Spatial Analysis of Dog Ownership and Car Use in the UK

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Findings

Walking the dog, and other dog-related practices, have been suggested to be particularly car-dependent. Secondary data analysis presented finds associations between the high energy use practices of car travel and dog ownership. There is a strong association between the rate of dog ownership and car km travelled per person. This relationship holds when controlling for income, level of urbanisation housing type and demographic variables.

1. RESEARCH QUESTIONS AND HYPOTHESES

While much transport research focuses on the journey to work, leisure and other non-work related activities are responsible for a large share of car mileage and related environmental damage (Anable 2002; Mattioli, Anable, and Vrotsou 2016; Schlich et al. 2002). In this context, there is suggestive evidence that dog-related activities may be associated with higher levels of car travel. Based on a survey of dog owners in Sydney Australia, Kent and Mulley (2017) identify "a high level of car use for dog-related trips" and "a propensity for people to travel relatively long … distances with their dogs" (p.281) for activities such as taking the dog to a recreational area, to training or to the veterinary. They estimate 2.4 million dog-related car trips occurring in Sydney each week. Mattioli et al. (2016) find that the time-use activity 'walking the dog' is associated with high levels of car use in the UK, because of its high frequency and car dependence. Recent studies in Seattle U.S. identify walking the dog as a generator of car travel (MacKenzie and Cho 2020). These findings illustrate the broader point that energy and carbon-intensive activities are often undertaken for the sake of household pets (Strengers, Nicholls, and Maller 2016). Murray et al. (2010) find in a survey (n ~3000) that in rural areas the dog ownership rates are high. They suggest housing is on average larger in rural areas, giving more space for pets, in addition to the influence of demographic factors.

In this paper, we test the following two hypotheses, derived from the above-mentioned research, based on unique spatial data for the UK:

1. there is a relationship between dog ownership and levels of car use

2. such a relationship remains substantial even after controlling for income, and urbanisation

Table 1. Data sources

Variables	Source (reference)	Spatial unit
Dog population by postcode outcode	(Animal and Plant Health Agency 2016)	Post code outcode[*]
Postcode polygons	Ordnance Survey Code Point Open Polygons https://digimap.edina.ac.uk	Post code outcode
Mean vehicle kilometres travelled per person per year	Cairns et al. (2014)	LSOA
Rural Urban Classification	http://geoportal.statistics.gov.uk/datasets/rural-urban-classification-2011-of-lower-layer-super-output-areas-in-england-and-wales	LSOA
Experian LSOA income estimates	(Experian Limited 2007)	LSOA
LSOA population weighted centroids	https://ons-inspire.esriuk.com/arcgis/rest/services/Census_Boundaries/Lower_Super_Output_Areas_December_2011_Centroids/MapServer	LSOA
lookup table to link LSOA and postcode geographies	ONS (2017)	LSOA

[*] Also known as Postcode Districts. There are 2235 in England and Wales

2. METHODS AND DATA

Car use data is available at LSOA[1] resolution and dog ownership is at a coarser non-overlapping postcode outcode geography (e.g. LS21). To avoid ecological fallacy (Openshaw 1984) we aggregated to postcode outcode resolution. A lookup table is available to link LSOA and postcode geographies (ONS 2017).

The data preparation phase produced variables at the postcode outcode level including: i) car kilometres travelled per person per annum; ii) dogs per person; iii) income quintile iv) rural-urban classification. Analysis was carried out using R and Rstudio (www.r-project.org). To aid reproducibility the code is shared by the authors https://github.com/DrIanPhilips/Dogs_and_car_use . Data sources are as shown in Table 1.

3. FINDINGS

There is a considerable positive correlation (R=0.67 Spearman, 0.55 Pearson) between car kilometres travelled per person per annum and dogs per person, suggesting that as dogs per person increase so do car km per person. Since both dog ownership and car use may be associated with wealth and high consumption lifestyles, we next controlled for median income of each area, showing the relationship between car kilometres travelled and dog ownership for each income quintile (Figure 1). The results show that the association between car kilometres per person and dog ownership is highest in high-income areas (fourth and fifth quintiles), but, remains higher than 0.5 in lower income areas. Furthermore, for each income group there appears to be

