

Predicting the prevalence of loneliness at older ages

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Abstract

This paper presents a prediction of the prevalence of loneliness among people aged 65 or over across small geographical units in England. It uses data from the English Longitudinal Study on Ageing (ELSA) survey to obtain predictors of loneliness and to test for the presence of spatial neighbouring effects (i.e. spatial dependence). The results are applied to data from the Census 2011 to predict the prevalence of loneliness across England.

Introduction

Little academic effort has been invested in estimating prevalence of loneliness among older people across small areas in a country considering that most interventions to tackle it by public and charity sector organisations and community groups are localised (Findlay, 2003; Cattan *et al*, 2005; Dickens *et al*, 2011; Masi *et al*, 2011; Honigh-de Vlaming *et al*, 2013; Gail *et al*, 2014; Collins and Rigley, 2014).

There have been studies looking into particular regions (Lauder *et al*, 2004; Wenger and Burholt, 2004; Steed *et al*, 2007) and cities (Moorer and Suurmeijer, 2001; Scharf and de Jong Gierveld, 2008; Woolham *et al*, 2013), but merely one attempt at presenting the overall picture of loneliness across all small areas in a country –the Netherlands (Deuning, 2014). Such exercises may help identify any hotspots and spatial patterns that could guide joined-up efforts by organisations in neighbouring areas.

The production of these estimates has been curtailed by data restrictions: the size of survey data (either cross-sectional or longitudinal) tend not to be big enough to obtain results for small geographical units with acceptable statistical power. On the other hand, census data do not record variables needed to carry out a study on loneliness among the elderly population. Notwithstanding, this paper presents one such attempt, for which it introduces at the same time a novel data analysis and data application approach.

The paper is structured as follows. The next section briefly reviews the literature on prevalence and predictors of loneliness in old age. Then the data and the statistical methods are described, followed by the local area level results. The following section explains how Census 2011 data were used to predict loneliness for local geographical units. The last section concludes and presents thoughts for further research and discussion.

Literature Review

Following cognitive theory, loneliness can be defined as a subjective experience, a feeling of a gap between desired and actual relationships, a perceived deficit in social relationships (Weiss, 1973; Perlman *et al*, 1998).

Loneliness is a prevalent phenomenon in later life (Holmen *et al*, 1992; Van Baarsen, 2001; Lauder *et al*, 2004; Savikko *et al*, 2005; Victor *et al*, 2005; Steed *et al*, 2007; Theeke, 2010; La Grow *et al*, 2012; Victor and Yang, 2012; Netz *et al*, 2013; Woolham *et al*, 2013; Dahlberg and McKee, 2014; Luo and Waite, 2014). This is particularly the case for the oldest old (Dykstra, 2009).

Apart from prevalent, loneliness is also a deleterious phenomenon: it is associated, among other conditions, with higher mortality risk (Tilvis *et al*, 2011; Luo *et al*, 2012), depression (Cacioppo *et al*, 2010), sleep problems (Hawkley *et al*, 2010a), impaired cognitive health (Wilson *et al*, 2007), heightened vascular resistance (Cacioppo *et al*, 2002), hypertension (Hawkley *et al*, 2010b; Momtaz *et al*, 2012), physiological stress (Doane and Adam, 2010), and mental health (Zebhauser *et al*, 2014).

Several studies have identified a number of loneliness risk factors in later life. In the United Kingdom (UK)ⁱ, Dahlberg and McKee (2014) reported that loneliness in later life is associated with being widowed, having low self-esteem, contacts with friends or family, social activity, well-being, and income comfort; and having unmet social care needs. (Regarding social engagement, other evidence suggests particularly in later life, the quality of contacts would be more important than frequency (Victor and Yang, *op. cit.*; Pinquart and Sörensen, 2001).

The Campaign to End Loneliness, a campaigning network across Great Britainⁱⁱ, has identified a number of risk predictors, including living alone, widowhood, low income, retirement, age, ethnicity, sexual orientation, poor health, mobility limitations, cognitive and sensory impairment, and material deprivation of area of residence (Goodman and Symons, 2013).

To these lists of overlapping factors, the following can be added:

- whether having a pet, given recently reported evidence that there is a positive association (Watt and Pachana, 2007; Pikhartova *et al*, 2014) despite early studies found no significant effects (Zasloff and Kidd, 1994)
- poor hearing, although the effects on loneliness seem to be confined to specific subgroups of older people, such as nonusers of hearing aids and men (Pronk *et al*, 2013)

Cross-national evidence suggests that loneliness in later life runs deeper in England than in other developed countries. Using survey data for England and the Netherlands, Scharf and de Jong Gierveld (2008) found that whilst in the latter country only 4 per cent of community-based older people felt severely lonely, the prevalence rate for England amounted to 13 per cent.

