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IZA DP No. 14731

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ABSTRACT

Economic Gradients in Social Health in Britain*

Studies have found that loneliness is as bad as smoking or obesity for mortality risk, and the prevalence of loneliness is predicted to increase with ageing populations, more people living alone, and with chronic health conditions. Despite the substantial literature on loneliness, there is little detailed research on the extent of economic gradients. In this paper we provide this evidence using a sample of around 400,000 respondents (aged 40-70) from the UK Biobank. We focus on differences in loneliness across educational attainment, household income and neighbourhood deprivation, as well as recent major life events including financial difficulties. Using two statistical approaches, we find a substantially higher probability of experiencing loneliness, but also social isolation and a lack of social support, for men and women with low socioeconomic status, even when comparing those residing in the same postcode district. Additionally, the recent experience of financial stress is strongly associated with worse social health. Our results are robust to a panel analysis that accounts for intercorrelations between loneliness, social isolation and lack of social support, and controls for sample attrition.

JEL Classification: I1, J1

Keywords: loneliness, social isolation, social support, UK Biobank, economic gradients

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1. Introduction

Loneliness is highly prevalent across the life course, and is predicted to increase with demographic changes: ageing populations, more people living alone, and with chronic health conditions (Cacioppo and Cacioppo 2018a). Some commentators even argue that there is an epidemic of loneliness in many countries (Murthy 2020), and lockdown restrictions in the COVID-19 pandemic have further heightened this concern (Banerjee and Rai 2020).[1] Recent surveys find that around half of all adults in Australia, the UK and US feel lonely at least sometimes, with the highest prevalence in the youngest and oldest age groups (e.g. Ballard 2019; Cigna 2018; Lim 2018; Lim et al. 2020). Moreover, a substantive literature finds that loneliness is strongly related to worse health outcomes and lower wellbeing (e.g. Cacioppo and Cacioppo 2018a, 2018b; Courtin and Knapp 2017; Gerst-Emerson and Jayawardhana 2015; Holt-Lunstad et al. 2015; Steptoe et al. 2013). In fact, loneliness has been found to be a bigger risk factor for mortality than obesity and physical inactivity, and is on par with smoking (Flegal et al. 2013; Holt-Lunstad et al. 2010, 2015). Loneliness is also strongly associated with suicidal ideation and suicidal attempts, even after accounting for common mental disorders (Stickley and Koyanagi 2016). Consequently, there are substantive costs of loneliness to healthcare systems (Kung et al. 2021; Mihalopoulos et al. 2020). Loneliness is therefore becoming increasingly recognised as a major public health, demographic and economic issue that needs to be addressed. In this paper we provide detailed evidence on the extent of economic gradients in loneliness, but also in social isolation and a lack of social support, using British data on around 400,000 individuals aged 40-70.

What is loneliness? It can be defined as the negative emotional response to the discrepancy between the quantity, or quality, of social relationships that individuals have, versus what they want (de Jong-Gierveld 1987; Peplau and Perlman 1982). It is therefore a measure of perceived social scarcity (Mullainathan and Shafir 2013), and has been described as "social pain" (Cacioppo et al. 2006). Pathways by which loneliness can lead to disease are highlighted in Cacioppo and Hawkley (2003), and include (1) direct effects (affecting health by influencing lifestyle, health behaviours and health care utilisation), (2) heightened or excessive response to stress (i.e. or reduced stress-buffering), and (3) poor physiological repair and maintenance processes (e.g. lack of sleep). In addition, there are good grounds to think that loneliness might be strongly linked to socioeconomic status (Kung et al. 2021). For instance, a lack of investment in children can hinder the development of the emotional skills necessary to seek out and maintain high quality social relationships (Qualter et al. 2015). The experience of unemployment can eliminate or reduce the potential for important work-related interactions and friendships. Moreover, a lack of financial resources can prevent or limit participation

[1] It is still unclear how modern communication technologies including social media are impacting on loneliness (e.g. Ryan et al. 2017).

in a wide range of social activities, and the lack of ability to own a home can reduce the incentive to invest socially in local communities. Similarly, individuals residing in more deprived areas may have less access to public amenities that encourage social interaction, and high crime rates might deter social activities such as walking in the neighbourhood (Janke et al. 2016). Additionally, financial stress is a major cause of marital separation leading to the loss of a fundamental intimate relationship (Kung et al. 2021). Despite the extensive literature on most aspects of loneliness, with limited exceptions, the main focus in psychology, epidemiology and public health has not been on potential economic drivers. However, some studies have shown that those with low education and limited income have a higher probability of being lonely. Nonetheless, many of these studies rely on descriptive analysis, or simple multivariate regression models, and often relatively small samples. Moreover, as Niedzwiedz et al. (2016, p. 25) note, "A disadvantaged socioeconomic position is linked with loneliness, but in general, studies have rarely adopted an inequalities lens."

It is also the case that few studies have simultaneously assessed the extent of economic gradients for loneliness with other salient social health measures, namely social isolation and perceived social support (Holt-Lunstad 2018; Holt-Lunstad et al. 2017). These are related but distinct constructs: in contrast with loneliness - a subjective measure reflecting perceived inadequacy of social engagements (i.e. some people report being lonely even when they have regular social interactions, while others enjoy solitude) - social isolation captures structural aspects including quantity and type, and provides a relatively objective measure (e.g. living alone; not regularly meeting with family or friends; not a member of a club or society) of an individual's involvement in social relationships (Scharf and de Jong Gierveld 2008; Valtorta et al. 2016). Importantly, evidence suggests that the correlation between measures of loneliness and social isolation are moderate (Kung et al. 2021; Newall and Menec 2017). However, social isolation has also shown significant associations with mortality and poor health outcomes, even after accounting for loneliness (Ge et al. 2017; Hakulinen et al. 2018; Newall and Menec 2017; Shankar et al. 2011; Steptoe et al. 2013). Social isolation does not tap into the function aspects, or quality, of these interactions; these are better captured by social support measures, where individuals appraise their interactions with regard to the availability of emotional support and/or access to resources (finances, goods, services or information) (Fiorillo and Sabatini 2015; Valtorta et al. 2016; Wang et al. 2017).