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1 English Lower Super Output Areas (LSOA) are UK census geographies including on average ca. 625 households and 1500 individuals. There are 32,844 LSOAs in England
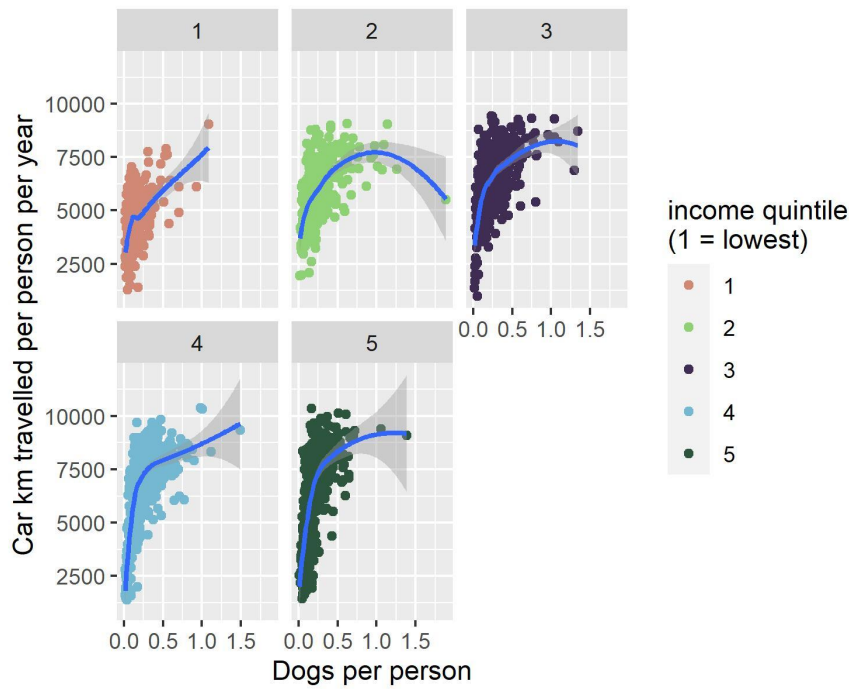
Figure 1. Line of best fit of the relationship of dogs per person and km per person by income quintile, with error bars (95% confidence interval). Quintile 1 is lowest income and 5 the highest. Spearman correlation coefficients by income quintile of the outcode-level median incomes as follows: income quintile 1 = 0.64, income quintile 2 = 0.55 income quintile 3 = 0.61 income quintile 4 = 0.68 income quintile 5 = 0.71.

a threshold of dog ownership at which the car km per person changes rapidly. We also plot the level of urbanisation and dog ownership (Figure 2). The strongest positive correlation between dog ownership and car use is in major conurbations, the association between dog ownership and car use is weakest in rural areas.

A bivariate Ordinary Least Squares regression model with car kilometres travelled per person as the dependent variable and dogs per person as the sole predictor has an adjusted R^2 of 0.32 (Model A) suggesting dog ownership alone is a moderate predictor of car km travelled, supporting hypothesis 1 above.

An adjusted regression model with car kilometres travelled per person as the dependent variable and dogs per person, income quintile and rural urban classification as predictors (Model B) gave an adjusted R^2 of 0.6103, with a positive, statistically-significant coefficient for dog ownership. When dogs per person was removed from the model (Model C), the adjusted R^2 dropped to 0.5802. This suggests that dog ownership retains some association with car km travelled even after accounting for income and level of urbanisation, supporting hypothesis 2 above.