There may be specific local area effects on loneliness. According to Moorer and Surrmeijer (2001), loneliness in England seems to be spatially distributed: spatial neighbouring effects would be stronger and there would also be greater variation across neighbouring areas in England than in similarly developed countries. Kearns *et al* (2014) list the following neighbourhood characteristics germane to the incidence of loneliness: structures of buildings and streets, the provision of local amenities, territorial boundaries, residential turnover, area reputation, and neighbourliness (i.e. frequency of contacts with neighbours). The regression model presented in this paper includes three area-level indicators: a measure of deprivation and of rurality, plus an identifier for each local area to account for other differences across local areas.

Importantly, however, Scharf and de Jong Gierveld (*op. cit.*) caution against interpreting associations between neighbourhoods and loneliness as direct, uni-dimensional causal mechanisms: neighbourhood-level factors in England, including subjective quality of the area, electoral ward, and relative deprivation, may affect loneliness but due to a complex interplay of factors such as crime, population composition, housing conditions, amenities, and local policies. The dataset used in this paper, however, prevented such a complex, but valuable, undertaking.

Research Design

Data

This study explores data from the English Longitudinal Study of Ageing (ELSA), a representative longitudinal survey of people aged 50 or over living in the community in England (Marmot *et al*, 2014). ELSA started in 2002/03 and is carried out every two years. It is co-funded by the UK government and the US National Institute of Aging. This paper reports results based on data from Wave 5, which took place in 2010/11. A total of 6,773 respondents were interviewed.

The first stage of the statistical analysis is a multi-level regression with Middle-Super Output Areas (MSOAs¹) as second-level units run on individual data from ELSA. This stage comprised the following variables:

Loneliness. ELSA includes one self-rating loneliness scale: respondents are asked how often they feel lonely, with options 1= “Hardly ever or never”, 2= “Some of the time” and 3= “Often” (respondents are also asked whether they felt lonely much of the time during past week, with options 1=Yes, 2=No, which has not been considered in this study following Pikhartova *et al*, 2014). Multinomial and logistic models were run and this paper only reports results from the latter as the findings for both specifications were similar. Therefore, reported findings are based on categorising loneliness as a dichotomous variableⁱⁱⁱ: respondents who answered “Often” were classified as “Lonely”, and the rest as “Not Lonely”. (Self-reported loneliness may underestimate true levels of loneliness - Koropecjy-Cox, 1998; consequently, the findings in this paper should be considered as conservative.)

Age. Four groupings were created to increase statistical power compared to using chronological age as a continuous variable: 65-69 years, 70-74 years, 75-79 years and 80+ years.

Gender. Female=0; Male =1.

Marital status. The original categories include “single”, “legally separated”, “divorced”, “married, first and only marriage”, “a civil partner in a legally-recognised civil partnership”, “remarried, second or later marriage”, and “widowed”. Some of these categories exhibited very low frequencies (e.g., 0.25% of the sample were in a civil partnership and another 0.64% of the sample were legally separated). For this reason, the number of categories were reduced to three: “single”, bringing together the first three categories; “married” (combining the next three categories), and “widowed”. Widowhood was distinguished from other forms of singlehood, following some findings in the literature suggesting a differential impact on loneliness, e.g. Rayburn (1986).

Household size. The dataset includes this variable as continuous. However, given that in only 1.8 per cent of the sample there were three or more people, the models include a dichotomised variable with categories “1-person household” and “2-persons or more”. Regarding household composition, just 9 per cent of households with two persons or more had at least one co-residing child.

Housing tenure. Aggregated into “Renting” (including rent free), and “Own property outright or buying it with mortgage” (which also includes shared ownership).

Health status. Self-reported health is measured by a question with five categories: “excellent”, “very good”, “good”, “fair”, and “poor”.

Pets ownership. Whether the respondent has a pet or not.

