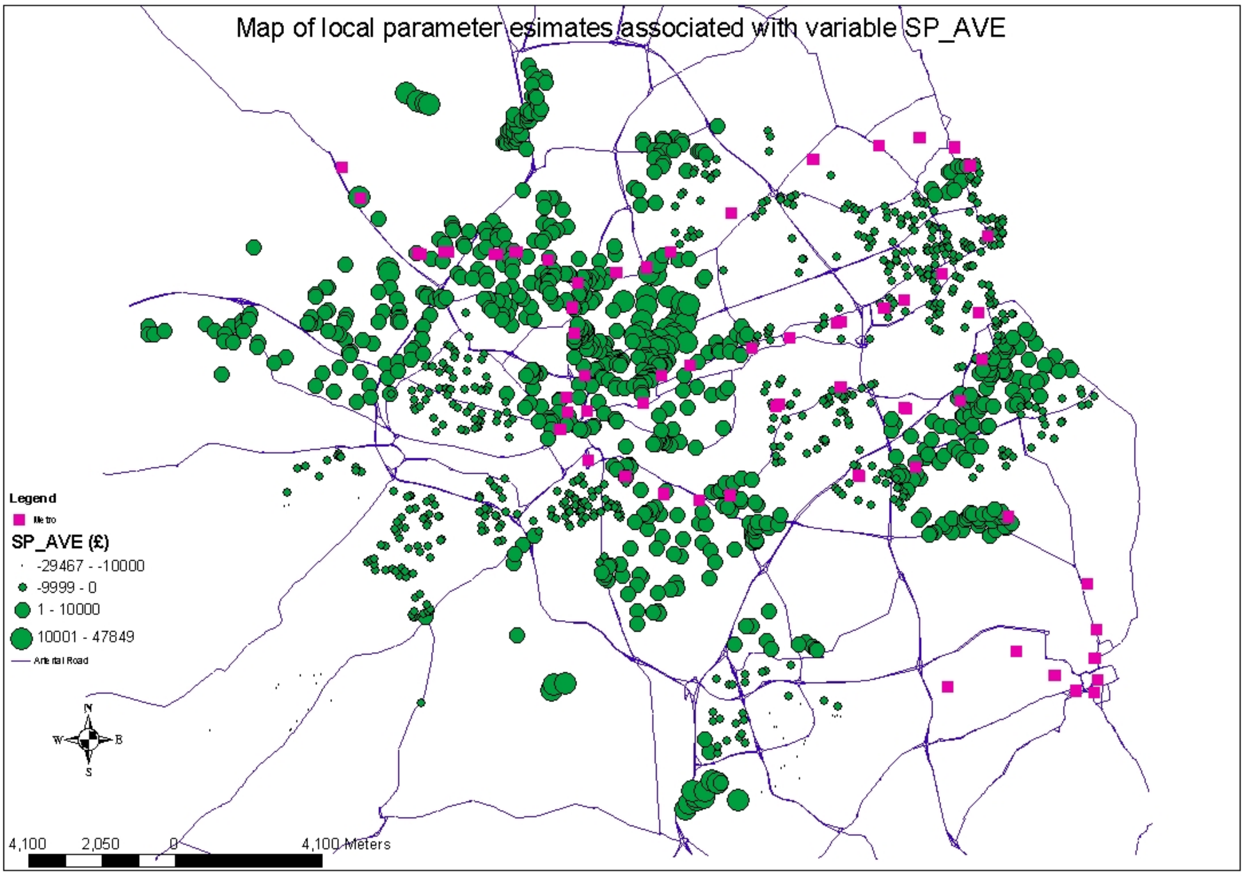

Figure 3: Map of the local parameter estimates associated with the variable SP_AVE

