An Urban-Rural Exploration of Depression, CVD and their Comorbidity in Ireland

Karyn Morrissey*

Department of Geography and Planning, University of Liverpool

The significant rise in the comorbidity of physical conditions with mental disorders is increasingly recognised as a public health issue. Spatial considerations and how they interact with individual level socio-economic characteristics also play a crucial role in influencing health outcomes. To date, most hypotheses tend to assume that health outcomes will be poorer in urban rather than rural areas. The aim of this paper is to examine whether the prevalence of cardio-vascular disease (CVD), depression and their comorbidity is higher across an expanded eight category classification of urban/rural areas once the known compositional determinants for both diseases are controlled for. It was found that the comorbidity of CVD and depression may be explained by individuals being exposed to spatially-variant demographic and socio-economic factors that may predispose them to both conditions. With regard to the location variables, it was found that health outcomes do not improve as space becomes increasingly rural relative to a city environment; suburban and mixed urban/rural residences bordering suburbs are consistently associated with poorer health outcomes, relative to city locations. Furthermore, residents of small towns have poorer health outcomes relative to city residents, whilst residents of large towns have better health outcomes relative to city residents. Thus, this paper concludes that health outcomes cannot be predicted on areas being dichotomously defined as rural versus urban and that non-linearities exist in health outcomes as areas become increasingly rural.

Key Words: Urban/Rural; Depression; Cardiovascular Disease; Comorbidity; Ireland

Introduction

With the on-going population aging of Western societies, not only is the number of individuals with a single morbidity expected to increase, but so too is the number of patients with one or more comorbidities (Katon 2011). The significant rise in the comorbidity of physical conditions with mental disorders is increasingly recognised (Scott *et al*. 2008). Data from the world mental health surveys have indicated that both depressive and anxiety disorders are equally and independently associated with a range of chronic physical conditions (Scott *et al*. 2008). This has been shown to be true for cardio-vascular disease (CVD) and depression (Mulle and Vaccarino 2013). Recent research indicates that the relationship between

* Email: karyn.morrissey@liv.ac.uk

CVD and depression is bi-directional, as depression may be both a cause and consequence of CVD (Katon 2011, Holt *et al*. 2013). The prevalence of depression is increased in people with CVD; between 25% and 40% of people have been found to have major or minor depression following a myocardial infarction (Carney and Freedland 2003, Katon 2011). Furthermore depression has been found to increase the risk of CVD by a factor of 1.5 to 2 in both men and women, independent of other risk factors (Van der Kooy *et al*. 2007).

A number of different factors determine the overall health of populations and individuals, ranging from the genetic and biological characteristics of the individual to political and policy context (Valderas *et al*. 2009, Mulle and Vaccarino 2013). In developed countries cardio-vascular disease (CVD) and depression are major contributors to the overall burden of disease, and socio-economically disadvantaged groups have higher rates of morbidity and mortality from these conditions (Kavanagh *et al*. 2010, Charlton *et al*. 2013). Examining the socio-economic determinants of both CVD and depression separately, individual determinants for both morbidities are well established at the national level and include low socio-economic status and unemployment (Fone *et al*. 2013). Studies have also begun to suggest that gender may affect the relationship between CVD and depression (Moller-Leimkuhler 2010, Holt *et al*. 2013).

However, spatial considerations and how they interaction with individual level socio-economic characteristics also play a crucial role in influencing health (Congdon 2006). Research in health geography has led to the realisation that people and their health are shaped by the places in which they live (Smith and Easterlow 2005, Gatrell and Elliott 2009). This is in part because people with similar characteristics, such as income level, age and employment status, cluster together (compositional influences) and in part because individuals living in the same neighbourhood are subject to common contextual influences such as an area's social capital and service availability (Merlo *et al*. 2005, Congdon 2006). The purpose of this paper is to explore the comorbidity of CVD and depression in Ireland and examine whether the compositional make-up of urban or rural residency is an important factor in explaining rates of comorbidity in the Irish population.