The aim of this paper is to build upon existing evidence (reviewed in Appendix Info 1) on the extent of economic gradients in loneliness, as well as social isolation and a lack of social support, by providing detailed statistical analyses using nearly 400,000 adults in the UK Biobank residing in over 1,400 postcode districts. As well as permitting extensive cross-sectional analysis, we also estimate a transitional model that simultaneously models each of the three social health measures, and

incorporates repeat observations on a sample of around 36,000 adults (collected as part of the Biobank Imaging study). The model also explicitly controls for sample attrition. Our primary focus is on differences across educational attainment, household income, as well as recent major life events including financial stress. Additionally, the Biobank provides detailed geographical identifiers at each interview, allowing us to identify respondents living in the same postcode district, and to measure the level of area deprivation in which respondents reside.

2. Data

To provide evidence on the extent of economic gradients in social health: loneliness, as well as social isolation and a lack of perceived social support; we use data from the UK Biobank, which is a large-scale prospective study of around 500,000 participants across the nation. The Biobank was established with the aim of improving prevention, diagnosis and treatment of a large array of serious and life-threatening diseases of middle and old ages. Between 2006 and 2010, the Biobank invited around 9.2 million 40- to 69-year-olds registered with the National Health Service (NHS), who lived within reasonable traveling distance (up to 25 miles), to attend one of 22 assessment centres across England, Scotland and Wales. The assessment centres were opened incrementally and Appendix Info 2 provides a map of the locations and information on their operation dates and recruitment.

The response rate was 5.5%. The baseline assessment visit involved a verbal interview and self-completion questionnaires pertaining to demographic and socioeconomic factors, and health and lifestyle behaviours. Additionally, a wide range of physical and anthropometric measurements were taken including body composition, grip strength and bone density; as well as blood, saliva and urine samples. Participants were asked to consent to have their health-related records (e.g. hospital admissions) linked to their Biobank data, and to be re-contacted for further sub-studies (Allen et al. 2012; Sudlow et al. 2015; UK Biobank 2007). Notably, participants are not representative of the general UK population: they have been shown to be economically better off, healthier and have better lifestyle behaviours, implying a "healthy volunteer" selection bias (Fry et al. 2017). While we are thus not able to estimate the national prevalence of loneliness, social isolation or lack of social support, with the Biobank, our analysis of economic gradients should be widely generalisable, given the very large sample and extensive heterogeneity in the socioeconomic circumstances of respondents and where they live. If anything, we expect that we might under-estimate the extent of economic gradients using this volunteer sample.

Since the baseline assessments (2006-10), subsets of participants have been followed up for additional data collection. This includes a multi-modal imaging assessment visit (ongoing since 2014) aimed at collecting data from 100,000 participants living within reasonable distance of dedicated,

purpose-built centres in Stockport, Newcastle-upon-Tyne, Reading and Bristol. These centres have been sequentially opened, starting with Stockport. For this imaging assessment, centre locations were selected based on availability of public transport links and driving times, as travel time was found to be an important factor determining response (Littlejohns et al. 2020). Importantly, we are able to employ data on loneliness, social isolation and social support, as well as other socioeconomic circumstances and relevant covariates from these additional assessment visits.

The Biobank data is continually being updated and we use the February 2021 release that provides baseline data for 502,488 participants, with imaging data available on 48,998 of these participants. However, our estimation sample consists of 380,505 participants (201,473 women, 179,032 men) at baseline (and referred to as wave 1 in our panel analysis), and 36,153 (18,040 women, 18,113 men) that we observe both at baseline and in the imaging data (waves 1 and 2). We note that we have dropped from the analyses participants who were at baseline: (1) living in temporary, sheltered or care accommodations, (2) living in households of with more than eight other individuals, (3) aged under 40 or over 70 years (very few), or (4) those with missing information on loneliness, social isolation, social support, socioeconomic status or other relevant covariates (defined below). The sample characteristics for the baseline participants, and for those we observe in both waves, are provided in Appendix Table A1. At baseline the average age of women and men is 55.7 years and 56.6 years, respectively; and around 69% of women and 78% of men report to be married. The average number of people in the household is around 2.5, and the average number of children is 1.8 (with around 36% having children living in the household). About one-third report having a long-term illness, disability or infirmity (29% of women, 34% of men) and the vast majority of the sample is ethnically white (96%). However, the participants who have attended at imaging centre (thus observed in both waves) are 1-2 years younger, more highly educated, more likely to be employed, and have high incomes, than the full baseline sample. By wave 2 the age range of these participants is 45-82 years, and the average number of years between the baseline interview and imaging assessment is just under 9 years (with a minimum and maximum of 3.8 and 13.8 years, respectively). Importantly, we control for the time between waves in our panel transition model.

Appendix Table A2 shows the broad geographical spread of participants with respect to the baseline (wave 1) interview centres. Due to this sampling framework the data is not geographically nationally representative, but it does provide a good coverage across Britain (England, Scotland and Wales). As we have already noted we observe individuals residing in 1,430 postcode districts. However, from the 36,153 individuals observed in both the baseline survey and imaging study, 21,438 (59%) attended the Stockport imaging centre, 9,339 (26%) attended the Newcastle centre and 5,325 (15%) attended the Reading centre, with only 51 having attended the Bristol centre by February 2021.

Measuring Social Health: Loneliness, Social Isolation and Social Support

Studies have measured the different aspects of social health in many ways. In Appendix Table A3 we provide some salient examples, which place the measures that we will use in context. Loneliness is most commonly measured using the UCLA Loneliness Scale (Russell et al. 1980) or its shortened revised versions. Rather than asking directly about loneliness, this scale is derived from three questions about how often a person feels that they lack companionship, feels left out, or isolated from others. To a smaller extent the de Jong Gierveld scale (de Jong-Gierveld and Kamphuls 1985) has been used to measure loneliness among older individuals (Courtin and Knapp 2017; Pinquart and Sorensen 2001; Routasalo and Pitkala 2003), which is based on six items relating to experiencing a general sense of emptiness, often feeling rejected, missing having people around me, not having enough people that you feel close to, but also social support aspects of having plenty of people to rely on when you have a problem (instrumental), and having many people that you trust completely (emotional).

