

Relationship Between Transport Accessibility and Land Value

Local Model Approach with Geographically Weighted Regression

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In recent years, land value capture has attracted increasing attention because of its potential for funding transport infrastructure. It is well acknowledged that transport infrastructure can improve accessibility to employment and amenities; thus one might expect that it is the improved accessibility that adds value to land. Therefore, the issues in the relationship between transport accessibility and land value rise in connection with the concept of land value capture. A study looked at the relationship between transport accessibility and land value with the implication of a local model, geographically weighted regression (GWR). Traditional techniques, such as hedonic models, used to understand the attributes of land value, are global models that could be misleading in examining the spatially varying relationships, such as transport accessibility and land value. By using the Tyne and Wear region in the United Kingdom as a case study, the study revealed that nonstationarity existing in the relationship between transport accessibility and land value indicates that transport accessibility may have a positive effect on land value in some areas but a negative or no effect in others; this suggests that a uniform land value capture would be inappropriate. The use of GWR allows such spatially varying relationships to be revealed, leading to a better understanding of the factors determining positive land value uplift and the implications of spatially dependent transport access premiums in housing values in the context of value capture policies.

Land value capture is topical in the United Kingdom as a potential means of financing transport infrastructure. Transport infrastructure, especially significant transport facilities, such as highway and modern light rail systems, are believed to have improved transport accessibility greatly to services (employment and amenities). The classical urban land economics theories (1–3) indicate transport cost is an important determinant of land value. With increasing distances to the central business district (CBD), where employment and amenities concentrate, the land value increases as a result of the decreasing transport cost. The policy of land value capture is based on this theory and relates to capturing the increased value of land arising from improving the accessibility provided by transport facilities to services to fund or partly fund transport infrastructures. To explore the

ideas behind land value capture, it is important to understand well the relationships between transport accessibility and land value.

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

In this paper, a relatively new technique, geographically weighted regression (GWR), which addresses the issue of spatial autocorrelation, is used to examine the relationship between transport accessibility and land value, aiming to make contributions to the land value capture policy discussions. By embodying spatial coordinates into the traditional global regression model, GWR provides a set of local estimates using a weighted least-squares process in which the weights are linked to the distance of the observation to the location of the regression point. The Tyne and Wear metro system, located in Tyne and Wear in the northeast of England, is used as a case study. This region has a population of 1.07 million (5) accommodated in five metropolitan districts comprising the cities of Newcastle upon Tyne and Sunderland and the boroughs of Gateshead, North Tyneside, and South Tyneside.

EXISTING LITERATURE, ITS DEFICIENCIES, AND IMPLICATIONS FOR THE STUDY

There have been substantial studies, particularly in United States, on the impact of transport investment on land value. Studies since the 1990s are summarized in Table 1. Most literature on this topic concentrates on the positive side of the results, but a closer look shows considerable variation in the findings. First, because different

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TABLE 1 Summary of Recent Literature

Study	Location	Impact of	Impact on	Findings	s/ns	Methods
Nelson (1992) (7)	Atlanta, U.S.	Heavy rail (HR)	Residential property (R)	+(lower income)/–(higher income)	s	N/A
Bollinger et al. (1998) (8)	Atlanta, U.S.	HR/highway	Office rent	–(HR)/+(highway)	s	Hedonic price (HP)
Gatzlaff and Smith (1993) (9)	Miami, U.S.	HR	R	up to +5%	s/ns	Comparison/HP
Landis et al. (1994) (10)	California, U.S.	HR/light rail (LR)/highway	R	+\$2.29/m for HR, +\$2.72/m for LT, no effect for highway	s/ns	HP
Armstrong (1994) (11)	Boston, U.S.	HR	R	+6.7% communities with commuter rail compared with other communities	s	Comparison
Chen et al. (1997) (12)	Portland, U.S.	LR	R	up to +10.5%	s	HP
Cervero and Landis (1993) (13)	Washington, D.C., U.S.	HR	Commercial property (C)	+	ns	Comparison
Cervero and Duncan (2001) (14)	Santa Clara, U.S.	HR/LR	C	+120%	s	HP
Weinberger (2001) (15)	Santa Clara, U.S.	LR	Commercial rent	+(within 0.8 km)	s	HP
Hack (2002) (16)	Dallas, U.S.	HR/LR	R	+25%	N/A	N/A
Weinstein and Clower (2002) (17)	Dallas, U.S.	LR	R/C	+12.6%(R)/+13.2%(C)	N/A	Comparison
Cervero and Duncan (2002) (18)	San Diego, U.S.	HR/LR	C	up to +91.1%–9.9%	s	HP to 3 types of properties
Cervero and Duncan (2002) (18)	San Diego, U.S.	HR/LR	R	up to +46.1%–7.1%	s	HP to 3 types of properties
Cervero and Duncan (2002) (19)	Los Angeles, U.S.	HR/LR	C	up to +16.4%–29.8%	s	HP to 3 types of properties
Cervero and Duncan (2002) (19)	Los Angeles, U.S.	HR/LR	R	up to +14.2%–15.2%	s	HP to 3 types of properties
Davouti (1993) (20)	Tyne and Wear, UK	LR	R/C	+–	ns	Comparison
Forrest and Glen (1995) (21)	Manchester, UK	Metro	R	up to –8.1%	s	HP
Lawless and Gore (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 submarkets
Chesterton (2002) (6)	London, UK	LR	R/C	+	N/A	Agent's survey
RICS (2004) (24)	Croydon, UK	Tram	R/C	no discernable impact	ns	Kriging/IDW/GWR ^a