A further regression model (Table 2, Models D and E) additionally considers age, gender, dwelling type employment status, and level of car ownership; the types of characteristics considered in an analysis of survey data by Kent and Mulley (2017). This model considers some other factors connected to the
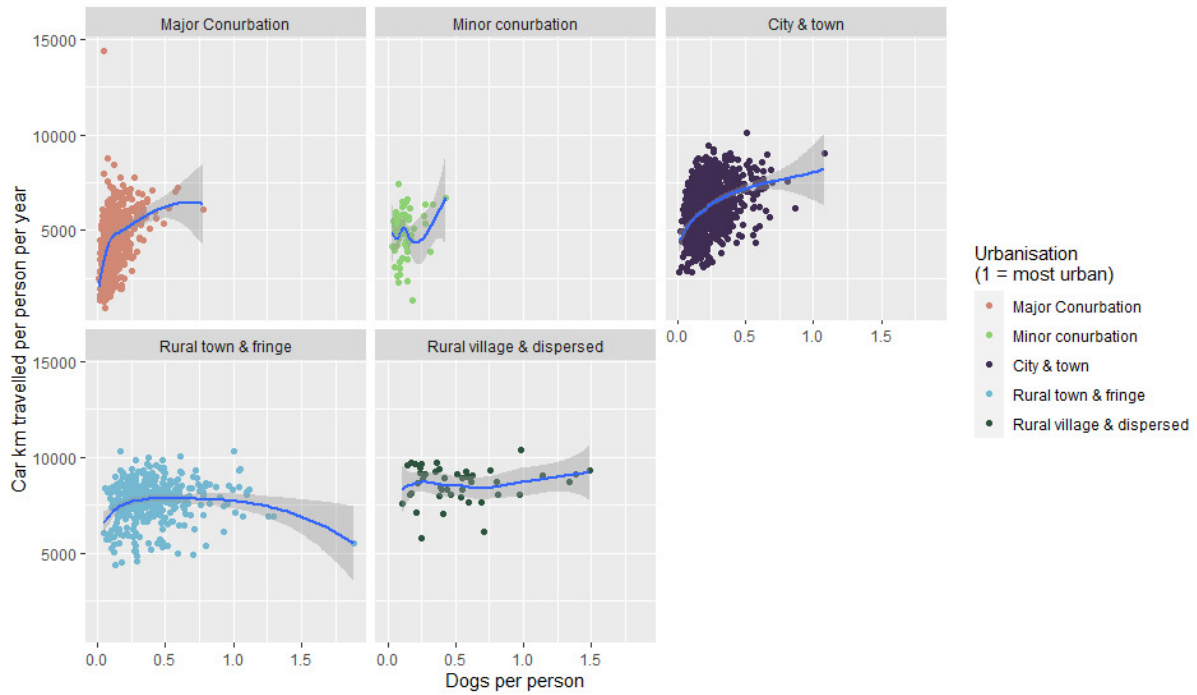
Figure 2. Relationship between dog ownership and car km travelled by level of urbanisation with error bars (95% confidence interval). Spearman correlation coefficients by level of urbanisation are: Major conurbation= 0.55; Minor Conurbation = 0.15; City and Town = 0.43; Rural Town and Fringe = 0.14; Rural Village and Dispersed = -0.03

built environment such as housing type. We also include the proportion of families with dependent children. When 'Dogs per person' was removed from the model, the adjusted R^2 still dropped albeit slightly. This model further supports the hypotheses above.

However, when we checked the OLS regression residuals we found all had significant spatial auto-correlation (See Table 2). Models A to C had strong autocorrelation, and Models D-E had moderate spatial autocorrelation. Spatial autocorrelation of residuals could lead to lead to underestimated standard errors and overstated statistical significance. LeSage (2014) suggests a Spatial Durbin Model is a good start point to try to address this. The model fit for each Spatial Durbin Model (using the AIC metric) improved upon their corresponding OLS model. Also, the model fit for models B and D which included dog ownership as a predictor have a slightly better fit than Model C and E respectively which did not have dog ownership as a predictor.

In both the OLS and Spatial Durbin Models, the coefficient on dogs per person gets smaller as more covariates are added. In the Spatial Durbin Models, the coefficients for dogs per person are smaller than in the corresponding OLS model, but in all models, dog ownership remains a significant predictor of car travel supporting the hypotheses above. The reduction in the magnitude of the coefficient of 'Dogs per person' between Models A and D (in both Table 2 and 3) is substantial, suggesting that much of the variable's effect is accounted for by socio-demographic and built

Table 2. Ordinary Least Squared Regression model outputs, Dependent variable is car km travelled per person per year.

	Model A	Model B (dogs per person included)	Model C (dogs removed from model)	Model D (dogs per person included)	Model E (dogs removed from model)
Dogs per person	5,531***	2,098***		669***	
	(180)	(167)		(100)	
Income quintile		357***	380***	73***	70***
		(18)	(19)	(17)	(17)
Urban minor conurbation		1,044***	1,111***	-2	-6
		(157)	(163)	(92)	(93)
Urban city and town		1,687***	1,934***	334***	359***
		(62)	(61)	(44)	(44)
Rural town and fringe		2,818***	3,406***	934***	1,029***
		(88)	(77)	(63)	(62)
Rural village and dispersed		3,378***	4,243***	1,060***	1,214***
(reference class Urban Major conurbation)		(189)	(183)	(119)	(118)
Median age				19***	22***
				(7)	(7)
% Female				-157***	-161***
				(15)	(15)
% Detached housing				48***	50***
				(3)	(3)
% Semi-detached housing				19***	18***
				(2)	(2)
% Terraced housing				21***	22***
(reference class % flats)				(2)	(2)
% Economically active				50***	52***
				(4)	(4)
% No car				-38***	-39***
				(3)	(3)
% families with dependent children				-17***	-20***
				(5)	(5)
Constant	4,610***	2,926***	3,089***	8,096***	8,272***
	(53)	(73)	(75)	(766)	(774)
Observations	2,037	2,037	2,037	2,037	2,037
Adjusted R^2	0.3174	0.6103	0.5802	0.8730	0.8703
Spatial Autocorrelation of OLS residual (Moran's I)	0.494***	0.518***	0.524***	0.296***	0.289***