Other studies have employed a single-item measure on the frequency of loneliness (e.g. "How often have you felt lonely"), although there is some concern that the direct inclusion of the term "lonely" can render the measure dependent on contextual effects, and respondents' values and understanding of the concept (Routasalo and Pitkala 2003). There may also be differences in willingness to self-report loneliness (Russell et al. 1980; Victor et al. 2005). However, evidence suggests that direct measures of loneliness are highly correlated with the UCLA three-item measure (around 0.88), meaning that a person who rates themselves as lonely on the UCLA items will rate themselves as lonely on the direct measure of loneliness (Osborn et al., 2018). In the Biobank, loneliness is only measured using a binary indicator for the direct question "Do you often feel lonely?", to which response options are "Yes" and "No". To allow for gender differences in the reporting of loneliness, all our analyses are conducted separately for women and men. In the baseline sample, 20.8% of women and 14.5% of men report often feeling lonely, which is around 20% less prevalent in the panel samples (16.5%, 11.6%; see Appendix Table A1).

The measures available in the Biobank for social isolation and perceived social support come from the items "How often do you visit friends or family or have them visit you?" and "How often are you able to confide in someone close to you?".[2] The responses to both these questions are provided on a six-point frequency scale, ranging from "almost daily" to "never or almost never" (with visits having an additional option for "no friends/family outside the household). Consistent with our loneliness measure, we use binary versions, namely having visits less than once a month to indicate social isolation, and never having someone close to confide in to indicate absence of social support

[2] Note that these are the only questions in the Biobank relating to social health, and thus we do not have a measure of instrumental social support (i.e. help with caring, or financial support).

(emotional support). Just over 6% of women, and 10% of men report to be socially isolated, and 10% of women and 19% of men report a lack of social support, in the baseline sample. Again, these figures are qualitatively consistent for the panel sample, but the prevalence rates are higher in the baseline sample. In sum, women report experiencing more frequent loneliness than men, but less social isolation and better social support.

The raw correlations between the three social health measures at baseline are: lonely/social isolation = 0.080 for men, 0.065 for women; lonely/lack of social support = 0.173, 0.156; and social isolation/lack of social support = 0.112, 0.097). This is consistent with previous studies that have found that these correlations are modest (Kung et al. 2021; Newall and Menec 2017). However, in our panel transitional model we explicitly allow for loneliness, social isolation and a lack of social support to be jointly determined (i.e. unobserved factors may jointly determine all three aspects).

Persistence in Social Health

Although limited to two waves the dataset allows us to distinguish between transient and persistent social health concerns. Previous research (Mund et al. 2019) indicates a reasonably high level of stability in loneliness, and the empirical persistence rates in Table 1 confirm this.[3] For loneliness and lack of social support, the empirical probabilities of having poor social health at wave 2 conditional on poor social health at wave 1 is around 0.5. But social isolation is far more persistent, with a recurrence probability of more than 0.9 for both men and women. This suggests that individuals vary considerably in their psychological responses over time to persistent social isolation – with social isolation in some cases being the outcome of personal choice, possibly reflecting underlying trait-like preferences for company.

Measuring Socioeconomic Status

Our primary measures of socioeconomic status are: (1) highest educational attainment (college or university degree, A or AS levels, O levels or GCSEs, professional or other qualifications, or none of these), (2) annual pre-tax household income bands (under £18,000, £18,000-£30,999, £31,000-£51,999, £52,000-£100,000, or above £100,000), and (3) neighbourhood socioeconomic environment is measured by deciles of the Townsend Deprivation Index in the Lower Layer Super Output Area (LSOA) in which respondents reside.[4] We additionally provide estimates for employment status (in

[3] In particular, from their meta-analysis Mund et al. (2019) find that, "loneliness has trait-like features and that some individuals always feel lonelier than others, irrespective of their current circumstances. However, because the stability coefficients were far away from perfect stability, there is still much room for individual and differential changes in all age groups."

[4] The Townsend Index includes four components to construct an overall measure of area socioeconomic deprivation: percentage of individuals unemployed, percentage of households who do not own a car, percentage of households who do

paid or self-employment, unemployed, retired, sick or disabled, or other situations including volunteering, studying and caring).

Appendix Table A1 provides descriptive statistics for these measures for the full baseline sample and for respondents we observe in the panel setting. At baseline, just over one-third of the men and women have a college or university degree (35.1%, 36.8%), and the sample provides a wide spread of household income. Even though the Biobank is a volunteer sample, around 20% of men and women reside in households with an annual income of less than £18,000. The median household income falls within the £31,000-£51,999 band, which is consistent with the average gross household income at the UK median (based on equivalised household disposable income, 2008-09 values) of £36,151 (Office for National Statistics 2020). Some 61.5% (59.7% of women, and 63.4% of men) in the baseline sample are working in some form of paid employment or self-employment, and given the age of the sample respondents (40-70) around one-third are retired. As previously noted, the panel sample is more educated, more likely to be employed, and have higher incomes.

Recent Major Life Events

Biobank participants are additionally asked about major life events that they experienced within the two years prior to interview in both waves. In particular, the events cover many potential drivers of social health: any serious illness, injury or assault to themselves (8.4% of women, 10.3% of men) or to a close relative (14.3%, 9.1%); death of a spouse or partner (1.9%, 1.0%) or a close relative (22.1%, 20.2%); and marital separation or divorce (3.5%, 3.1%). Most importantly for the focus of our analysis is that respondents were asked if they experienced financial stress in the past two years (12.6%, 12.2%). For participants observed in both waves, 9.7% of women and 9.2% of men reported such financial difficulties.