s = significant, ns = nonsignificant.

^aGWR was applied as an experiment with just three variables due to lack of data source.

approaches have been taken, the results are not comparable for the unit of values used, and Table 1 has tried to ameliorate this by presenting the results as the percentage of average values. Second, the table identifies a somewhat surprising lack of significant results for UK studies in contrast to U.S. studies. For example, the Jubilee Line Extension study failed to identify any significant effect in Phase 1 by using a hedonic price model, and this was substituted by the adoption of an agents survey in Phase 2 (6). Although this latter demonstrates positive results, the methodology is not as robust. Insignificant results in the UK might relate to difficulties of data acquisition in the UK, where transaction property data are not open to researchers. The table also highlights the frequent use of hedonic price models, and it is notable that the latest studies are applying hedonic price models to sub-categories of housing markets or seek to find alternative approaches to cope with the awareness of the variation that exists in the property market.

The hypothesis of this paper is that the use of global statistics, as used in previous studies, does not give a useful insight into issue of land value. As shown in Table 1, the relationship between transport

improvements and property values examined is not consistently treated because of the way in which the global statistics have been utilized, and this can be misleading in the examination of spatial relationships. For example, the global statistics for England may show that the age of houses does not affect house prices significantly. But in some parts of England, old houses, such as those built in Victorian times, have desirable character, thus generating higher prices than newer houses in the same area. In other urban areas, however, older houses built to lower standards to house workers in rapidly expanding cities in the 1850s may be in poor condition, resulting in substantially lower prices than for newer houses. The contrasting relationships in different areas are likely to have a canceling effect so that on average, across England, the age of houses appears to have no impact on the house prices. This means that use of a set of local statistics, in which data are analyzed at local level, is necessary to provide more accurate results in a study linking house prices to accessibility.

Some studies (7, 10, 18, 19, 23) have revealed nonstationarity between different areas in the relationship between transport accessibility and land value. For example, in Atlanta, Georgia, proximity to

rail has a positive effect on house prices on the south side, where neighborhoods are dominated by higher-income groups, and negative effects were found on the north side, where neighborhoods are dominated by lower-income groups (7). Such spatial nonstationarity can arise for two reasons. One cause is model misspecification, particularly when there are missing variables arising from data unavailability or there are simply data that have been overlooked. Indeed, mapping local statistics can help improve the accuracy of the global model through the spatial patterns hinting at the presence of omitted variables. The second cause is the way in which fundamental differences exist across space for some variables. For instance, the same three-bedroom house is likely to be cheaper in a poorer area as compared to a richer area. This type of variation needs to be studied on the basis of demography varying over space, and a better local model, such as GWR, is able to deal effectively with this spatial nonstationarity.

DATA ACQUISITION

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

House Price Data

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

At the time of data collection for this study, a website (www.icnewcastle.co.uk) advertised properties for sale in the Tyne and Wear region with sufficient information on property characteristics. With the information of full postcode unit (e.g., NE1 7RU), the data for this study were collected at the full postcode district (e.g., NE1) level, for which various numbers of advertisements, between 50 and 200, can be found on this website every day. The main advantage of this Internet data source is the easy access to considerable data provided by a number of major estate agencies in Tyne and Wear, in contrast to relying on a single agency, normally covering a local area. This data source provided 2,855 records that could be linked to the output area (OA) for census data. OAs are the smallest unit for UK 2001 census output data and are formed by grouping together full postcodes. OAs are designed to have similar population sizes and social homogeneity by reference to the characteristics of actual census data by using a recommended size of 125 households.