Urban and Rural Health

National level socio-economic analyses of health are beneficial, as they highlight the main determinants of health for a country and allow for cross-country analysis and comparisons. However, health geographers have long recognised that the prevalence of health problems (and related behaviours) varies across geographic space and is related to local social conditions (Smith and Easterlow 2005, Gatrell and Elliott 2009). Thus, whilst the health community is still unsure of the specific role that geographical location plays in determining health outcomes, it is generally hypothesised that both physical and mental illnesses may be more prevalent in areas with high rates of negative life occurrences, such as unemployment and deprivation. Geography may be incorporated into health research via various

degrees of spatial aggregation or disaggregation, such as the region, city, small area, etc. Much of the recent health research in geography has focused on describing and/or estimating health outcomes and the factors associated with these outcomes at the small area level (Edwards *et al.* 2009, Morrissey *et al*. 2010, 2013, Smith *et al.* 2011). Small area health analysis allows one to capture spatial heterogeneity between smaller groups of individuals. The urban/rural status of an individual's living environment has been found to be a significant predictor of health outcome for a number of conditions (Teljeur and Kelly 2008).

The difference between urban and rural living in health research has both face value and utility. At government level it can be used to drive policy decisions and address inequalities in society. At the individual level, contextual and compositional differences and inequities in service provision, including their distinction between urban and rural areas, are important in health research (Nicholson 2008, Teljeur and Kelly 2008). With regard to contextual differences, rural culture and countryside form a significant part of Irish society with a very different social dynamic to urban living (McNerney and Gillmor 2005, Mahon, 2005, Teljeur and Kelly 2008). The differing dynamics of rural areas compared to urban areas, including greater space, less traffic and a slower pace of life, is often perceived as advantageous in terms of health outcomes (Valentine 1997, McNerney and Gillmor 2005, Teljeur and Kelly 2008). The composition of rural societies is also diverse, with research finding that rural areas have a greater proportion of both high income and low-income groups living within the same area compared to urban populations (Mahon 2005, Frawley *et al*. 2005, Shubin 2007, Nicholson 2008). Using data from the Survey of Income and Living Conditions (SILC) for Ireland 2011, the Central Statistics Office (2013) found that the at risk of consistent poverty rate was higher in rural areas than urban areas (at 7.1% in rural areas compared with 6.8% in urban areas) and net equivalised disposable household income was higher in urban households (€44,612 and €37,441) compared with rural households (€37,441 and €19,486). The SILC also reported that only 19% of rural residents compared to 29% of urban dwellers had a higher education qualification. With regard to inequalities in service provision, the manner in which individuals obtain goods and services from the private and public sector remains predominantly urban (Nicholson 2008). Services such as healthcare, higher education, transport and communication links are all centralised, and people living in rural areas are generally expected to travel to urban centres to access them. Government policy, particularly in health care has for the most part reflected this urban bias (Asthana 2002, Nicholson 2008). Indeed, research by Teljeur and Kelly (2008) found that only 7% of rural residents in Ireland were within walking distance of a general practitioner (GP), compared to 88% of urban residents. Poorer access to health services may also be compounded by a higher than average aging population in rural areas (Teljeur and Kelly 2008).

Although it is evident that compositional, contextual and service provision inequities exist between rural and urban areas, there is no universal agreement on how these differences may be used to define rurality or rural life (Nicholson 2008). In the past, research tended to present a dichotomous definition in which rural

was everything that was non-urban (Nicholson 2008, Teljeur and Kelly 2008). Whilst there are certainly clear urban centres and sparse rural regions, between these two there is a range of community types, many of which are remarkably dynamic. For example, there are former villages that have become commuter towns but perhaps lack the services and links that might properly label them urban centres. Thus, a number of health-related studies have concluded that the use of a simple dichotomy does not capture the range of rural area types (Crandall *et al*. 2002, Judd *et al*. 2002, Levin 2003, Teljeur and Kelly 2008). In response, recent classification systems have tried to identify the degree of rurality and urbanicity within and across areas (Teljeur and Kelly 2008). There are no a priori theoretical grounds for developing such a classification system, but definitions to date can be broadly divided into spatial, socio-economic and sociological (Nicholson 2008).