Other Covariates

In our statistical models we also more comprehensively (compared to most other studies) control for respondents' demographic characteristics that might reasonably be thought to be risk factors for loneliness, social isolation or lack of social support. They are age, marital status, ethnic background, household composition (number of people, and number of own children), number of siblings (brothers, sisters), whether their mother or father is still alive, and whether they have any long-standing illness, disability or infirmity. Additionally, we control for area-level characteristics using assessment centre locations at baseline (i.e. 22 locations spread across Britain in both the fixed effects and transitional

not own their home, and the extent of household overcrowding. There are multiple LSOA's in each postcode district, which allows us to identify the effects of deprivation whilst also controlling for postcode fixed effects.

models), and area of residence (i.e. 1,430 postcode districts in the fixed effects model) at the time of assessment.[5]

3. Empirical Strategy

We use two statistical approaches, the first that takes advantage of the large baseline sample, comprising participants who reside across all the postcode districts, while the second approach uses the panel sample that allows for a model of transitions in social health. Importantly, both modelling approaches provide a very similar conclusion: economic gradients in social health for men and women are substantial whether measured by educational attainment, household income or local area deprivation, and financial stress is strongly associated with worse social health. Our estimates can therefore provide guidance on where to target or focus potential interventions to improve population social health, and reduce inequalities.

Regression Analysis with Postcode Fixed Effects

We start by using a linear probability regression model that includes fixed effects (intercepts) for each of the 1,430 postcode districts where respondents are observed to reside. This means that on average we observe 670 respondents per postcode district. Consequently, our gradient estimates are identified by comparing individuals who differ in their socioeconomic status (e.g. education, income) but reside within the same local area. The benefit of this is that it eliminates any potential for local area confounding factors between socioeconomic status and social health.

More formally, the regression model takes the form:

$$Y_{ia} = X_{ia}\beta + U_a + \varepsilon_{ia} \quad (1)$$

where Y_{ia} is any of the three (binary) indicators for loneliness, social isolation and lack of social support; i, a indexes the ith observed individual within the ath postcode area, X_{ia} is a vector of covariates (all varying between and within areas), U_a is a postcode-specific fixed effect and ε_{ia} a random term varying independently across individuals and postcode areas. No restriction is imposed on the correlation between X_{ia} and U_a. The predicted probability of an adverse outcome for Y_{ia} conditional on $X_{ia} = X$ is $\hat{p}_{ia}(X) = X\hat{\beta} + \widehat{U}_a$. We summarise the economic gradients captured by this

[5] Postcode districts are obtained by reverse geocoding the easting-northing coordinates corresponding with the postcodes at which participants were believed to be resident at the time of assessment. These coordinates were constructed based on the Ordnance Survey (OSGB) reference, rounded to the nearest kilometre. We first transformed these rounded coordinates into longitude and latitude values, which we then reverse geocoded into postcode districts using the Stata opencagegeo module (Zeigermann 2016).

model by calculating the mean estimated effect of varying (for example) household income from any category 0 to any other category 1. Define $X_{ia}^{(0)}$ and $X_{ia}^{(1)}$ to be the covariate vector X_{ia} but with the income indicators modified for all individuals to give income categories 0 and 1 respectively. The average marginal effect of varying income from category 0 to 1 is then $N^{-1}\sum_{ia}\left[\hat{p}_{ia}\left(X_{ia}^{(0)}\right) - \hat{p}_{ia}\left(X_{ia}^{(1)}\right)\right]$, where N is the number of individuals across all areas.

Non-Linear Transitional Panel Analysis

Our second approach exploits the two-wave panel aspect of the data available for 36,153 respondents, using a transition model with allows for non-ignorable attrition between waves 1 and 2. Re-defining the notation, the model uses the three binary indicators Y_1 ... Y_3 of loneliness, social isolation and lack of social support. We have two waves of observation, giving outcomes Y_{1it} ... Y_{3it} for sampled individuals $i = 1$ ... n over waves $t = 1,2$. At the baseline wave $t = 1$, we observe a vector of explanatory covariates X_i, and at re-interview (in the imaging wave) $t = 2$ another set of covariates Z_i. There are thus eight outcome regimes for wave 1, Y_{1i1} ... $Y_{3i1} = 0,0,0$ to $1,1,1$. Define $R_i = [R_{i1}$ ... $R_{i8}]$ to be the set of binary indicators identifying which of those eight outcomes is observed for individual i.

For a large proportion (around 90%) of baseline respondents, there is no wave 2 observation available. As previously noted, this is mostly because of survey design reasons – re-interviews (as part of the ongoing imaging study) are limited in the Biobank to respondents living in the catchment areas of imaging centres. However, even for those within the catchments, there will likely be to some degree the usual processes of non-contact, refusal and mortality. These processes may be endogenously related to social health, so we incorporate an endogenous attrition process in the statistical modelling.

The full model is:

$$Y_{1i1}^{*} = X_i\beta_1 + U_{1i} \quad (2)$$

$$Y_{2i1}^{*} = X_i\,\beta_2 + U_{2i} \quad (3)$$

$$Y_{3i1}^{*} = X_i\,\beta_3 + U_{3i} \quad (4)$$

$$Y_{1i2}^{*} = Z_i\,\gamma_1 + R_i\delta_1 + V_{1i} \quad (5)$$

$$Y_{2i2}^{*} = Z_i\,\gamma_2 + R_i\,\delta_2 + V_{2i} \quad (6)$$

$$Y_{3i2}^{*} = Z_i\gamma_3 + R_i\,\delta_3 + V_{3i} \quad (7)$$

$$A_i^{*} = X_i\lambda + R_i\theta + W_i \quad (8)$$

where Y^*_{1i1} ... Y^*_{3i2}, A^*_i are latent continuous variables driving the three observable binary indicators of social health. The vectors $\beta_j, \gamma_j, \delta_j$ $(j = 1,2,3)$; λ, θ contain coefficients to be estimated. The variables $U_{1i}, U_{2i}, U_{3i}, V_{1i}, V_{2i}, V_{3i}, W_i$ are random terms assumed to be normally distributed with zero means and unit variances. The correlations within U_{1i}, U_{2i}, U_{3i} are $\rho_{12}, \rho_{13}, \rho_{23}$ and within V_{1i}, V_{2i}, V_{3i} are $\varphi_{12}, \varphi_{13}, \varphi_{23}$, which are estimated as parameters. The two blocks of error terms U_{1i}, U_{2i}, U_{3i} and V_{1i}, V_{2i}, V_{3i} are assumed to be independent, since the wave 2 outcomes are modelled conditionally on the wave 1 outcome. The random attrition term W_i is independent of the U_{1i} ... U_{3i}, since the attrition model is conditional on the observed wave 1 outcome. We also assume W_i to be independent of V_{1i}, V_{2i}, V_{3i}.

The observed binary indicators Y_{jit} are generated through the following mechanism. For the observed outcome at wave 1:

$$Y_{ji1} = 1 \text{ if } Y^*_{ji1} > 0 \text{ and } 0 \text{ otherwise}, \quad j = 1,2,3; \quad i = 1 \ldots n \tag{9}$$

giving the eight possible outcome regimes indicated by R_i. At wave 2, there are nine possible outcomes, since attrition is another possibility. Thus:

$$Y_{ji2} = 1 \text{ if } Y^*_{ji2} > 0, A^*_i < 0 \text{ and } 0 \text{ otherwise}, \quad j = 1,2,3 \tag{10}$$

$$A_i = 1, [Y_{1i2} \ldots Y_{3i2}] \text{ missing if } A^*_i > 0 \tag{11}$$

The composite likelihood for individual i is:

$$\begin{aligned} L_i \; = Pr(Y_{1i1}, Y_{2i1}, Y_{3i1} | X_i) \times \{ & A_i Pr(A_i = 1 | Z_i, R_i) \\ & + \; (1 - A_i)[1 - Pr(A_i = 1 | Z_i, R_i)] Pr(Y_{1i2}, Y_{2i2}, Y_{3i2} | Z_i, R_i)\} \end{aligned} \tag{12}$$

The components $Pr(Y_{1i1}, Y_{2i1}, Y_{3i1} | X_i)$ and $Pr(Y_{1i2}, Y_{2i2}, Y_{3i2} | Z_i, R_i)$ are computed as trivariate normal d.f.s and $Pr(A_i = 1 | Z_i, R_i)$ as a univariate normal d.f. The ML estimator is computed by maximising numerically the log likelihood $L = \sum_i L_i$.

4. Results

Both models are estimated separately for men and women. The full set of parameter estimates for the linear probability model are presented in Appendix Tables A4 and A5, and the estimated parameters for the non-linear transition model are shown in Appendix Tables A6, A7 and A8. All estimates and

calculations we present in this section are derived from these estimates. Our main focus is on the extent of economic gradients across four dimensions: household income, financial stress, educational attainment and local area deprivation. Overall, we find robust evidence of substantive economic gradients in social health, but they do differ in extent across the three outcomes and by gender. Results for employment status, demographic and household characteristics are also discussed. Appendix Table A6 shows that the correlation parameters from the joint modelling of the three outcomes in the transition model are highly significant, but strongest for loneliness and lack of social support (around 0.3), and weakest for loneliness and social isolation (around 0.15). The modest size of these residual correlations and the significant coefficient differences across equations (2)-(4) and (5)-(7) confirms that our three measures of social health are distinct aspects rather than alternative indicators of a single underlying concept. At the end of this section, we also discuss our estimates of sample attrition.

Household Income

We start with household income, which is captured by five broad bands in the Biobank. Figure 1 shows the estimated gradients graphically from the linear probability model (a,c,e) and the baseline component of the transition model (b,d,f). The plotted points are estimates of $E_{X^*}\{\Pr(Y = 1|\text{income category } j, X^*)\}$, where Y is any of the social health indicators, X^* is the baseline covariate vector with the exception of the income variables, and $E_{X^*}\{.\}$ is the expectation with respect to the population distribution of the covariates X^*. For estimation purposes, $\Pr(Y = 1|\text{income category } j, X^*)$ is given by the fitted model and $E_{X^*}\{.\}$ is replaced by the analogous sample average. Confidence intervals (95%) take into account sampling variation in the model parameters and the averaging over sampled X^*.

For the income profiles at baseline (wave 1), both models provide very similar income profiles. These show that more women than men report often feeling lonely across the whole income distribution, whereas more men than women consistently report more social isolation and particularly a lack of social support. In every case there is a significant (with tight confidence intervals) household income gradient, which is particularly pronounced for loneliness and a lack of social support. In contrast to men, the gradient in social isolation for women is close to flat across the income distribution. The implication of this is that the amount of income that a household has is not a strong predictor of how often women interact (visit) with friends or family.

Figure 2 shows the income profile of the sample mean of the estimated joint probabilities for the three social health measures, as we hypothetically vary each individual's income from the lowest to highest category. The income gradient in this joint probability is apparent for loneliness, social isolation and lack of social support, but only achieves statistical significance for loneliness for this

smaller sample of individuals present at both waves. Table 2 gives quantitative summaries of the overall income gradients between the top and bottom household income categories. From the baseline (wave 1) component of the model, the estimated rise in the mean probability of experiencing loneliness as household income moves from the highest to lowest income category is just over 5 percentage points, amounting to a proportional rise of 31.1% for women and 50.1% for men. Similarly, very strong income gradients are found for both social isolation and a lack of social support. Again, we find that the smallest gradient is for social isolation for women.