Neighborhood Environment Data

Neighborhood environment data, including social economic data, such as household status in relation to household income and ethnic group, as well as environment data, like schooling environment, are required to explain the external factors of house prices other than transport accessibility. In this study, household status is captured by "higher managerial and professional occupations" and "long-term unemployed," which are found in one of the widely used standard socioeconomic classifications in the United Kingdom [National Statistics Socio-economic Classification (NS-SeC)]. Ethnic distribution focuses on ethnic minority households and excludes white and mixed households. NS-SeC and ethnic data were extracted from UK 2001 census data at OA.

Proximity to good schools has been identified as a key factor with which to determine the choice in location of houses in Tyne and Wear (26). This is confirmed by other empirical studies (27–29), although whether primary school quality or secondary school quality adds more to house price appears to vary from city to city (28). Therefore, the environment data in this study use 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 general terms, it refers to the ease of reaching a 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 the accessibility study. Hansen–gravity accessibility measures, which measure the general accessibility to a certain service, such as employment by public transport (32), have been considered as the most robust approach. 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, must be measured in a different way, by using the nearest destination as the potential opportunity for accessibility measurement, since, in principle, every child at a certain age is regarded as living in the catchment area of the nearest school.

Accessibility within the region of Tyne and Wear is being modeled by Newcastle City Council, on behalf of the Tyne and Wear Partnership. At the time of this study, this modeling produced travel time as an accessibility measurement, by 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, or education, calibrated at 1-min 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 by using the highway speed by 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 complex, calculated by reference to a gravity-based formulation as follows:

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

where

t_i = travel time in zone i (OA $_i$),

j = index of available destination zones reachable from zone i ,

A_j = number of jobs at zone j accessible to large employers,

λ = deterrence parameter consistent with the trip distribution, and

t_{ij} = overall travel time from zone i to zone j (both journey time and walking to and 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 that identifies whether a property has good access to a metro station within walking distance, which is interpreted as within 500 m of the property. This has been achieved by setting up a buffer of 500 m around each metro station by using the geographic information system (GIS). There are few empirical studies on walking distances to and from light rail transit stations, but a study based on a survey in the city of Calgary, Canada, indicates that average walking distance to light rail stations is 326 m in the CBD area or 649 m in the suburban area (33). Consequently, 500 m is thought to be an appropriate walking distance to a Tyne and Wear metro station.

ANALYSIS AND RESULTS

This study uses 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

Numerous studies on the housing market have used hedonic price modeling to estimate house prices. To identify the main characteristics on which house buyers have placed value, Sirmans et al. reviewed 125 U.S. studies published in the last decade that have used hedonic price modeling (34). Their review found that a large number of characteristics have been included in hedonic price models. The most frequently included characteristics are plot size, square feet, age, number of stories, number of bathrooms, number of rooms, number of bedrooms, fireplace, central air-conditioning, basement, garage, deck, pool, brick exterior, distance to CBD, time on the market, and time trend. However, problems with model specification can often be observed, and this appears 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 hypothesizes house prices as a function of a bundle of attributes, which can be thought of as 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 neighborhood. Consequently, house prices can be seen as a function of a group of variables contained by three vectors:

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

where

\mathbf{H} = 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);

\mathbf{N} = vector of the neighborhood environment including two classifications of NS-SeC (hprof, unemp), ethnic minority group (ethnm), and average point score for secondary school (edu13pt); and

\mathbf{T} = 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 proximity to metro stations (inmsca).

