A Spatial Analysis of modes of commuting in urban and rural areas

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Abstract

This study compares global and local analyses of non-car commuting modes and the probability of living in different urban and rural areas for a case study in Yorkshire, UK, with commuter residence area are used as the response variable. The analyses compare Generalized Linear Models describing bus, cycling and walking to estimate the impact of different commute modes in urban and rural areas. The three variables were found to be significant predictors for the models and indicate different odds of the commuter living in the urban area, as would be expected. An analysis of the non-stationarity of these was undertaken using a Geographically Weighted Regression analysis, which showed how the probability of residing in a particular type of urban and rural area, as described by commuting patterns, varied spatially within the study region. The local analyses provide critical evidence to support and guide local policy in its ambition to reduce car dependence in both rural and urban areas.

Keywords: Commuting mode, Spatial variation, Geographically Weighted Regression.

1. Introduction

In recent years, governments have encouraged people to use healthy and public modes of transport instead of private vehicles for their daily commuting trips, thereby reducing the consumption of energy, environmental pollution, traffic congestion. People travel to work in the United Kingdom accounts for 16% of all trips traveled (Beck,2016). Commuting by active transport (cycling walking, etc) and public transports is not widely practiced and people are highly car-dependant in the UK (Goodman,2013). Furthermore, there is a large difference in the modal shares amongst urban and rural area. This is because bus, cycling, and walking are more advantageous in urban settings with well-established networks (cycle routes) transportation services and with a more compact form than the rural area (Susilo,2008). The commuting modal share in urban areas results from different commuting choices by urban and rural commuters, as shown in the results. The primary aim of this study is to evaluate the relationship between commuting patterns and modes and the probability of living in different urban and rural area types.

2. Methods

2.1. Data and study region

The present study uses census commuting flow data for the Yorkshire and the Humber region in the UK (Figure 1) extracted from the 2011 census, available through UK Data Service. This includes counts of workers who live and work in the region, the location of their usual residence, their place of work and their usual commute modes. The analyses use the Middle Layer Super Output Areas(MSOAs) level of geographical aggregation for commute trips. The 2011 Rural-Urban Classification (Bibby,2013), allows MSOAs to classified into Urban area and Rural areas.

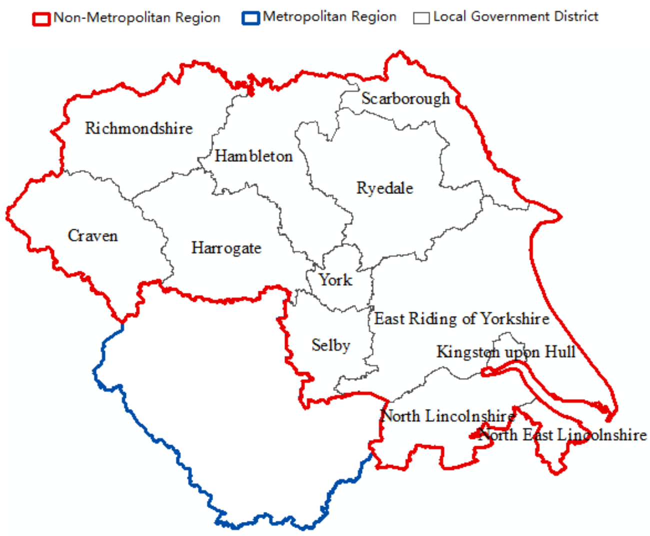

Figure 1: The study region, Yorkshire and Humber, UK.

The analysis considered the non-metropolitan region of Yorkshire and the Humber as a case study (see Figure 1). There are 12 local government districts and 221 MSOAs which comprise of 142 urban areas (classified in Bibby (2013 as *City and Town* and *City and Town in a Sparse Setting*) and 79 rural areas (classified as *Town and Fringe*, *Town and Fringe in a Sparse Setting*, *Village*, *Village in a Sparse Setting*). A total of 0.63 million employed workers, aged 16–74 are described by the data from the 2011 census in the study region, of whom 0.43 million lived in the urban area, 0.20 million lived in rural areas.