The joint probabilities of loneliness, social isolation or lack of social support at both waves 1 and 2 indicate the longer-term relationship between income and social health. The mean joint probability is necessarily less than the marginal probability for wave 1, and the absolute impact is consequently smaller. However, in terms of proportional impacts, the estimates are very large for all three aspects of social health, ranging from a 44.1% rise (loneliness in women) to 81.6% (social isolation among men). These income gradients are also substantial relative to other non-economic influences, particularly for perceived loneliness and lack of social support. Moving from the highest to lowest income category, for example, raises the mean probability of loneliness by almost half the effect of being single rather than married, and a fifth to a quarter of the short-term impact of the death of a spouse (estimates shown in Appendix Tables A4-A6).

Financial Difficulties

While the Biobank provides information on the level of household income, it also asks respondents about the occurrence of financial stress in the two years prior to interview; which may arise from unemployment, high expenses or debt accumulated in the past. However financial difficulties arise, they could act as a severe constraint on an individual's social activities. Table 3 shows the estimated mean impacts of financial difficulties, with 95% confidence intervals shown in squared brackets. These estimates are average effects: mean differences $Pr\left(Y = 1\middle|X^{(1)}\right) - Pr\left(Y = 1\middle|X^{(0)}\right)$ predicted by the relevant model, where Y is any of the three indicators for loneliness, social isolation and lack of social support; and $X^{(0)}$ and $X^{(1)}$ are the observed covariate vector with the financial stress indicator set to 0 and 1 respectively. Again, we show alternative estimates from the linear probability model and the non-linear transition model for the baseline (wave 1). We also show corresponding estimates for wave 2 respondents derived from the transition model, conditioning on the observed wave 1 outcome.

In relation to the sample prevalence of loneliness, social isolation and perceived lack of social support, these are again large effects. The estimated average effect of recent financial difficulties is a proportionate increase in the number of people experiencing frequent loneliness by 27-58% (i.e. 5.7/20.8; 12.0/20.8) for women and 38-72% (i.e. 5.5/14.5; 10.4/14.5) for men, depending on the model

and wave used. Similarly, social isolation rises by one or two percentage points, equivalent to a 23-25% (i.e. 1.4/6.1; 1.5/6.1) rise in the number of women classed as socially isolated, with a corresponding 16-21% (i.e. 1.6/10.2; 2.1/10.2) increase in the number of men. For lack of social support, the estimated impacts are similar: 22-32% (i.e. 2.2/10.2; 3.3/10.2) for women and 17-23% (i.e. 3.1/18.5; 4.2/18.5) for men.

Educational Attainment

The estimates provided in Appendix Tables A4-A6 clearly show that the better educated have a substantively lower probability of reporting feeling lonely and lacking social support at baseline, but this is not so clear cut for social isolation. These are summarised in the top panel of Table 4, which provides estimates of the difference in the probabilities between the highest education level (degree) and the lowest (no qualification). From the linear probability model, a college or university degree is associated with differences in the probability of loneliness by around 35% (6.5) and lack of social support by 60% (5.1) among women; with the corresponding estimates for men being smaller at around 8% (1.1) and 40% (6.5), respectively. Similar estimates are found from the baseline (wave 1) estimates from the transition model. In contrast, we find that having a degree is significantly associated with a higher probability of being socially isolated for both women (-10.0%) and men (-5.9%); that is, being less likely to often visit friends or family, or have them visit you. This could be explained by those with a degree being more likely to be employed, and thus having less time for such social interactions, but these estimates are conditional on controlling for employment status in the models.

Turning to the transition (the difference in social health between waves 1 and 2), from the final column of Table 4 we see that having a degree relative to no qualifications is highly predictive of a substantively lower joint probability of loneliness and a lack of social support in both waves 1 (baseline) and wave 2 (imaging study). In fact, the proportionate change in the probabilities is even greater for loneliness (46%, 21.6%) and lack of support (91.8%, 60.9%) for women and men, respectively, than when we focus only on wave 1. One interesting change, however, is that when we consider both waves of data, we now find that education does reduce social isolation (12.9%, 10.1%). Finally, the gradients across each level of educational attainment are plotted in Figure 3 for the linear probability model (wave 1) and the joint probabilities from the transition model. These highlight that the education gradient in loneliness is steeper for women than men, about the same for lack of social support, but that the relationship between education and social isolation might not be monotonic across the education levels.

Neighbourhood Deprivation

Economic disadvantage may operate at the level of the individual and/or at the level of the neighbourhood. We measure neighbourhood deprivation using deciles of the Townsend Deprivation Index calculated at the small LSOA level. The estimated differences between the deciles are jointly statistically significant in both the linear probability and transition models, for all three outcome measures and both genders.[6] Note that these effects are identified by comparing individuals who reside in the same postcode district, but differ in the level of deprivation in their smaller area (neighbourhood). Figure 4 shows the estimated average effect of varying the level of neighbourhood deprivation from the bottom to top decile, while keeping other observed characteristics at their observed values. Estimates from both the linear probability model (a,c,e) and the transition model (b,d,f) are shown. Moreover, although statistically significant, the neighbourhood gradient is quantitatively small for loneliness and lack of social support, but much stronger for social isolation, driven by a particularly strong gradient in the top 30% of the deprivation range.

Our social isolation measure is an indicator of the absence of social interaction rather than its perceived quality. Deprived neighbourhoods tend to have poorer quality housing, few local amenities, poor environmental quality and greater concerns about personal safety, all of which are potential barriers to exercising the personal demand for social activities. Low incomes and long working hours of others within the same deprived neighbourhood may also have the effect of reducing the potential supply of opportunities to socialise with others.

The bottom panel of Table 4 further provides quantitative summaries of these deprivation gradients which, for perceived loneliness and lack of social support, are considerably smaller than the gradients found for education and household income shown in Tables 3 and 5. For social isolation, the deprivation gradient is nearly twice the size of the income gradient for women, whereas for men, the deprivation gradient is slightly smaller than the income gradient. For these neighbourhood deprivation gradients (unlike the income, education, and financial stress impacts), the linear probability model gives larger gradients than does the transition model – a difference attributable to its ability to control for postcode district effects.