These variables are described in Table 2. These specific variables modify Equation 2 to Equation 3:

$$\begin{aligned} P_i = & \alpha_0 + \alpha_1 \text{flat}_i + \alpha_2 \text{terr}_i + \alpha_3 \text{deta}_i + \alpha_4 \text{flatbed}_i \\ & + \alpha_5 \text{terrbed}_i + \alpha_6 \text{detabed}_i + \alpha_7 \text{bedroom}_i + \alpha_8 \text{edu13pt}_i \\ & + \alpha_9 \text{ethnm}_i + \alpha_{10} \text{hprof}_i + \alpha_{11} \text{unemp}_i + \alpha_{12} \text{pt08e13}_i \\ & + \alpha_{13} \text{carcemp}_i + \alpha_{14} \text{inmsca}_i \end{aligned} \quad (3)$$

In the United Kingdom, for internal attributes, the floor area, the age of the building, and the number of bathrooms have been found to be important determinant variables other than the number of bedrooms (35). However, constrained by data availability, the 14 variables included in the model were chosen. To avoid multicollinearity, transport accessibility variables were 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, and deta, respectively. In addition, scatter plots of the dependent variable against each independent variable suggest a linear regression model is suitable for this study.

GWR Model

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 modeled holds everywhere in the study area. However, this is not necessarily the case for house prices because spatial data are 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 non-stationarity, and misspecification. Misspecification always relates to the process of model establishment, leaving little that can be done through improvements of the technique. However, spatial dependency

TABLE 2 Global Regression Statistics and ANOVA Table

Variable	Estimate	t-Value	Outcome Matches Expectations (agree ✓/disagree ✗)
Property attributes			
flat (1 = yes; 0 = no)	15,197.95	1.44	N/A
terr (1 = yes; 0 = no) (terraced property)	-24,762.75	-2.57 ^a	N/A
deta (1 = yes; 0 = no) (detached property)	5089.74	0.43	N/A
# flatbed = flat * bedrooms	-16,132.52	-4.02 ^a	✓
# terrbed = terr * bedrooms	2135.57	0.67	✗
# detabed = deta * bedrooms	12,601.54	3.47 ^a	✓
bedroom: total number in the house	35,098.76	13.57 ^a	✓
Neighborhood attributes			
edu13pt: the average point score of the secondary school in 2003 nearest to the house	950.15	5.12 ^a	✓
% ethnm: % of ethnic minority in OA	121.86	0.54	✗
% hprof: % of higher professional occupations in OA	5,179.36	27.82 ^a	✓
% unem: % of long-term unemployment in OA	-4,290.68	-5.30 ^a	✓
Accessibility			
pt08e13: public transport travel time (minutes) to secondary school at peak hour (8:00 am)	-1,046.96	-3.62 ^a	✓
carcemp: car travel time (minutes) with capacity speed to employment	749.51	3.87 ^a	✗
inmsca: within 500 m of metro station catchment area (1 = yes; 0 = no)	10,407.59	3.76 ^a	✓
Summary statistics			
No. observations = 2,837 (18 outliers have been identified and removed)			
Dependent mean = 159,915			
R ² = 0.60 (GWR: 0.73)			

ANOVA	Sum of Squares	df	F-Value
OLS residuals	7,754,132,163,030.3	15.00	
GWR improvement	2,960,569,139,200.0	258.29	
GWR residuals	4,793,563,120,640.3	2563.71	6.13

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 α_7 and $\alpha_4/\alpha_5/\alpha_6$, and the intercept is given by adding the estimate α_0 and $\alpha_1/\alpha_2/\alpha_3$.

^a = significant at 1% level for a one-tailed test.

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 modeled through geographically varying parameter estimates rather than through the error term (35). Nevertheless, GWR can be seen as an alternative to, and one that is perhaps more intuitive than, spatial regression modeling.

In contrast to hedonic price models, and by assuming that all the assumptions of multiple regression are met, the local estimators provided by GWR are not best linear unbiased 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, Equation 4, is rewritten as

Equation 5 so that fitting by using the least-squares method gives an estimate of the parameters at the location (u_i, v_i) . GWR does this by weighting the data nearer to (u_i, v_i) more heavily than the 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.

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

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

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 a £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 type 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 α_4 (35098) in fact represents the price for one bedroom of a semidetached house. The estimate for flatbed α_{12} means the value for one bedroom of a flat compared to a semidetached house and similarly for a terraced or detached house. The value of one additional bedroom of flat/terraced/detached is then given by adding α_4 and $\alpha_{12}/\alpha_{13}/\alpha_{14}$; as a result, one additional bedroom of flat/terraced/detached is worth £18,966/£37,234/£47,700, respectively. Some results, such as for edu13pt, confirm the expectation of the parameters. However, some results of the global regression parameters either are nonsignificant at the 5% level or reverse to the expectation above where significant, and this is shown in Table 2.