Spatial classifications of urban/rural areas depend on factors such as population numbers, population density, and in some cases distance to cities and other urban centres (Teljeur and Kelly 2008). Socio-economic classifications look at factors such as the principal employment in an area and other socio-economic characteristics of the population (Nicholson 2008). Sociological definitions consider the subjective aspects and experiences of rurality; for example, asking the study participant or researcher to decide for themselves whether or not they would define themselves as rural. In Ireland, Teljeur and Kelly (2008) created a new six category urban-rural classification for health research in Ireland based on multiple data sources including demographic data from the census of population and topographic information from the CORINE land use dataset. Following a more nuanced approach to the definition of urban and rural areas such the one offered by Teljeur and Kelly (2008) is important. To date, studies on urban-rural rates of depression and anxiety (Paykel *et al*. 2000, Weich *et al*. 2006, Morrissey *et al*. 2013) and CVD (Diez-Roux *et al*. 2001; Jarvrie *et al*. 2011, Rodriguez *et al*. 2013) have been limited to a dichotomous two category urban-rural variable and have produced mixed results. Whilst the requisite data used by Teljeur and Kelly (2008) to create an urban-rural classification is available within the census, data on depression and comorbidity is not. The Quarterly National Household Survey (QNHS) special module on health and health service utilisation is currently the only dataset for Ireland that records these two health outcomes for each individual. Although the data in the QNHS is not available at the small area level, it does include an eight category spatial residency variable; (1) city, (2) suburbs of cities, (3) mixed urban/rural bordering on suburbs of cities, (4) towns and their environs with a population of 5,000 or more, (5) mixed urban/rural areas bordering on the environs of larger towns, (6) towns and their environs 1,000 to 5,000, (7) mixed urban/rural areas and (8) rural areas. While not been designed specifically for health studies, the additional six categories between urban and rural residency may offer a spatial insight into the relationship between different degrees of urban and rural space on depression, CVD and their comorbidity.

The aim of this paper is to examine whether the prevalence of CVD, depression and their comorbidity is higher across an expanded eight category classification of

urban or rural areas once the known compositional determinants for both diseases are controlled for in Ireland. The demographic, socio-economic and spatial determinants of each disease category will be analysed using a multinomial log linear model and the QNHS dataset. The first age-sex specific tables for depression, CVD and their comorbidity for Ireland are also presented. This paper continues as follows: the data section provides an overview of the data, the Quarterly National Household Survey, used in this research. This is followed by a brief introduction to multi-nominal regression modelling. The results of the multi-nominal analysis are then presented, after which they are discussed in the context of research to date on the determinants of CVD, depression and their comorbidity. The final section offers some concluding comments.

Data

The Quarterly National Household Survey (QNHS) is a weighted representative micro-level dataset and the main source of data on the Irish labour market. Estimates are derived from data collected in face-to-face interviews with individuals in selected households. The country is geographically classified into eight area type strata based on the Census of Population. Within strata, blocks of 75 households are identified as Primary Sampling Units. A sample of 1 in 6 blocks is selected, and within each selected block five clusters of approximately fifteen households are identified using systematic sampling (Haase and Pratschke 2012). While the main purpose of the QNHS is the production of quarterly labour force estimates, there is also a provision for the collection of data on social topics through the inclusion of special survey modules. In Quarter 3, 2007 a special module on health and health service utilisation was collected. This module was commissioned by a specially-created health liaison group which comprised experts in several fields of medical research and officials in the Department of Health. This data is linked to the core data collected as part of the QNHS and therefore demographic, socio-economic and spatial variables are included in the dataset. The health module collected in Quarter 3, 2007 forms the basis of this paper. Whilst the main component of the QNHS includes over 40,000 household responses, the additional 2007 health survey was only administered to 21,253 individuals within the overall sample. Nationally representative weights are also included within the dataset and, utilising the weights, the sample population becomes nationally representative for residents aged 16 years and over (3,221,366). The variables included a variety of medical health status, health conditions and health utilisation data, as well as demographic and socio-economic data from the broader QNHS.

The survey contained information on the incidence of individual level cardiovascular disease (CVD) and self-reported depression (i.e. had the individual ever been diagnosed with depression by a doctor), as well as an urban-rural spatial category. The urban-rural variable in the QNHS is based on the Central Statistics Office definition of urban-rural areas (CSO 2003). These districts are aggregates of the Electoral Divisions (EDs) used for the national census (Teljeur and Kelly 2008). The CSO defines an area as being urban if the population density

is greater than 1,500 people per square kilometre. Whilst these boundaries provide a relatively low resolution for distinguishing between urban and rural areas in Ireland, a limitation of the CSO's definition of urban-rural areas is that it has been in use since 1966, whereas in reality the Irish economic and social environment has changed over the last 40 years (Teljeur and Kelly 2008).