Difficulty in performing activities of daily living (ADL). ELSA records self-reported difficulty in performing the following six functional ADLs because of a physical, mental, emotional or memory problem that are expected to last longer than 3 months:

- dressing, including putting on shoes and socks
- walking across a room
- bathing or showering
- eating, such as cutting up food

¹ An MSOA is a geographical unit created in 2001 with a population between 5,000 and 15,000 people and between 2,000 and 6,000 households. There are 6,791 MSOAs in England. See: <http://www.ons.gov.uk/ons/guide-method/geography/beginner-s-guide/census/super-output-areas--soas-/index.html>. (Accessed on 28 August 2014).

- getting in and out of bed
- using the toilet, including getting up or down

Compared to the list of items included in the widely used Katz scale of ADLs (Katz *et al*, 1963; Katz & Akpom, 1976), the ELSA items “are aimed at the milder end of limitations” (Breeze and Lang, 2008; p. 5). Continence is the only activity included in the Katz scale not covered in ELSA as part of the battery of ADL-related questions –an exclusion done elsewhere (e.g. LaPlante, 2006; Al Snih *et al*, 2009). A scale was constructed using a cumulative classification: “no difficulty”, “difficulty with 1 ADL”, “difficulty with more than 1” (Wittenberg *et al*, 2006).

Eyesight condition. Whether confirms diagnosis for at least one eyesight condition or not. Conditions included: glaucoma, diabetic eye disease, macular degeneration, and cataract.

Hearing condition. Self-reported hearing while using hearing aid, if appropriate. Options include “excellent” (reference group), “very good”, “good”, “fair”, and “poor”.

Social connectedness. An index was constructed following Jivraj *et al* (2012). For quantity of social contacts, the questions about how often the respondent meets up with, speaks on the phone with and writes to or emails their children, other relatives and friends were combined. These variables have the following categories: “Three or more times a week”, “Once or twice a week”, “Once or twice a month”, “Every few months”, “Once or twice a year” and “Less than once a year or never”. With regards to quality of social relationships, the questions about how much the respondent can open up to their spouse/partner, children, other relatives and friends if they need to talk were combined. Each quality variable is categorised into “a lot”, “some”, “a little”, and “not at all”.

Ethnicity was omitted from the analysis due to extremely low records, even when dichotomised as white/non-white (1.2 % of sample).

To check for spatial variation across local areas and, if there was any, to estimate prevalence of loneliness by area, Middle Super Output (MSOA) identifiers were included as the second-level confounders in the multilevel model. Two confounders were entered at the second level: the MSOA’s deprivation score and Rural/Urban classification.

Local area deprivation. The weighted index of multiple deprivation score by MSOA (ERPHO, 2011).

Local area rural/urban definition by MSOA. This variable is classified into six categories: Urban (Sparse); Town and Fringe (Sparse); Village, Hamlet and Isolated Dwellings (Sparse); Urban (Less Sparse); Town and Fringe (Less Sparse); and Village, Hamlet and Isolated Dwellings (Less Sparse) (ONS, 2013). For modeling purposes, this variable was recoded as continuous, from 1 - Village, Hamlet and Isolated Dwellings (less sparse)- to six –Urban (sparse). This classification can be used with any data source at MSOA level and is more useful for broad statistical analyses across units, such as the work presented in this paper, than for studies of individual areas (DEFRA, 2014).

Table 1 presents descriptive statistics (relative frequencies, nominal or ordinal) for each variable:
Descriptive measures

Variable	(% in sample) (N=4,041)
<i>Marital Status</i>	
Married/re-married/civil partner	61.0%
Divorced/separated/single	14.5%
Widowed	24.6%
<i>Hearing</i>	
Poor or registered deaf	5.6%
Fair	18.8%
Good	34.7%
Very good	26.6%
Excellent	14.3%
<i>Housing Tenure</i>	
Owner outright	77.8%
Mortgage	6.2%
Renting	16.0%
<i>Self-reported Health</i>	
Poor	8.1%
Fair	20.5%
Good	34.5%
Very good	27.5%
Excellent	9.4%
<i>Age group</i>	
65-69	31.5%
70-74	29.4%
75-79	20.9%
80+	18.2%
<i>Gender</i>	
Female	55.7%
Male	44.3%
<i>Educational Level</i>	
No qualification	31.4%
NVQ1/CSE other grade	5.0%
NVQ2/GCE O Level	17.9%
NVQ3/GCE A Level + Foreign/Other	15.7%
NVQ4/NVQ5/Degree	15.1%
Higher education below degree	14.9%
<i>Eye conditions</i>	
None	58.8%
1	33.8%
2	6.7%

3+	0.7%
<i>Rurality</i>	
Urban & Town	84.8%
Village & Hamlet	15.2%
<i>Loneliness</i>	
No	91.5%
Yes	8.5%
<i>Deprivation Index</i>	
0.59->8.35 (Least deprived)	25.0%
8.35->13.72	26.8%
13.72->21.16	21.6%
21.16->34.21	16.3%
34.21->86.36 (Most deprived)	10.4%
<i>Pets</i>	
No	73.3%
Yes	26.7%
<i>Household size</i>	
1 person	33.7%
2+ persons	66.3%

Concerning the missing data, there is no additional information to reject the assumption that they are not missing at random. Hence, only records with no missing values were included in the analysis.