For the internal factors, flatbed and terbed were expected to have less value than semibed, whereas detabed was thought to be more expensive than semibed. For socioeconomic 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 variables. Thus it can be seen that in the global regression model, the factors of high professional and unemployment reflecting household status do, as expected, significantly contribute positively and negatively to property value, respectively.

For car and public transport accessibility, more travel time means worse accessibility, so the alternative hypothesis H_1 for these parameters is expected to be negative; thus one more minute of public transport or car travel time (worse public transport accessibility to secondary schools and car accessibility to larger employers) would lead to lower property prices, that is, better accessibility would increase house value. Although H_1 is confirmed for the public transport variable pt08e13 at the 5% level, for the car variable carcemp, H_0 must be accepted. These results say that, in general terms, a house with better accessibility (1 min less) to secondary schools by public transport can add £1,046 to house value, whereas, for cars, 1 min closer to larger employers will reduce house value by £749. inmsca is significant at a 1% level, suggesting that, in accordance with expectation, a house within 500 m of a metro station is worth £10407 more than a house more than 500 m away.

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, this implies that the GWR model gives a better explanation, after degrees of freedom are taken into account.

As identified earlier, GWR gives the ability to examine spatial variability hidden in a global regression model. All the local parameter estimates can be mapped, but this paper concentrates on transport accessibility variables—pt08e13, carcemp, and inmsca. These parameter estimates are mapped in Figures 1, 2, and 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*-value 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 to identify the areas in which 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 Figures 1 and 2 and six bands in Figure 3. In all three figures, the lightest areas and darkest areas are significant, but the lightest areas exhibit positive house premiums, and the darkest exhibit negative house premiums.

It is clear from the maps that the parameters demonstrate considerable spatial variation. Although globally better public transport accessibility to secondary schools can add significant value to house price, from Figure 1 it can be seen that in most of the region, the two variables appear to be unrelated. Only two areas—the west end of the Tyne and Wear region and the Newcastle central area—emerge with such relationship, with value added from £2,500 to £6,240. In the west end, bus access to secondary schools is associated with the positive premiums, whereas in the other area public transport accessibility appears to be positively capitalized in relation to the metro access to secondary schools for pupils. As can be seen, the value of the global parameter (£1,046) is not in any of the significant value categories. As a global average value, it is also not indicative of the local value for most households.

The results from global regression show that better car accessibility to large employers reduces house value. Figure 2 shows that there are some areas where better car accessibility can add value from £4000 up to £17783, in particular, a large area in the center of Tyne and Wear, where the negative relationship confirms the latest trend of gentrification in the United Kingdom (36). The northwest area, with a positive relationship between car travel time to large employers and house prices, is hypothesized to have other stronger environment features, such as a countryside landscape, which contributes more strongly to property value than proximity to employment by car. The northeast area's high positive relationship is thought partly to be the result of proximity to a seaside amenity and partly to be caused by the attractiveness of metro access to employment. The reason behind this positive relationship in the southeast area needs to be identified with more detailed socioeconomic information in further study.

In contrast to the global value of £10407.59 as the premium of being within 500 m of a metro station catchment area, such positive premium does not occur in most areas in the region, as shown by Figure 3. This suggests the global model has overestimated the value associated with metro access for most houses. In the south and the southwest of Tyne and Wear, the estimate values are 0 as these areas are so far away from the metro network that they are not accounted for in comparable areas by the local model. Two locations, where proximity