2.2. Analysis

Global Trend Analysis

The analysis used Generalized Linear Models (GLMs) to globally model the impact of commuters' tendency to the three commute modes on the probability of living in urban area. The urban and rural classification of MSOA residence areas of the commuter were set as the response variables and bus, cycling and walking commuting shares calculated for each residence area as predictors. Note that the response has two categories: urban area which was given a value of 1 and rural area which given a value of 0. The first independent variable to be considered was bus share, with cycling share and walking share added sequentially to GLM. Thus three models were considered:

$$pr(y = 1) = logit(b_0 + b_1 m_1)$$

Model 1

$$pr(y = 1) = logit(b_0 + b_1 m_1 + b_2 m_2)$$

Model 2

$$pr(y = 1) = logit(b_0 + b_1 m_1 + b_2 m_2 + b_3 m_3)$$

Model 3

Where y is a 0/1 indicator showing whether the category of residence area is urban, m_1, m_2 and m_3 respectively indicate bus share, cycling share and walking share in respondent residence area.

Geographic Variation

For analysis of non-stationary relationships (Comber,2011; Li, Z.,2013) between the probability of living in the urban area and independent variables, the Model 3 was extended to a Geographically Weighted Regression (GWR) analysis, as described in Brunsdon et al., (1996), as follows:

$$pr(y=1) = logit(b_{0(u_i,v_i)} + b_{1(u_i,v_i)}m_1 + b_{2(u_i,v_i)}m_2 + b_{3(u_i,v_i)}m_3)$$

Model 4

Where (u_i, v_i) are the coordinates of ith residence area centroid in two-dimensional geographical space, the coefficients including b_0,b_1,b_2 *and* b_3 can be considered as functions of these coordinates.

3. Results

3.1. Differences in commute modal share between urban and rural areas

Table 1 shows that urban commuter relative to rural commuter are associated a) with greater levels of active transport (12.16% greater for all modes, 7.52% walking, 4.64% from bicycle) and public transport (4.84% greater for all modes, 4.71% for bus, although similar levels (0.12%) for train), b) lower levels of private motorized transport(-17.49% for all modes, -18.95% car). The results show that urban commuters are more likely to travel to work by walking, cycling and bus than rural commuter and the difference in walking share are bigger than that in cycling and bus shares which have almost same difference value.

Commuting mode	All commuter	Urban commuter	Rural commuter	Difference
Public transport	7.35	8.91	4.07	4.84
Bus	6.02	7.53	2.82	4.71
Train	1.31	1.35	1.23	0.12
Underground (incl. light rail)	0.02	0.03	0.02	0.01
Private motorized transport	71.13	65.52	83.01	-17.49
Car(van)	63.63	57.56	76.51	-18.95
Passenger	6.54	6.94	5.69	1.25
Motorcycle (incl. scooter)	0.96	1.02	0.81	0.21
Active transport	20.81	24.71	12.55	12.16
Walking	14.93	17.34	9.82	7.52
Cycling	5.88	7.37	2.73	4.64
Taxi and Other	0.71	0.86	0.37	0.49
Taxi	0.42	0.55	0.14	0.41
Other	0.29	0.31	0.23	0.08

Difference = Urban commuter- Rural commuter

Table 1: The modal share of usual main commute modes among regional commuters, with differences in modal share between urban and rural commuter.

3.2.Trend of living in urban area for commuter by three commute modes

Global trends

As shown in Table 2, the three independent variables are added one by one, starting with the bus, then adding cycling, finally, walking, and show concomitant decreases in Akaike's Information Criterion(AIC) score with each additional variable. This indicates that the cycling and walking variables significantly improve the model. The result of deviance tests between Model 1, Model 2 and Model 3 are shown in Table 3 and all three variables were found to be significant. The odds ratios in Model 3 indicate the following statements:

- -The relative odds of living in urban area are associated with an additional 53% probability commuting by bus compared to rural areas;
- -The relative odds of living in urban area are associated with an additional 72% probability commuting by cycle compared to rural areas;
- -The relative odds of living in urban area are associated with an additional 12% probability commuting by walking compared to rural areas.