Method

A two-level mixed-effects logistic regression model was applied with loneliness as the independent variable. First-level covariates include age, gender, marital status, household size, housing tenure, health status, pets ownership, difficulty with ADLs, eyesight condition and hearing condition.

In two preliminary model specifications without the mixed effects, quantity and quality of social contacts - either incorporated separately or as a combined index of social connectedness constructed as a latent variable after running a factor analysis- were found not to be significant. Consequently, social connectedness was not included in the final model. The lack of statistical significance of the social connectedness construct is somewhat surprising. Further investigation needs to be carried out, but one possible explanation may be that the social connectedness construct is conflating significant types of social relationship and modes of contact with non-significant ones.

The literature on multilevel models has found that unbiased regression estimates can be obtained with groups as small in size as 5 units provided there are at least 50 nested groups (Mass and Hox, 2004; Marshall *et al*, 2014). Given the statistical requirement that at least five respondents must belong to a second-level group for it to be included in the models, the estimates in this paper are based on a sub-sample of 3,540 respondents (i.e. 38 per cent of all valid records) in 540 MSOAs (out of 6,791 MSOAs in England).

This reduction in sample size is not a cause of concern for we ran chi-square tests weighted by MSOA and could not reject the null hypothesis that the proportions in the subsample of 3,540 respondents are equal to the proportions in the full sample. Therefore we can accept that the sub-sample is representative of the population over 65 or over in England. However, there is another dimension whose representativeness needs

be checked: the MSOAs. In this regard, we compared using non-parametric methods² the distribution of loneliness by gender and age group in both the sub-sample and the full sample. The results were indicative of no significant differences³.

The results from the local-area regression model were used to predict the prevalence of loneliness among people aged 65 or over in England in each MSOA using data from Census 2011.

Local-area regression results

Table 2 presents the results of the final model specification:

Table 2				
Two-Level Mixed-Effects Logistic Regression Results				
Dependent variable: Probability of Feeling Lonely				
Variables	Estimate	Standard Error	z value	p-value
<i>Marital Status</i>				
Married/re-married/civil partner (base category)	1			
Divorced/Separated	0.36	0.28	1.29	0.20
Widowed	1.03	0.26	3.96	0.00
<i>Household Size</i>				
Household Size	-0.99	0.24	-4.11	0.00
<i>Housing Tenure</i>				
Mortgage (base)	1			
Owner outright	-0.07	0.28	-0.27	0.79
Renting	-0.13	0.16	-0.80	0.43
<i>Educational Attainment</i>				
No qualifications (base)	1			
Educational level NVQ1	0.23	0.34	0.68	0.50
Educational level NVQ2	0.18	0.26	0.70	0.48
Educational level NVQ4+	-0.23	0.30	-0.75	0.46
<i>Self-reported health</i>				
Excellent (base)	1			
Poor	2.22	0.38	5.83	0
Fair	1.69	0.37	4.63	0
Good	1.03	0.36	2.85	0
Very Good	0.59	0.38	1.56	0.12
<i>Age</i>				

² Kolmogorov-Smirnov and Anderson-Darling two-sample tests (Davison, 2003). We used the dgof (Arnold, 2015) and kSamples (Scholz, 2015) packages in R, respectively.

³ Results available from the author.