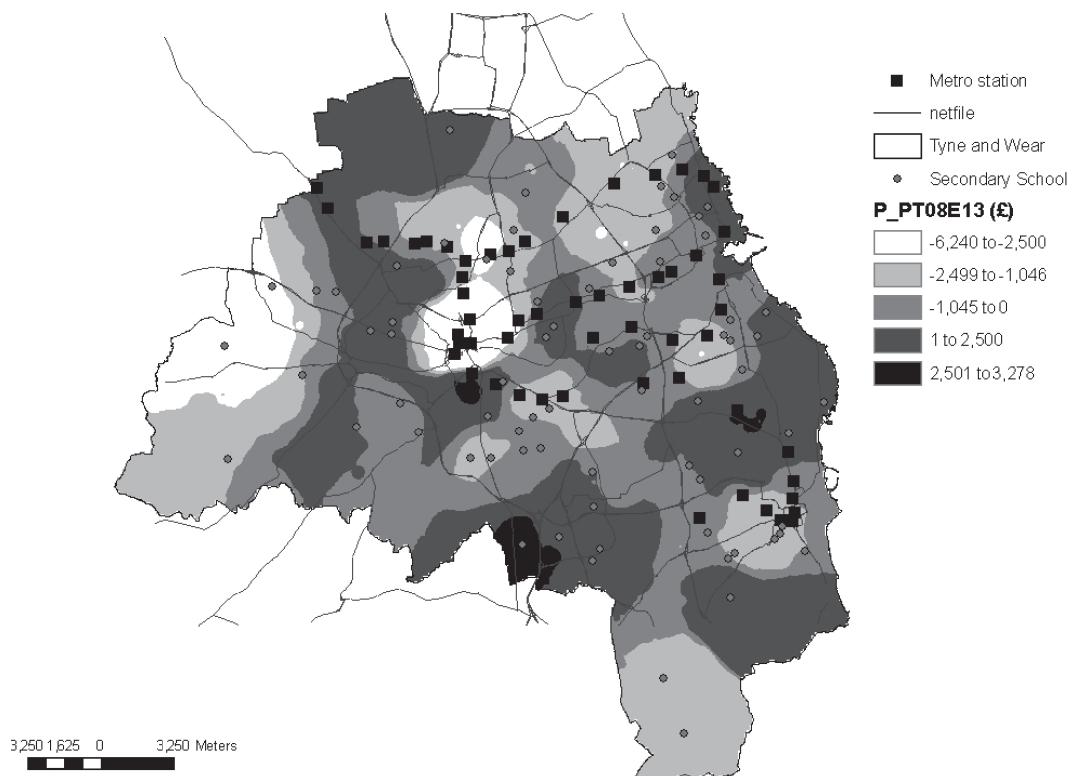


FIGURE 1 Map of parameter estimates associated with variable pt08e13.

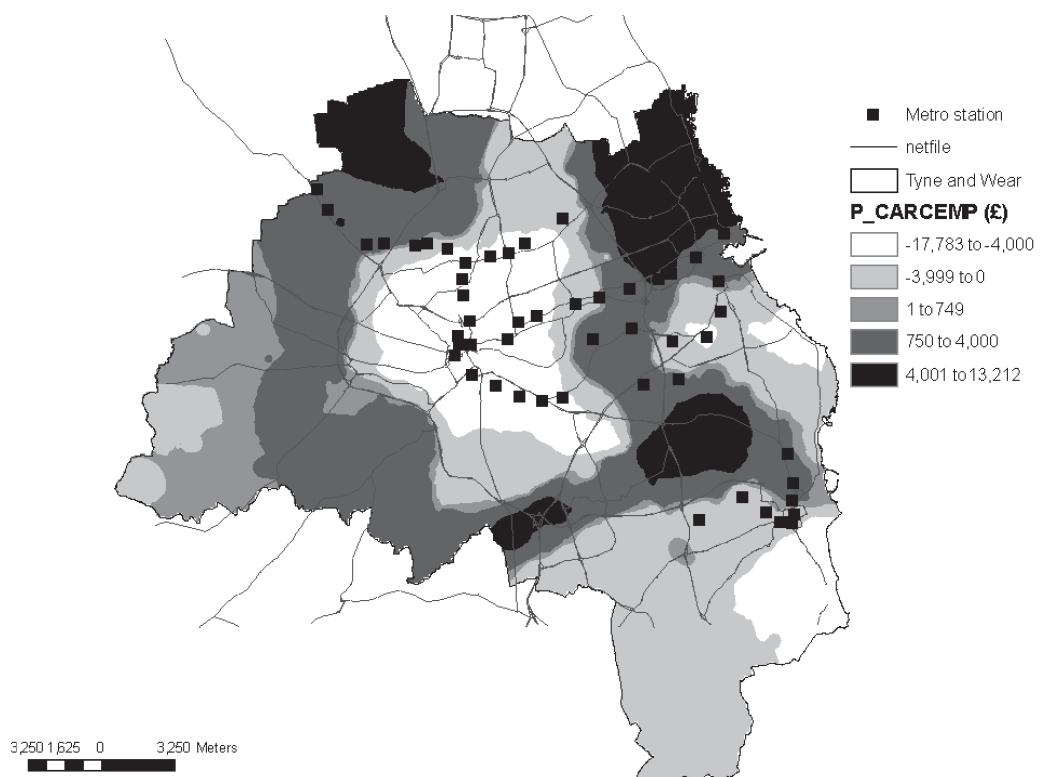


FIGURE 2 Map of parameter estimates associated with variable carcemp.