Examining the depression variable and using the individual weights provided by the QNHS, it was found that in 2007, 3.6% (118,773 individuals) of the Irish population reported having being diagnosed with depression. CVD includes angina (chest pain on exertion due to inadequate blood flow to the heart muscle), stroke, myocardial infarction (heart attack) and heart failure. Grouping these four health conditions together, a CVD variable (i.e. had the individual ever been diagnosed with any of these four conditions by a doctor) was created. Examining the newly created CVD variable and using the QNHS weights, it was found that 4% (131,943 individuals) of the Irish population reported having being diagnosed with CVD by a doctor.

Methodology: Multinomial Logistic Regression

This paper uses a multinomial log-linear model to model the urban and rural prevalence of the comorbidity of CVD and depression controlling for demographic and socio-economic factors at the individual level for Ireland. Multinomial log-linear models are used when the dependent variable to be explained is polytomous and categorical, i.e. it has more than two categories with no global order between them. The comorbidity of CVD and depression is studied using a response variable y with four categories, corresponding to the product of all possible CVD and depression status for the Irish population; concisely: no depression or CVD, no-morbidity ($y = 1$); depression, no-CVD ($y = 2$); CVD, no-depression ($y = 3$); depression and CVD ($y = 4$). The probability for an individual i to be in the comorbidity category c is modelled under the multinomial log-linear model as

$$P(y_i = c) = \frac{e^{\beta_c X_i}}{1+\sum_{k=2}^{8} e^{\beta_k X_i}} \qquad (1)$$

Where X_i is the vector of values of the independent variables X for individual i i, and β_c is the vector of regression coefficients for the comorbidity category cc, with the non-morbid category ($y = 1$) selected as reference: $\beta_1 \equiv 0$. The easiest way to interpret the fitted multinomial model is to look at its log-odds, which correspond to the logarithm of the relative risks of moving from the reference category ($y = 1$) to a comorbidity category cc:

$$\log\left(\frac{P(y_i=c)}{P(y_i=1)}\right) = \beta_c X_i$$

By denoting by β_c^j and X_i^j the components of β_c and X_i, respectively, the log-odd expression $\beta_c X_i$ expands as a sum of terms $\beta_c^j X_i^j$; the effect of each log-odd coefficient β_c^j is additive and must be only considered when X_i^j is non-zero. All the independent variables are categorised using dummies, so that each X_i is in fact

a vector of 0 and 1 values. The final model was the one with the set of regressors with the best chi-squared goodness of fit, thus giving the best compromise between goodness of fit and complexity. Significance values were computed from the standard errors using the Wald statistic in Stata. The final model coefficients and their significances are reported in Table 2.

Results

This study focuses on the comorbidity of CVD and depression using nationally represented weighted data from the QNHS on Health for 2007. Using the weight QNHS and examining the relationship between depression and CVD it found that 8% of individuals with depression had CVD and conversely 7% of individuals with CVD had depression. This represents a 0.02% prevalence of CVD and depression comorbidity within the wider population. Table 1 presents age-sex specific rates per 10,000 of the population for individuals with depression, CVD and depression/CVD comorbidity (referred to simply as comorbidity) in Ireland. With regard to the age-sex specific rates, one can see that the rate of depression is higher for females (430; 473; 419; 354) compared to males (288; 397; 317; 174) across all age categories per 10,000 of the population. Comparing the rate of female depression and CVD, depression is much higher for women aged 18-54 and 55-64 (430, 473) compared to the same age category for women with CVD (81, 371) per 10,000 of the population. In contrast, rates of CVD (127; 1099; 1906; 2215) are greater than rates of depression for all age groups for men (81; 372; 1003; 1609) per 10,000 of the population.