Employment Status

Noting that the minimum age of respondents is 40, Tables A3 and A4 (linear probability regression) show that even controlling for educational attainment, household income and local area deprivation in the models, that employment status is a significant predictor of social health for women and men.

[6] *P*-values for joint significance of the deprivation dummies are less than 1%, except for the loneliness equation in the transition model for women, where $P = 0.0117$.

Compared to being employed (employee or self-employed), being unemployed is associated with an increased probability of loneliness (by 5.6 percentage points), social isolation (2.0) and a lack of social support (3.2) for women, and loneliness (3.1) and a lack of social support (1.9) for men. Unemployment is not associated with increased social isolation for men. In contrast, across all three measures, being retired is significantly associated with better social health outcomes. Moreover, being unable to work due to disability is strongly linked to an increased risk of loneliness, and to a lesser extent a lack of social support, and (for women) increased social isolation. These findings are largely confirmed by the wave 1 transitional model estimates as shown in Appendix Table A6. In terms of explaining transitions, the wave 2 estimates presented in Appendix Table A7 suggest that moving to retirement is associated with better social health, particularly reduced loneliness and social isolation. However, there is no evidence that retirement changes perceived social support. While not being able to work due to disability does not predict a change in social health for women, it does suggest greater loneliness and decreased social support for men.

Demographic and Household Characteristics

Age is consistently found across our models to have a predominantly protective effect on social health, with loneliness, social isolation and lack of support all declining with age after controlling for the wide range of other characteristics represented by the covariates in the models. The one exception to this is for women, where the predicted probability of a lack of support rises up to age 47, declining thereafter.

As expected, marriage (or cohabitation) greatly reduces the estimated probability of loneliness in particular, but also to a lesser extent the probabilities of social isolation and (for men) a lack of social support. The protective effect of marriage is substantially stronger for men than for women, which is consistent with the findings that men tend to have a stronger reliance on their spouses as confidants, and for the maintenance of social contacts (Stroebe et al. 2001; Wörn et al. 2020).

Household size and structure have complex effects. For both men and women, the probability of loneliness is monotonically decreasing in household size but the probability of social isolation is more strongly increasing – the existence of many contacts within the households thus appears to act as a substitute for contacts outside. As might be expected, the largest step in these household size profiles is the distinction between a single person and a couple. For women, unlike men, there is evidence of only a small negative household size effect on the probability of lack of support. Family appears to meet support needs better for men than for women. Having children increases the risk of loneliness and – for women only – that effect rises with the number of children she has. In contrast, a greater number of children reduces the probability of social isolation for both parents. To a smaller extent, large families also tend to reduce both parents' probability of a lack of social support. Thus,

children appear to be a mixed blessing in terms of social health – it is possible to have an active social life built around one's children but still experience loneliness nonetheless.

Having family external to the household is also important: having surviving parents appears to be protective against loneliness, social isolation and lack of support. This relationship is stronger for women than for men and with the exception of social support, it is stronger with a surviving mother than a surviving father. The existence of siblings is associated with a small reduction in the probabilities of loneliness and lack of support for women. In contrast, for men there is some evidence that (a large number of) siblings tends to increase loneliness and social isolation. These sibling effects are likely to be a mixture of short- and very long-term influences: current availability of siblings increases the pool of potential social contacts, while we might speculate that having a large number of siblings during childhood affects the social skills that are carried into adult life.

There is strong evidence of differences between ethnic groups. Women with South Asian heritage have a substantially higher probability of loneliness, isolation and lack of support than the reference white group, but the relationships for South Asian men are smaller for the probability of lack of support and negligible for social isolation. East Asian ethnicity is associated with elevated probabilities of social isolation and lack of support (especially for women), but not loneliness. Black African and Caribbean ethnicities (and to a lesser extent, mixed race) are estimated to reduce rather than increase the probability of loneliness relative to whites, significantly so for men. However, black ethnicity is linked to higher probabilities of social isolation and lack of support, particularly for women.

Attrition

The transition model we specified contains an attrition component, which we present in Appendix Table A7. Note that the attrition process here is a composite, covering elements of survey design (i.e. living close to an imaging centre), refusal and non-contact, and also potentially mortality given the age of the samples. Nevertheless, the pattern is consistent with what is found in many other longitudinal surveys: the probability of attrition rises strongly with age, illness and disability, minority ethnic identity, low educational attainment, low income and financial distress, and extreme neighbourhood deprivation. Moreover, attrition is found to be endogenous in the sense that at least one of the possible outcome states involving loneliness at wave 1 significantly raises the probability of attrition at wave 2. Thus, including the modelling of attrition as we have done is important.

5. Conclusion

Despite having a high GDP per capita, poor social health is highly prevalent in Britain. This is important because loneliness, social isolation and a lack of social support have all been linked to worse

health and wellbeing, including an increased risk of mortality. Moreover, these social health issues are predicted to increase with demographic changes: ageing populations, more people living alone, and with increased chronic health conditions. While there has been a great deal of research on these health links, there have been fewer studies focusing on the extent of socioeconomic inequalities in social health (Niedzwiedz et al., 2016). Such studies are important for shedding light on the focus of potential policies aimed at improving social health in the population.

The contribution of this paper is to provide a detailed study of economic gradients in loneliness, but also social isolation and lack of social support, using data on nearly 400,000 respondents observed in the UK Biobank. It is important to study each of these different dimensions of social health because while they will be to some extent jointly determined, the correlation between them is only modest (e.g. a person can be lonely without being socially isolated or lacking in social support). However, we find that the correlation between loneliness and lack of social support is stronger than the correlation between loneliness and social isolation. In particular we examine the extent to which these measures of social health vary by educational attainment, household income, financial stress and neighbourhood deprivation. We fit two different statistical models, one that exploits the large sample size and detailed geographical information about where respondents live, and one that exploits the fact that around 36,000 respondents are tracked so that we observe their social health and socioeconomic circumstances at two points in time. This allows us to shed light on the persistence of social health by socioeconomic status. However, a limitation of our study is that, although we have been able to control for a rich host of covariates in our models, we cannot make any strong claims of causality.