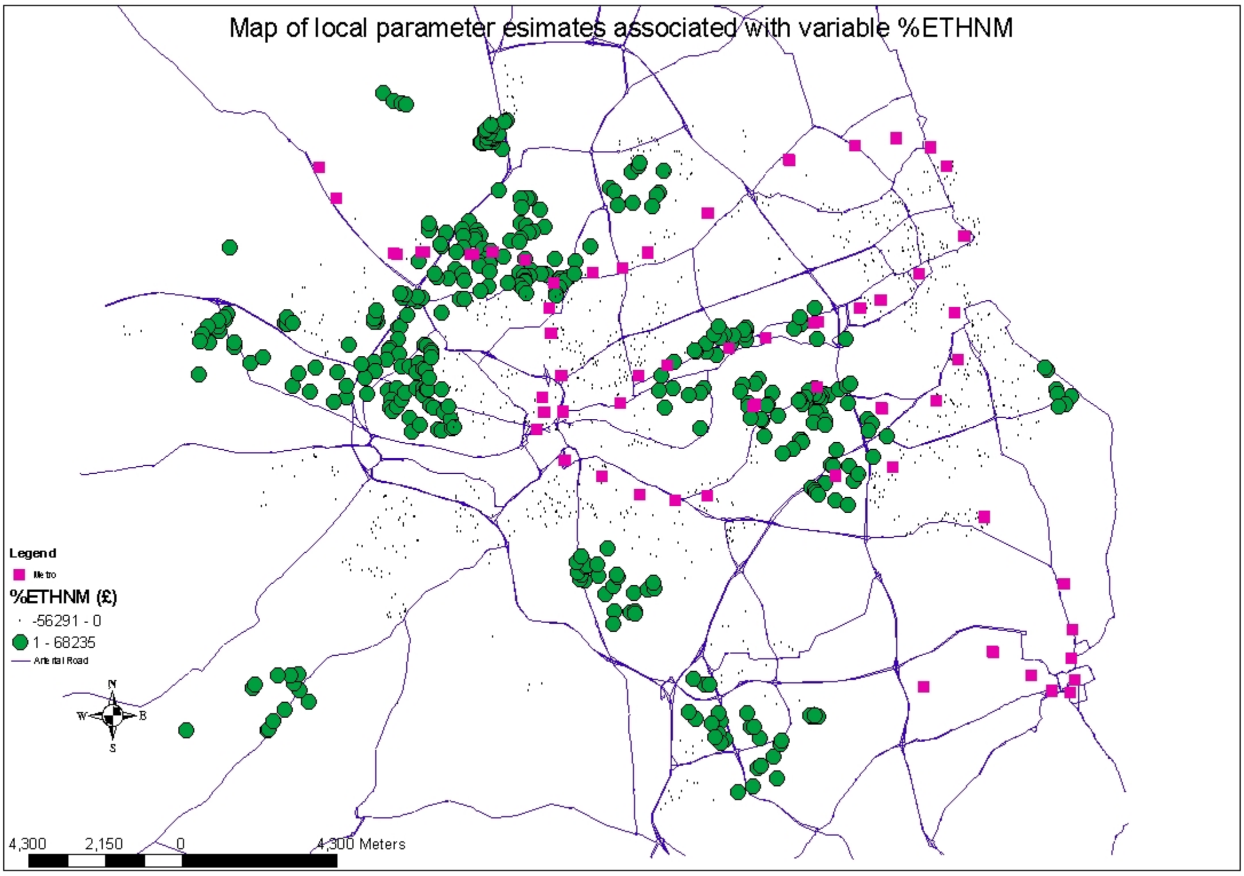

Figure 4: Map of the local parameter estimates associated with the variable %ETHNM

Figure 1 shows that there is clear variation in the local parameter estimates for variable PT_Han over different areas, being negative in some relatively poor neighbourhoods and positive in relatively rich neighbourhoods. A negative relationship between public transport travel time and property price is expected whilst a positive relationship between public transport travel time and property price is opposite to expected. These local parameter estimates in Figure 1 reveal the spatial variation in the impact of public transport accessibility on property prices showing that public transport accessibility contributes more in value terms to properties in poorer neighbourhoods as compared to richer neighbourhoods. The fact that the property prices in poorer areas are generally much cheaper than richer areas might make the expected negative relationship particularly evident, with up to -£23850 value, in the Fenham area which is well known as a poor neighbourhood. So, we can see that the public transport accessibility to employment (as measured by the PT Han variable) has a more important impact on properties in poorer neighbourhoods than richer neighbourhoods.

Similarly, Figure 2 exhibits clear variation in the local parameter estimates for the variable Car_HCon over different areas, being positive in some areas, and negative in others, but the areas concerned are not easily classified as all poor or all richer neighbourhoods. Again, the negative relationship between car travel time to the city centre and property price is expected and where this relationship exists in areas close to the city centre, accessibility to city centre (in terms of reducing travel time by one minute), gives an additional estimated value to the property price of £17428 and this confirms the latest trend of gentrification in the UK, “Where professional small households or single people were increasingly seeking out core city residential options…this trend…seems to be particularly prominent in Manchester, Newcastle and Birmingham” (Hass-Klau *et al.* 2004). Those areas with positive relationships between car travel time to city centre and property price are, as a result of these results, hypothesised to have other, stronger neighbourhood features, such as low income, specific amenities, such as the seaside or being close to a major shopping centre. For instance, Fenham is such a poor neighbourhood that the fact that it is close to city centre does not help the property value rise in this area. Nevertheless, the coast is a specific amenity which contributes more strongly than proximity to city centre to the property value in North Shields.

In the global regression model, there is no evidence that school performance plays an important role in property value explanation. But in the local estimates provided by the GWR model, the evidence for significant spatial variation can be seen in Figure 3. There are clear clusters and this may be because some good secondary schools and their feeder primary schools do play an important part in property value.

In the global regression model, the contribution from the %ETHNM variable is not significantly greater than zero at the 5% level but the spatial estimates are identified as significant at 0.1% level. As can be seen from Figure 4, there are some areas where the percentage of ethnic minority shows a positive impact on property prices and which needs further socio-economic study to examine this issue.

CONCLUSION

In conclusion, the global regression model offers the basis for explaining variation in property prices with the additional results from GWR clearly revealing a spatially varying relationship between property prices and the variables concerned. Based on the results from global regression model, property prices are mainly determined by the internal factors and socio-economic classification. Public transport accessibility does affect property prices particularly in relatively poor neighbourhood albeit this effect is marginal in absolute terms. In general, properties further away from city centre tend to be more expensive as a result of suburbanisation in the UK in the past decades. Taking a closer look by using GWR model, it can be seen that property value is increased in some areas by being close to the city centre and this confirms the recent trend of gentrification. Primary schools performance seems not to be a useful determinant of property value but its spatial variation suggests it might be related to the quality of secondary school. The factor of ethnic issue attributing property value requires further study.

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