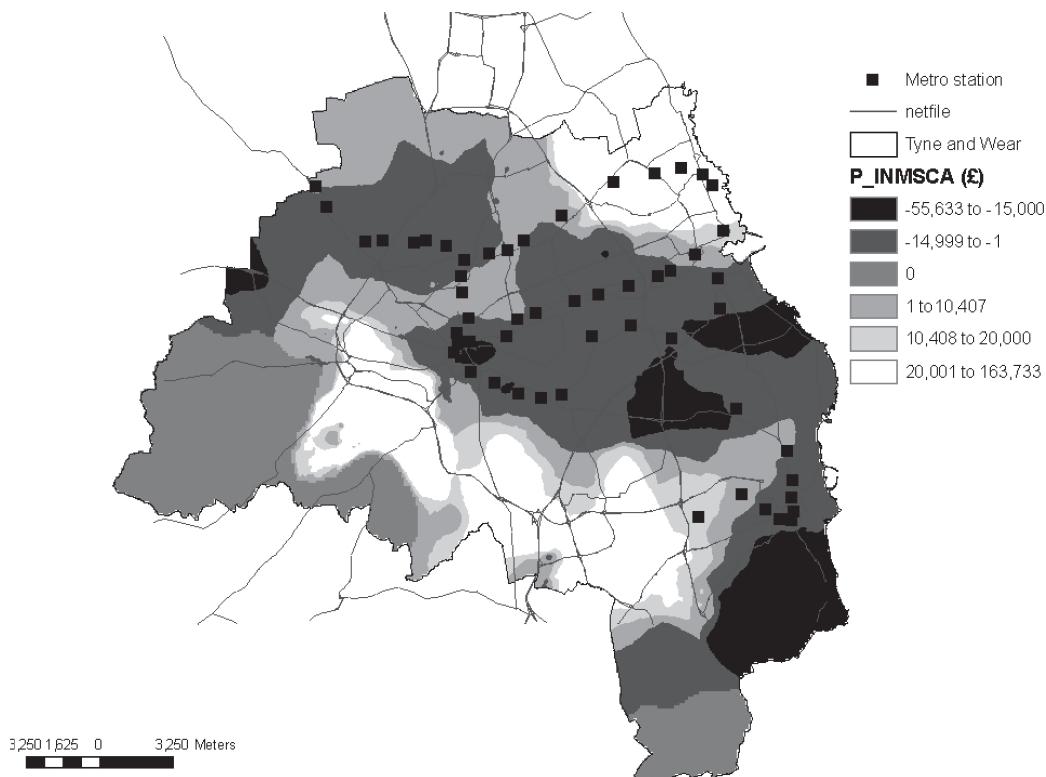


FIGURE 3 Map of parameter estimates associated with variable inmsca.

to a metro station has a significant negative effect on house prices, relate to city center properties located adjacent to metro lines, which may acquire a negative effect from this proximity. Two areas exhibit significant positive premiums. The area to the southwest of Tyne and Wear is not located in any catchment areas of metro stations, and in the northeast of the region, Whitley Bay, the closeness of metro stations raises the prices of properties by more than £20000.

DISCUSSION AND CONCLUSION

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

The global regression model offers the basis for explaining variation in house prices with the additional results from GWR clearly revealing a spatially varying relationship between house prices and transport accessibility variables. On the basis of the results from the

global regression model, there is strong evidence that proximity to metro stations can uplift house price significantly, and better public transport accessibility to secondary schools also can add significant value to a house, whereas the closer to larger employers by car, the lower the house price. By taking a closer look by using the GWR model, one can find the relationships are not stationary in connection with neighborhood features, which appear in some cases to obscure possible benefit from transport accessibility as translated into house prices to various degrees.

This empirical work suggests that the local model approach with GWR is appropriate for examining the relationship between transport accessibility and land value. The existence of nonstationarity between transport accessibility and land value means that transport accessibility may have a positive effect on land value in some areas but in others a negative or zero effect. Neighborhood features may help explain such variation, but this means a uniform land value capture policy would be inappropriate. Therefore, great care should be taken in the consideration of a policy of land value capture for the funding of transport infrastructure. The way forward is to understand better the factors that 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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