Note: *p<0.1 **p<0.05 ***p<0.01

Units for % variables are 0-100 e.g. the coefficients are an estimate of the effect of a 1% change in the predictor variable

environment covariates. However even though the size of effect is reduced, the association still remains significant after considering the covariates in model D.

The Spatial Durbin Model offers an improved global model. However, when we run a Geographically Weighted Regression as a further step in exploring relationships as suggested by MacLachlan and Dennett (2021), we see that there is a non-stationarity; the relationship between variables differs between places (Fotheringham 2002). This is shown in [Figure 3](#); Dog ownership in London, parts of the South East and The North East has a higher coefficient than elsewhere.

While model form and specification could be investigated further in a future paper, our findings from all the models support the hypotheses of an association between dog ownership and car use, after controlling for obvious confounders. This is consistent with research suggesting that dog ownership is a car travel generator (Kent and Mulley 2017; MacKenzie and Cho 2020; Mattioli, Anable, and Vrotsou 2016) for social practices such as walking the dog and veterinary appointments. Our research provides support for those findings based on large-scale, spatially fine-grained data for England. As such, it provides support for calls for a greater use of practice theory in sustainable transport research (Kent 2021). From a policy perspective, it highlights the need for measures that aim at reducing car use, but are targeted to the specific social practices that motivate it (Hui 2013; Mattioli, Anable, and Vrotsou 2016). In this particular case, some have suggested specific policy interventions facilitating travelling with dogs on public transport and allowing off-leash dogs in neighbourhood parks (Kent, Mulley, and Stevens 2020; MacKenzie and Cho 2020) though others also note the need for more research with those who may feel intimidated by or excluded from spaces by a greater presence of dogs (Mayorga-Gallo 2018).

Table 3. Spatial Durbin model outputs: Dependent variable is car km travelled per person per year

	Model A	Model B (dogs per person included)	Model C (dogs removed from model)	Model D (dogs per person included)	Model E (dogs removed from model)
Dogs per person	2,815***	1,309***		710***	
	(166)	(132)		(95)	
Income quintile		558***	582***	13	13
		(20)	(20)	(21)	(21)
Urban minor conurbation		772***	755***	256	236
		(279)	(286)	(198)	(201)
Urban city and town		734***	810***	211**	235***
		(123)	(126)	(89)	(90)
Rural town and fringe		1,670***	1,889***	788***	859***
		(129)	(130)	(95)	(96)
Rural village and dispersed		2,300***	2,639***	980***	1,089***
(reference class Urban Major conurbation)		(177)	(179)	(132)	(132)
Median age				36***	38***
				(7)	(7)
% Female				-128***	-132***
				(14)	(15)
% Detached housing				37***	38***
				(3)	(3)
% Semi-detached housing				5*	4
				(3)	(3)
% Terraced housing				9***	9***
				(3)	(3)
% Economically active				50***	50***
				(5)	(5)
% No car				-42***	-43***
				(4)	(4)
% families with dependent children				-16***	-17***
				(5)	(5)
lag.(Intercept)	-935***	-549***	-573***	-381	-400
	(29)	(32)	(33)	(256)	(260)
lag. Dogs per person	10	-53		-115***	
	(52)	(48)		(36)	
lag. Income quintile		-96***	-99***	15***	16***
		(5)	(5)	(6)	(6)
lag. Urban minor conurbation		-92	-83	-58	-54