The rate of comorbidity per 10,000 of the Irish population for depression and CVD is very small across both age-sexes specific groups. Interestingly, females have higher rates of comorbidity across all age groups except for the 18-54 year olds. Indeed, the rate of comorbidity for females for those aged 75 plus is 79 compare to 18 per 10,000 of the population. This is an interesting finding and indicates that males have better health outcomes compared to females with regard to the comorbidity of CVD and depression. This result is consistent with recent research (Mulle and Vaccarino 2013) that found that women contribute disproportionately to the depression–CVD comorbidity. From Table 1, one may infer that this higher rate for comorbidity is primarily driven by the higher rates of self-reported depression recorded for females compared to males across all age groups.

Table 1. Age-sex specific rates per 10,000 of the population for individuals with depression, CVD and depression/CVD comorbidity

	Depression		**CVD**		**Comorbidity**	
	Female	Male	Female	Male	Female	Male
18-54	430	288	81	127	8	15
55-64	473	397	372	1099	83	73
65-74	419	317	1003	1906	100	77
75+	354	174	1609	2215	79	18

Table 2. Multinomial Model for Depression, CVD and Depression-CVD Comorbidity with no depression, CVD or Comorbidity as the base outcome

Variable	Coefficient	S. Error	P-Value	95% Confidence Intervals	
Outcome 0: No morbidity; Base Category					
Outcome 1: Depression					
Sex (0-female; 1-male)	-0.19	0.007	0	-0.203	-0.178
Age 55-64 (ref. age 18-54)	0.016	0.01	0.097	-0.003	0.034
Age 65-74 (ref. age 18-54)	-0.484	0.013	0	-0.509	-0.459
Age 75 plus (ref. age 18-54)	-0.866	0.016	0	-0.897	-0.836
Employed	-1.039	0.007	0	-1.053	-1.025
Suburbs of cities	0.473	0.01	0	0.454	0.492
Mixed urban/rural bordering suburbs	-0.679	0.042	0	-0.761	-0.596
Large towns population > 5,000	0.194	0.01	0	0.175	0.213
Mixed urban/rural bordering large towns	-0.147	0.023	0	-0.192	-0.101
Small towns population 1,000-5,000	0.126	0.014	0	0.099	0.153
Mixed urban/rural	-0.068	0.011	0	-0.089	-0.047
Rural	-0.62	0.012	0	-0.644	-0.597
University Degree	-0.1	0.01	0	-0.119	-0.082
Married	-0.378	0.007	0	-0.391	-0.365
Holder of Private Insurance	-0.324	0.007	0	-0.338	-0.31
Constant	-2.351	0.008	0	-2.367	-2.334
Outcome 2: Cardiovascular Disease					
Sex (0-male; 1-female)	0.856	0.006	0	0.843	0.869
Age 55-64 (ref. age 18-54)	1.76	0.01	0	1.741	1.779
Age 65-74 (ref. age 18-54)	2.268	0.01	0	2.248	2.288
Age 75 plus (ref. age 18-54)	2.616	0.01	0	2.596	2.636
Employed	-0.996	0.009	0	-1.014	-0.978
Suburbs of cities	0.26	0.011	0	0.24	0.281

Mixed urban/rural bordering suburbs	-0.691	0.051	0	-0.792	-0.59
Large towns population > 5,000	-0.048	0.011	0	-0.069	-0.027
Mixed urban/rural bordering large towns	0.138	0.02	0	0.099	0.177
Small towns population 1,000-5,000	0.313	0.013	0	0.288	0.339
Mixed urban/rural	-0.043	0.01	0	-0.063	-0.022
Rural	-0.127	0.01	0	-0.146	-0.108
University Degree	-0.179	0.012	0	-0.201	-0.156
Married	0.305	0.007	0	0.292	0.317
Holder of Private Insurance	-0.374	0.007	0	-0.388	-0.361
Constant	-4.476	0.011	0	-4.498	-4.454
Outcome 3: Comorbidity Depression & Cardiovascular disease					
Sex (0-male; 1-female)	0.34	0.021	0	0.298	0.381
Age 55-64 (ref. age 18-54)	1.775	0.027	0	1.722	1.829
Age 65-74 (ref. age 18-54)	1.363	0.03	0	1.304	1.423
Age 75 plus (ref. age 18-54)	0.731	0.036	0	0.66	0.803
Employed	-2.37	0.041	0	-2.45	-2.29
Suburbs of cities	0.414	0.032	0	0.351	0.478
Mixed urban/rural bordering suburbs	0.573	0.094	0	0.39	0.756
Large towns population > 5,000	-0.226	0.034	0	-0.293	-0.159
Mixed urban/rural bordering large towns	-0.944	0.111	0	-1.161	-0.726
Small towns population 1,000-5,000	0.205	0.04	0	0.126	0.284
Mixed urban/rural	-0.273	0.035	0	-0.342	-0.205
Rural	-0.635	0.035	0	-0.705	-0.566
University Degree	-0.519	0.056	0	-0.628	-0.41
Married	-0.482	0.023	0	-0.526	-0.437
Holder of Private Insurance	-1.358	0.03	0	-1.417	-1.299
Constant	-5.182	0.03	0	-5.24	-5.123