Age 65-69 (base)	1			
Age 70-74	-0.17	0.17	-0.98	0.33
Age 75-79	-0.3	0.19	-1.56	0.12
Age 80+	0.09	0.19	0.47	0.64
Pets	0.43	0.14	3.14	0.00
Income	-0.08	0.15	-0.55	0.58
Paid employment	-0.13	0.22	-0.57	0.57
<i>Disability</i>				
No difficulties with ADLs (base)	1			
Difficulty with 1 ADL	0.32	0.17	1.87	0.06
Difficulty with 2+ ADLs	0.38	0.18	2.11	0.03
<i>Eye conditions</i>				
No eye conditions (base)	1			
Eye conditions 1	0.12	0.14	0.9	0.37
Eye conditions 2	0.36	0.22	1.64	0.1
Eye conditions 3+	0.86	0.51	1.69	0.09
<i>Hearing</i>				
Excellent (base)	1			
Poor	0.33	0.29	1.16	0.25
Fair	-0.05	0.23	-0.2	0.84
Good	-0.1	0.21	-0.49	0.62
Very Good	0.2	0.21	0.97	0.33
Gender (Male=1)	-0.18	0.18	-1.05	0.29
Threshold	Estimate	Standard Error	z value	
0/1	-2.33	1.47	-1.59	
Random effects	Var	St Dev		
MSOA effect	0.14	0.37		
Rural/Urban	0	0		
Deprivation	0	0		

Being single, divorced or separated and widowhood are associated with a higher prevalence of loneliness compared to being married.

Household size is inversely related with prevalence of loneliness.

Either owning a house outright or renting are negatively associated with the probability of feeling lonely compared to paying a mortgage on the property.

Education level is only significant and negatively associated with prevalence of loneliness for the highest educational level.

The regression coefficients for self-reported health show a negative gradient: the poorer the self-reported health, the more likely the respondent feels lonely.

Age is not significant. An alternative model with age as a continuous variable including age squared to account for non-linear relations between prevalence of loneliness and age (i.e. the ‘loneliness increase with ageing’ hypothesis –Yang and Victor, 2011) but failed to find any significant non-linear association.

Having a pet, the level of household income and whether the respondent is in paid employment are not found to be significant.

Having difficulty with one or more ADLs is positively associated with the prevalence of loneliness. Neither hearing problems nor the number of eye conditions were (although it is marginally significant for respondents with 3 or more eye problems).

Finally, gender is not statistically significant. The literature is equivocal with regards to the association between gender and loneliness. Women have been reported to exhibit a higher prevalence but when mediated with widowhood, the latter variable was found to be more important (Dahlberg and McKee, 2014).

With regards to the second-level regressors, we fail to find any significant association between loneliness and rurality or multiple deprivation of the area. Furthermore, no MSOA effects are significant.

The literature reports conflicting findings regarding the importance of rurality to the experience of loneliness in later life. Its lack of significance tallies with Paúl *et al* (2003), Burholt and Scharf (2014). It is worth noting that contrary to the expected positive association between rurality and loneliness, some papers report a higher risk of loneliness in urban areas (Savikko *et al*, 2005; Routasalo *et al*, 2006; Ferreira-Alves *et al*, 2014).

An internal validation of a fitted model was carried out to ‘ascertain whether predicted values from the model are likely to accurately predict responses on future subjects or subjects not used to develop’ the model (Harrell, 2001, p. 90). The validation was done on a model with the same specification, including deprivation and rurality as regressors, but without MSOA mixed effects, using a bootstrap procedure (N=1,000) that corrects for over-fitting as described in (Harrell, 2001)^{iv}.

It produced acceptable results (Table 3):

Table 3
Internal Validation of Fitted Model

	Predictive accuracy score of fitted model	Training	Test	Optimism	Predictive accuracy score of fitted model corrected for overfitting	Bootstrap (n)
rho	0.4061	0.4112	0.4013	0.0099	0.3962	1000
RN ²	0.1813	0.1864	0.1771	0.0093	0.1720	1000
Slope	1.0000	1.0000	0.9678	0.0322	0.9678	1000
g	0.9689	0.9865	0.9548	0.0317	0.9372	1000
pdm	0.1784	0.1808	0.1769	0.0039	0.1745	1000
<i>Notes:</i> <i>rho= Spearman's rank correlation</i> <i>RN²= Nagelkerke R² index</i> <i>Slope= slope shrinkage</i> <i>g= g-index of agreement</i> <i>pdm= the mean absolute difference between 0.5 and the predicted probability that risk is equal to or greater than the marginal median</i>						

A Moran test on the predicted prevalence of loneliness by MSOA to check whether there were any spatial neighbouring effects failed to find any^v -the prevalence of loneliness would not be spatially correlated across MSOAs in England. Having found no significant spatial neighbouring effects, the regression results were applied to data from the Census 2011 to predict the prevalence of loneliness across all the MSOAs in England.

We also checked for co-linearity between the variables but the pairwise correlation coefficients were not problematic –not even those between hearing and eye conditions and health status⁴.