	Model A	Model B (dogs per person included)	Model C (dogs removed from model)	Model D (dogs per person included)	Model E (dogs removed from model)
		(57)	(59)	(41)	(41)
lag. Urban city and town		-46*	-47*	-4	-9
		(27)	(27)	(20)	(20)
lag. Rural town and fringe		-143***	-114***	-27	-34
		(34)	(32)	(26)	(26)
lag. Rural village and dispersed		-341***	-299***	-83*	-97**
		(60)	(58)	(45)	(44)
lag. Median age				-7***	-7***
				(2)	(2)
lag. % Female				3	3
				(5)	(5)
lag. % Detached housing				-1	-1
				(1)	(1)
lag. % Semi-detached housing				3***	3***
				(1)	(1)
lag. % Terraced housing				2**	2**
(reference class % flats)				(1)	(1)
lag. % Economically active				-5***	-5***
				(2)	(2)
lag. % No car				5***	5***
				(1)	(1)
lag. % families with dependent children				1	1
				(1)	(1)
Constant	6,007***	3,705***	3,876***	7,512***	7,753***
	(131)	(150)	(153)	(779)	(790)
Akaike Inf. Crit.	34,422	33,303	33,405	31,763	31,814

Note: *p<0.1 **p<0.05 ***p<0.01

Units for % variables are 0-100 e.g. the coefficients are an estimate of the effect of a 1% change in the predictor variable
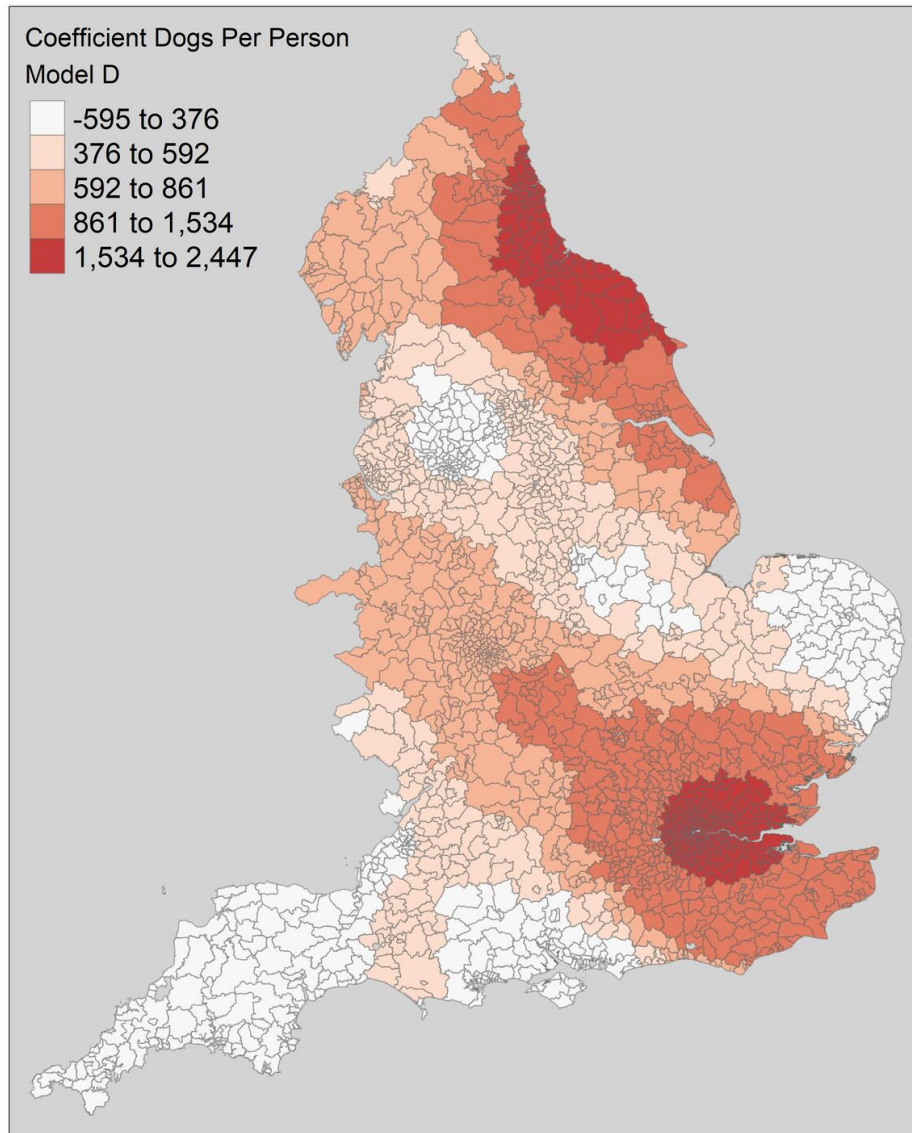
Figure 3**. *Co-efficient estimates for Dogs per person Model D using Geographically Weighted Regression (Quasi-Global R Squared = 0.9159 and AIC = 31506).

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11