Table 2 presents the results of the multinomial log liner model (multinomial model) for depression, CVD and comorbidity using the weighted QNHS. The base outcome to which the three levels of disease categories are compared in the multinomial model is individuals with no reported depression, CVD or comorbidity. The comparison between intercepts in the multinomial model shows that the risk of comorbidity between CVD and depression is less probable for the reference group (non-married females living in cities, under the age of 55 that are not working and do not have a degree or private health insurance). From Table 2 one can see that controlling for demographic and socio-economic factors and the spectrum of urban-rural locations that female gender is significantly associated with depression. However, males are significantly more likely to have reported having CVD and CVD and depression. With regard to the age variables, depression is negatively associated with all three age groups, 55 to 64 years, 65 to 74 years and 75 years plus, relative to the base category (-0.016, -0.484 (non-significant), -0.866) 16 to 54 years of age. In contrast, both CVD (-1.76, 2.26, 2.61) and CVD and depression comorbidity (1.775, 1.36, 6.731) have a strong positive association with increases in age relative to the base category 16 to 54 years old. Whilst the model indicates that aging is significantly negatively associated with depression, interestingly individuals older than 75 years have the highest likelihood of having depression and CVD as a comorbidity. This indicates that for the Irish population sampled within this paper, old age (75 years plus) is not a protector from depression when coupled with CVD. Being married has a significant positive relationship with CVD (0.305) relative to the base category, not married. However, being married was found to have a significant negative relationship with depression (-0.378) and comorbidity (-0.482) relative to not being married. Thus, in this instance being married is a protector from depression and comorbidity. However, it is not a protector from CVD.

Examining the socio-economic variables included in the final model, Table 2 indicates that being employed (-1.039; -0.996; -2.37) has a significant negative association with each of the three disease categories. Being employed has the second largest negative affect for individuals reporting comorbidity. The education variable, having a university degree, has a significant negative association with all three disease categories (-0.1; -0.179; -0.635) relative to the base category, individuals without a university degree. Ireland's health system is a complex mix of public and private health care. Almost half the Irish population now pays for private health insurance (Nolan 2004). This is despite the fact that hospital care is what private health insurance mostly covers, and everyone has entitlement to public hospital care from the state. The insured can avail of 'private' health care, but much of this private care is actually delivered in public hospitals. The main benefits for individuals who pay for private health insurance relate to speed of access to health services and perceived quality of accommodation within private rooms or smaller hospital wards. For many years those towards the top of the income distribution in Ireland have been encouraged to take out 'private' health insurance (Nolan 2004). Thus, without an income data, private insurance may also be used as a proxy for higher income levels.

From Table 2, one can see that private health insurance has a significant negative association with depression (-0.324), CVD (-0.374) and comorbidity (-1.35). Using private health care as a proxy for higher income levels indicates that individuals in higher income categories are less likely to have depression, CVD and comorbidity. Thus, the three socio-economic variables included in the model, private insurance, having a university degree and being in-work indicate that socio-economic status has a strong association with both CVD and depression and their comorbidity. Indeed, the size of the coefficients for each of these three variables (employed -2.37; university degree, -0.519; private insurance, -1.35) was highest in the comorbidity category relative to depression and CVD as single morbidities. Thus, similar to research on single morbidities, comorbidity is strongly associated with socio-economic factors.