Using aggregated Census 2011 data to predict prevalence of loneliness

The Office for National Statistics (ONS) carried out a population census in England (and Wales) on 27 March 2011. The Census did not include questions about feeling of loneliness. However, the results from a reduced version of the model presented above (see Table 4), based on the extended ELSA dataset, were applied to 2011 Census data to obtain predicted estimates of prevalence of loneliness among the resident population aged 65 or over by MSOA in England.

This reduced-version included only the statistically significant variables in Table 2 and had no second level covariates as none was found to be significant. Therefore, this modified model was run on the extended sample of respondents with full records (n= 9,316), given that the MSOA identifiers were omitted in this specification and hence the requirement to have at least records per MSOA did not apply.

⁴ Results available from the author.

Table 4 Logistic Regression Results Reduced model on Extended Sample Dependent variable: Probability of Feeling Lonely				
Variables	Estimate	Standard Error	z value	Probability
Intercept	-4.55	0.37	-12.32	0.00
Divorced/Separated	0.54	0.28	1.91	0.06
Poor Health	2.32	0.37	6.21	0.00
Fair Health	1.77	0.36	4.93	0.00
Age 75-79	-0.31	0.19	-1.67	0.09
1-person household	-0.97	0.24	-3.98	0.00

The ONS National Wellbeing Team ran the coefficient results in Table 4 on the individual records from the 2011 Census Microdata files –a 10 per cent representative sample of all individuals to obtain predicted incidence of loneliness across most Output Areas (OA), Lower layer Super Output Areas (LSOA), and Middle layer Super Output Area (MSOA), and all Local Authorities (LA) in England. Map 1 depicts the results for MSOAs and Figure 1 presents the density distribution of the prevalence of loneliness across the 6,791 MSOAs.