Model	**Variable**	**Odds ratio**	**Lower 95% CI**	**Upper 95% CI**	**AIC**
Model 1	Bus	1.75	1.49	2.11	200.336
Model 2	Bus	1.5	1.25	1.85	165.297
	Cycling	1.77	1.42	2.3	
Model 3	Bus	1.53	1.26	1.92	143.666
	Cycling	1.72	1.35	2.27	
	Walking	1.12	1.07	1.19	

Table 2: Results of the GLM analyses of probability of living in urban area for commuter (Models 1 to 3), all variables significant at the 99.9% level

Terms	**Df**	**Residual Df**	**Residual Deviance**	**Deviance Reduction**
NULL	NA	220	288.1603	NA
Bus	1	219	196.3363	91.82395
Cycling	1	218	159.2971	37.03918
Walking	1	217	135.6661	23.63103

Table 3: Analysis of deviance of the terms associated with the probability to be living in urban area, significance at the 99.9% level.

Geographic Variation

The results of the GWR analysis are shown in Table 4. The inter-quartile ranges indicate the spatial variation in the odds ratios in Table 2 when they are considered using local analyses. From Table 4, little variation was found walking, ranging from 43.7% to 72.5%. Considerable variation in the odds ratio was observed in cycling which ranged from 1.308 to 2.176.

Variable	Minimum	1st Quartile	Median	3 rd Quartile	Maximum	IQR	Global
Bus	1.099	1.437	1.551	1.725	1588	0.288	1.53
Cycling	0.9597	1.308	1.517	2.176	92.23	0.868	1.72
Walking	0.4258	1.134	1.16	1.186	6.801	0.052	1.12

Table 4: The variation in the odds ratios of the independent variables from the GWR model(model 4), with the Inter-Quartile Range (IQR) providing a measure of the spatial variation.

Figure 2 maps the spatial variation in the odds ratios for cycling and walking. This indicates that local variation in cycling is less than for bus which has more short-range variation and evident clusters. From the North West to the South East of the study region, the probability of living in the urban area for the commuter who cycle to work increases evenly. There is a cluster around York that was clearly defined as a mono-centric city in both of cycling and bus. It is evident that the influence range of York is bigger for patterns of bus travel than for cycling.

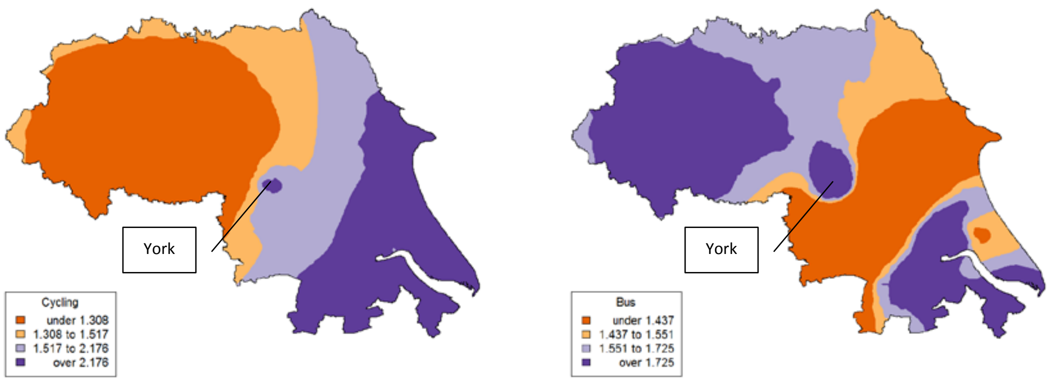

Figure 2: Spatial variation in the odds ratios associated with cycling and bus.

4. Conclusions

In this research, we examined the relationship between urban and rural areas and the modal shares associated with three types of sustainable commuting. We successfully used the GLMs to globally evaluate impact of the tendency of commuter to the three commute modes on the probability of living in urban area in study region and used a GWR analysis to capture the spatially non-stationary relationships. The results showed that the relationship of the three commute modes on the tendency to live in urban area varied across the study region but with some interesting and policy relevant patterns.

5. Acknowledgements

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