The location variables in the multinomial model included suburbs, mixed urban/rural areas bordering suburbs, was urban residence, large towns, population greater than 5,000, mixed urban/rural areas bordering large towns, small towns, population 1,000-5,000, mixed urban/rural areas and rural areas relative to the base category cities. Table 2 indicates that each of the location categories is significant across all three disease categories, relative to the base category cities. Examining depression first, individuals living in suburbs (0.473), large towns (0.194) and small towns (0.126) have a positive association with depression relative to the base category city residence. In contrast, individuals living in mixed urban/rural areas bordering suburbs (-0.679), mixed urban/rural areas bordering large towns (-0.147), mixed urban/rural areas (-0.068) and rural areas (-0.62) have a negative association with depression. This is an interesting result and indicates that individuals living in areas that are rural or mixed urban/rural have a lower association with depression compared to more built environments in Ireland.

With regard to CVD, individuals living in suburbs (0.26), mixed urban/rural areas bordering large towns (0.138), small towns (0.313) have a positive association with CVD relative to the base category city residence. In contrast, individuals living in mixed urban/rural areas bordering suburbs (-0.691), large towns (-0.048), mixed urban/rural areas (-0.048) and rural areas (-0.127) have a significant negative association with CVD. This differs somewhat to the findings for depression, whereby individuals in large towns and more rural residencies have a negative association with depression compared to cities in Ireland. Examining comorbidity, individuals living in suburbs (0.414), mixed urban/rural areas bordering suburbs (0.573) and small towns (0.205) have a positive association with comorbidity relative to the base category city residence. Whilst, individuals living in large towns (-0.226), mixed urban/rural areas bordering large towns (-0.944), mixed urban/rural areas (-0.273) and rural areas (-0.635) have a negative association with depression relative to the base category city residence. Thus, the model indicates that living in a large town or its environs, mixed urban and rural areas and rural areas are protectors from comorbidity.

Analysing the results of the location variables above, one can surmise that whilst none of the three disease categories shared the same location profile,

individuals living in the most rural areas, mixed urban-rural and rural, all had a strong negative association with each disease category relative to city residences. Conversely, individuals living in suburbs and small towns had a positive relationship with each disease category relative to city residences. Thus, in terms of the respondents of this survey one can state that rural areas are healthier places to live relative to cities – they have a negative association with depression, CVD and their comorbidity. Whilst interestingly controlling for the demographic and socio-economic profile, residents of suburbs and small towns are positively associated with all three disease categories.

Discussion

The overlap of physical and mental conditions has impacts for both the individuals concerned and their treatment providers (Scott *et al*. 2008). International studies have reported increased rates of depression and CVD based comorbidity (Katon 2011, Holt *et al*. 2013). At the same time, epidemiological studies have supplied growing evidence of an association between urbanisation and the prevalence of both psychical and mental illness. These studies are generally based on the premise that urban environments are more stressful and morbidities rates will therefore be higher in urban rather than rural areas (Paykel *et al*. 2000, Teljeur and Kelly 2008). However, exploring the demographic and socio-economic factors that may predispose individuals to both conditions, this paper argues that this assumption overlooks the growing rate of socio-economic risk factors associated with both morbidities, such as high levels of poverty, low educational levels and employment opportunities, which are found in rural areas. Furthermore, previous studies have tended to use a binary definition of urban and rural areas, whereby everything non-urban is classified as rural. This analysis aimed to establish whether the comorbidity of CVD and depression may be explained by individuals being exposed to spatially-variant demographic and socio-economic factors that may predispose them to both conditions. Stepping away from the simplistic dichotomous definition of urban and rural areas (Teljeur and Kelly 2008), the analysis used an eight category urban/rural stratification variable from the QNHS. Examining the prevalence of the depression, CVD and their comorbidity, Table 1 indicates that their comorbidity is small in the Irish general population when specified by age and sex. Table 1 further found that males have better health outcomes compared to females with regard to the comorbidity of CVD and depression across all age categories. This result is consistent with recent research that found that women contribute disproportionately to the depression-CVD comorbidity (Mulle and Vaccarino 2013). This result seems to be primarily driven by the higher rates of self-reported depression recorded for females compared to males across all age groups.