Map 1. Predicted Prevalence of Loneliness by MSOA in England, 2011

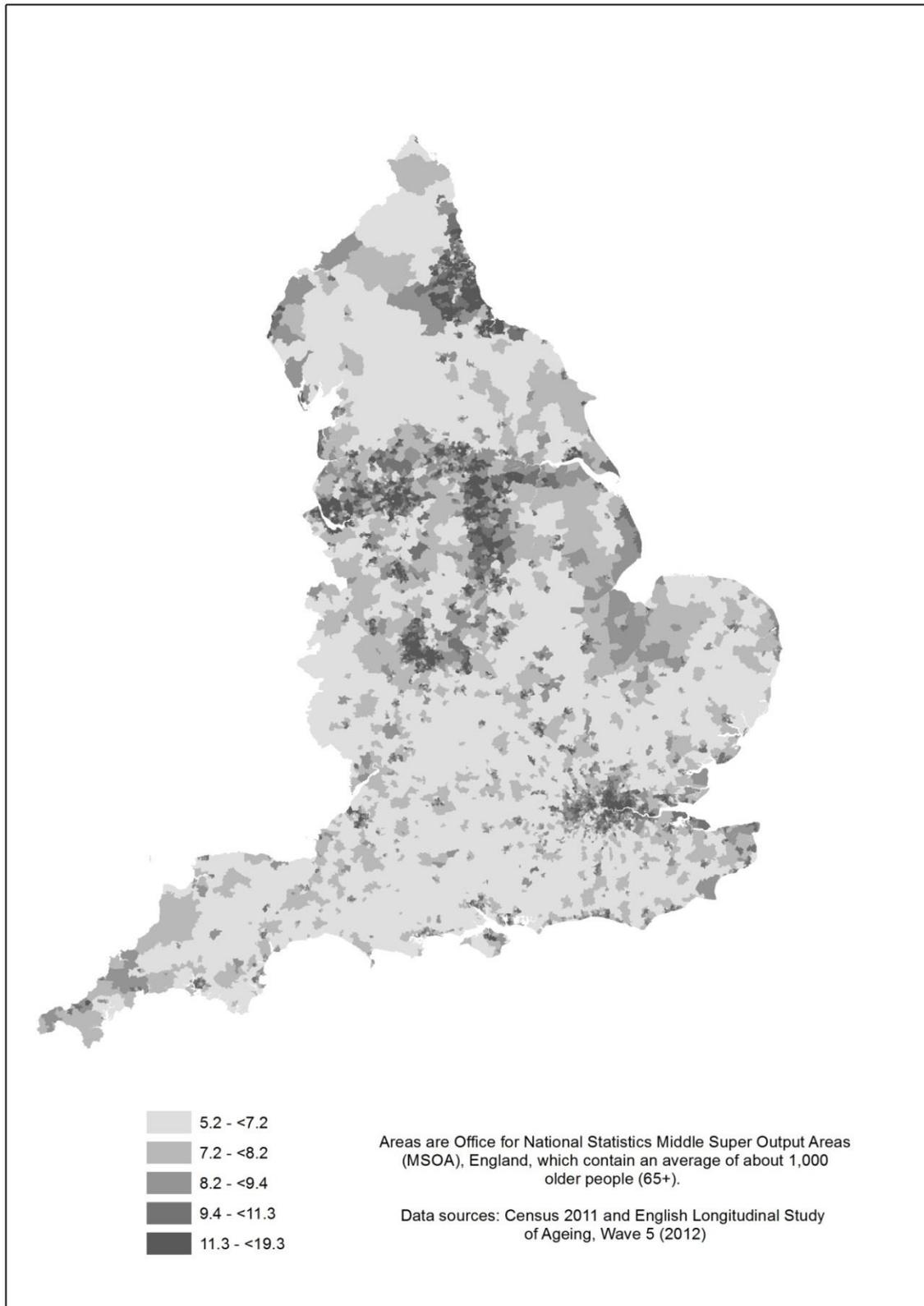
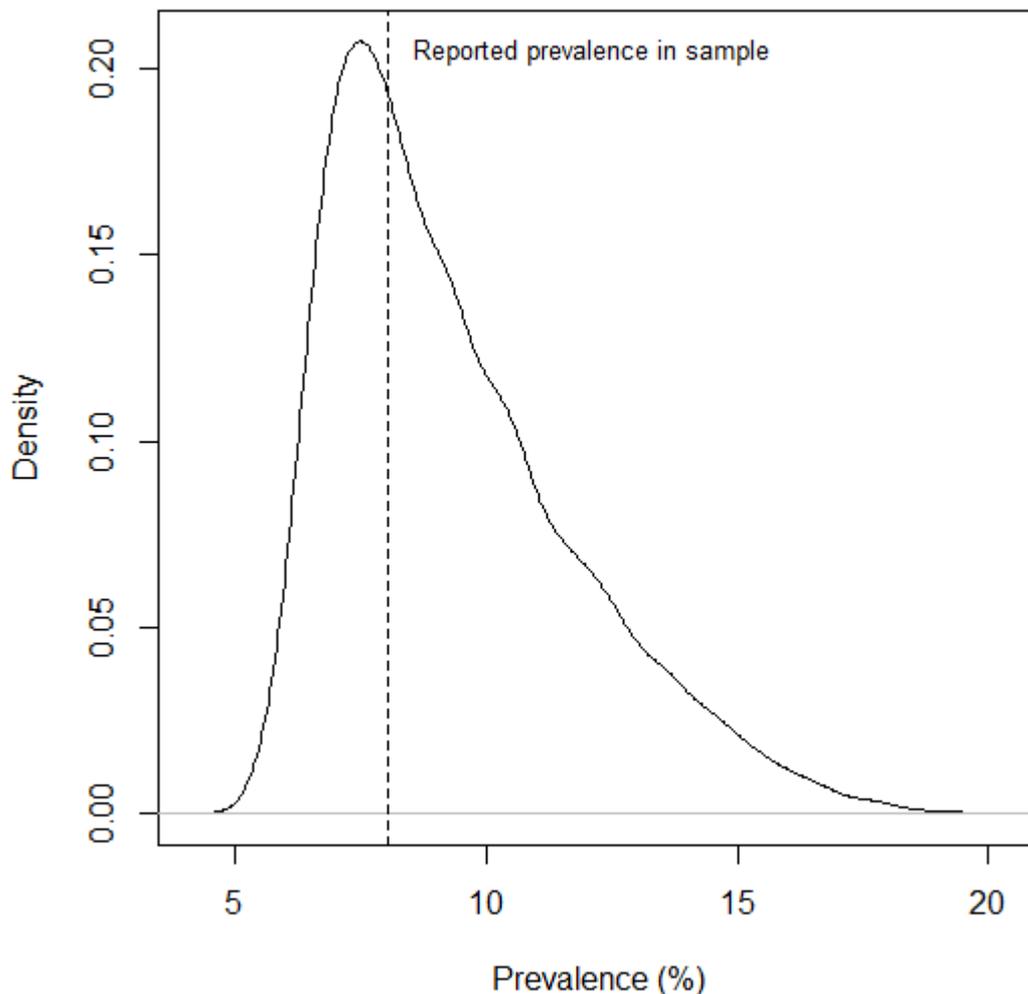