Exploring the demographic and socio-economic factors that may predispose individuals to both conditions, this paper found that similar individual level demographic and socio-economic characteristics are associated with depression and CVD as single morbidities in Ireland. The same factors are also significantly

associated with their comorbidity. This result reinforces recent research in the UK by Holt *et al*. (2013) that indicates that the social factors that influence depression and CVD risk potentially operate in tandem across an individual's life course. However, this paper expanded on that research by adding a geographical dimension. With regard to spatial variation, using a multinomial model, this paper found that relative to cities, the most rural areas (mixed urban/rural and rural) are negatively associated with depression, CVD and their comorbidity. However, disaggregating the urban/rural variable from a simple dichotomous variable, allows the spatial non-linearities associated with health outcomes to be highlighted. This paper found that health outcomes, in this case depression, CVD and their comorbidity, do not improve as space becomes increasingly rural relative to a city environment. In this study, suburban and mixed urban/rural residences bordering suburbs are consistently associated with poorer health outcomes, relative to city residents. Furthermore, residents of small towns have poorer health outcomes relative to city residents, whilst residences of large towns have better health outcomes relative to city residents. Thus, as noted by Teljeur and Kelly (2008) spatial health outcomes cannot be predicted on areas being defined simply as rural versus urban. When demographic and socio-economic factors are controlled for, health outcomes differ within urban areas (small versus large towns) and non-urban areas (mixed urban/rural bordering urban areas and mixed urban and rural bordering countryside) as well as between urban and rural areas.

From a spatial health policy perspective, these results raise important issues on both the individual demand side and institutional supply side. With regard to individual level demand, socioeconomic inequalities in health status are observed in all countries (Charlton *et al*. 2013). In Europe, lower socioeconomic position and measures of social and material deprivation are associated with greater morbidity and mortality (Navarro 2004, Zhang *et al*. 2013). The existence of this inverse relationship between socioeconomic status and the incidence or mortality rates has been demonstrated for many health outcomes including CVD and depression (Kavanagh *et al*. 2010, Zhang *et al*. 2011). As noted by Kavanagh *et al*. (2010), to change socio-economic outcomes in health outcomes, research concentrating on individual risk factors needs to be conducted in tandem with research on the generators of socio-economic inequalities. With regard to health service supply, in addition to the beneficial effects of not having comorbidity on an individual's quality of life, the prevention of comorbidity can possibly also curb the growing demands for health care, particularly among high-risk groups (Struijs *et al*. 2006, Fontin *et al*. 2007). This study indicates that in Ireland, managing physical and mental health separately is not suitable for the provision of health care for patients with depression or CVD. Current care programmes for both physical and mental health services must be extended to include additional care modules that are suitable to treat individuals presenting with comorbidity of physical and mental illnesses in the general population taking into account spatial considerations.

Finally, while this paper offered a wider definition of urban and rural areas than previous research, the eight category variable was defined by the Central Statistics

Office in Ireland. A health dataset with local level geographical references would have allowed us to use and/or further expand the urban/rural classification system for Ireland developed by Teljeur and Kelly (2008). Health data at the small areas level in Ireland is currently limited (Morrissey *et al*. 2008). The census of population only includes three questions regarding general health and access and, it is not possible to access the raw QNHS data and its primary sampling unit within a safe-setting in Ireland as it is in other countries such as the UK. Thus, the availability of spatial data is constrained to the urban/rural classification scale in the QNHS. Within this context, this paper proposes that future policy work on comorbidity should involve the development of a spatial micro-simulation model. Spatial micro-simulation models are designed to create data initially at the individual or household scale if such spatially disaggregated data is missing from available datasets. Internationally, spatial micro-simulation techniques have been used to examine a host of public health policy areas to date (Tomintz *et al*. 2008, Edwards and Clarke 2009, Smith *et al*. 2011). In Ireland, SMILE a spatial micro-simulation model has been used to examine a host of health questions at the small area level including GP access and the inverse care rule in rural Ireland, depression and the determinants of acute hospital care (Morrissey *et al*. 2008, 2010, 2013). The development of spatial micro-simulation models from existing datasets such as the QNHS and the Census of population also cuts down on respondent burn-out and the resource implications of funding another survey.

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