Figure 1. Density distribution of the prevalence of loneliness in England (n=6,791)



Discussion

ELSA is a representative survey of older people in England; however, for statistical considerations, only a small sample of records can be used in multilevel models investigating small area effects. On the other hand, the Census 2011 covers the whole country but has not recorded the variable under study –i.e. feeling of loneliness. What to do, then, in order to predict prevalence of loneliness by local area? This paper presents one approach: predict prevalence of loneliness among people aged 65 or over for as small the geographical unit as feasible and –provided no spatial effects are detected- apply the regression results on Census individual records.

The main result is that there is a huge variation of prevalence of loneliness across the country, which cannot be explained by local area characteristics such as rurality or multiple deprivation, and which is not spatially correlated either. However, further analysis is required in this regard, because terrain characteristics and existing amenities in the area and distance to access to these amenities have been recently reported to be

statistically associated with feelings of loneliness among older people (Rantakokko, 2014) –local area aspects not included in this analysis. As Scharf and de Jong Gierveld (op. cit, p. 113) state that Parkes and Kearns’s recommendation that survey data should be “complemented by detailed neighbourhood case studies in order to elucidate potential mechanisms for neighbourhood effects on health for particular groups in specific residential contexts” (Parkes and Kearns, 2003; p. 16) is applicable to spatial effects on loneliness in later life.

With regards to predictor variables, the results tend to confirm what has been reported in the literature: widowhood, housing tenure, and poor self-reported health are associated with higher prevalence of loneliness while household size is inversely associated. The literature is not unanimous about the effects of age, gender, eyesight and hearing conditions or owning a pet on loneliness; we found these covariates not statistically significant.

One limitation of this study is the operational definition of loneliness. ELSA contains one question with three categories, and using either these three categories or a combined dichotomous definition did not change the results. However, other more detailed measures exist. For example, Victor and Bowling (2012) used a 4-category variable, the de Jong Gierveld Scale encompasses 11 items (de Jong-Gierveld and Kamphuis, 1985) and Russell *et al* developed the 20-item UCLA scale (Russell *et al*, 1978). As mentioned earlier, the dichotomisation of the loneliness measure has been validated in the literature (Perissinotto *et al*, 2012). However, multi-item measures attempt to capture the multidimensionality of loneliness, whilst a dichotomous indicator does not distinguish between specific emotional, social or psychological underlying factors.

Another limitation is that it could not be checked whether missing data introduced any bias, as it was not possible to rule out missing records were a random feature of the data or not. This could have affected the significance of second-level indicators such as rurality, although the literature is inconclusive in this regard.

A final limitation is that findings from exploratory work suggest that loneliness would be more prevalent among ethnic minority elders than in the general population in England (Victor *et al*, 2012). However, ethnicity was not included because of under-representativeness in the ELSA sub-sample with full records used in the regression model.

Conclusion

This paper presents a novel approach at predicting the prevalence of loneliness among older people across small areas in a country.

The rationale is to use a sub-sample with enough records for a sample of small geographical units, assess the presence of spatial neighbouring effects, and test the representativeness of the sub-sample. If no spatial effects are found and no bias is detected in the sub-sample, the regression results can be applied to Census data to estimate and predict prevalence of loneliness across small areas in a country. As a result, the estimates can be used to identify hotspots and design tailor-made interventions to address particular characteristics behind prevalence of loneliness in each area. Even if the initiatives are localised and administered by local governments or locally-based organisations, having the nation- and region- (or state-) wide picture of the prevalence of loneliness across local areas should be a useful tool towards designing and evaluating joined-up policies. This paper presents such a tool.

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ⁱ The United Kingdom includes four constituent countries: England, Scotland, Wales, and Northern Ireland.

ⁱⁱ England, Scotland and Wales.

ⁱⁱⁱ See Theeke (2009) for a similar dichotomisation of the loneliness measure. Moreover, Perissinotto *et al* (2012) report dichotomous constructs of loneliness exhibit high correlation with multi-item scales.

^{iv} rms package (Harrell, 2013) under the software R (R Core Team, 2014).

^v Moran's I test statistic (under randomisation)= 0.62; Moran's I statistic standard deviate = 41.96; p-value=0