Overall, we find strong and robust evidence of substantial economic gradients in loneliness, social isolation and lack of social support, after controlling for a wide array of socioeconomic and demographic characteristics. Those with low education levels, low household income, and residing in the most deprived areas have a high probability of experiencing poor social health. Additionally, the recent experience of financial stress substantially compounds that risk. These general results are consistent across both our modelling approaches and hold to differing extents for each of our measures of socioeconomic status and by gender.

The literature contains discussions on how income can influence loneliness insofar as it leads to opportunities for more (quantity) and/or better (quality) social connections (Beere et al. 2019; Klinenberg 2016; Pinquart and Sorensen 2001). Qualitative results have shown that higher income can provide resources that allow sociable leisure activities, whereas low income jobs may include shift work, irregular hours and multiple jobs resulting in less time for socialising (Finlay and Kobayashi 2018). Several studies have found that loneliness appears more closely related to quality rather than quantity of connections (e.g. Fokkema and Naderi 2013; Pinquart and Sorensen 2001), although the

opposite might be true in deprived communities (Paúl et al. 2003). Our findings suggest that income is strongly related to increases in both the quantity (isolation) and quality (social support) of connections. However, we do find important differences by gender: the gradient in loneliness and social isolation is stronger for men than women, whereas the gradient in social support is stronger for women. In other words, for men, income is potentially more likely to enable the maintenance or rise in quantity of connections, whereas for women, income may be more helpful with regard to improving or creating higher-quality connections.

We also find that neighbourhood deprivation is most strongly related to social isolation for both men and women. Deprived neighbourhoods can impede social activities, through for example having limited safe, public and free spaces to commune and socialise (e.g. Finlay and Kobayashi 2018). Education, on the other hand, appears to impact women's perceptions of loneliness and (especially) social support, but only perceptions of support among men. This is consistent with the literature that human capital attainment – which involves non-cognitive skills – is important for social functioning, among other outcomes (Heckman et al. 2006; Smithers et al. 2018). Naturally, this would include the ability to develop and nurture high-quality relationships (Qualter et al. 2015).

While this study is not without limitations, we believe that it provides the most detailed investigation into economic gradients in loneliness, and additionally social isolation and a lack of social support, to date. The identification of groups most at risk of the three aspects of poor social health can be used to help target interventions and policies aimed at reducing inequalities.

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Tables

Table 1: Empirical probabilities of persistence at wave 2 conditional on loneliness/social isolation/lack of social support at wave 1

Social health indicator	Women	Men
Loneliness	0.508 [0.492, 0.525]	0.463 [0.442, 0.483]
Social isolation	0.935 [0.930, 0.939]	0.937 [0.933, 0.940]
Lack of social support	0.448 [0.424, 0.471]	0.507 [0.489, 0.524]

Note: 95% confidence intervals in brackets.

Table 2: Summary of income gradients in loneliness, social isolation and lack of social support

	Linear probability model: Impact[a] on mean wave 1 probability	**Transition model**	
		Impact[a] on mean wave 1 probability	**Impact[a] on mean wave 1 and 2 joint probability**
Women			
Loneliness	4.6 p.p. (24.8%)	5.4 p.p. (31.1%)	3.2 p.p. (44.1%)
Social isolation	1.5 p.p. (28.1%)	1.4 p.p. (25.4%)	0.6 p.p. (59.2%)
Lack of support	2.5 p.p. (27.3%)	3.2 p.p. (38.9%)	1.2 p.p. (68.5%)
Men			
Loneliness	5.3 p.p. (45.3%)	5.6 p.p. (50.1%)	2.6 p.p. (65.9%)
Social isolation	3.7 p.p. (43.7%)	3.4 p.p. (39.8%)	0.9 p.p. (81.6%)
Lack of support	3.8 p.p. (22.3%)	4.8 p.p. (30.4%)	1.5 p.p. (68.3%)

Note: Impact is expressed as a difference in percentage points (p.p.) or proportionately (%).

[a] Difference between mean probability when all sample individuals have income reset to the highest category and mean probability when all individuals are assigned to the lowest income category.

Table 3: Estimated impact[a] in percentage points of financial stress

Model	Loneliness	Social isolation	Lack of support
Women			
Linear model (wave 1)	12.0 [11.4, 12.6]	1.5 [1.1, 1.8]	3.2 [2.7, 3.7]
Transition model (wave 1)	10.8 [10.2,11.4]	1.4 [1.1, 1.8]	3.3 [2.8, 3.7]
Transition model (wave 2)	5.7 [3.6, 7.8]	1.4 [0.0, 2.8]	2.2 [0.5, 4.0]
Sample proportion (wave 1)	20.8	6.1	10.2
Men			
Linear model	10.4 [9.8, 10.9]	2.1 [1.6, 2.5]	4.2 [3.6, 4.8]
Transition model (wave 1)	8.7 [8.2, 9.3]	1.9 [1.4, 2.3]	4.0 [3.4, 4.6]
Transition model (wave 2)	5.5 [3.5, 7.5]	1.6 [-0.3, 3.4]	3.1 [0.6, 5.5]
Sample proportion (wave 1)	14.5	10.2	18.5

Note: Figures in square brackets are 95% confidence intervals.

[a] Difference (in percentage points) between mean probability when all sample individuals have the financial difficulty indicator set to 1 and mean probability when all individuals are assigned no recent financial shock.

Table 4: Summary of education and neighbourhood deprivation gradients in loneliness, social isolation and lack of social support

	Linear probability model: Impact[a] on mean wave 1 probability	Transition model	
		Impact[a] on mean wave 1 probability	Impact[a] on mean[b] wave 1 and 2 joint probability
Education gradients			
Women			
Loneliness	6.5 p.p. (34.7%)	6.9 p.p. (37.6%)	3.8 p.p. (46.0%)
Social isolation	-0.7 p.p. (-10.0%)	-0.7 p.p. (-10.3%)	0.2 p.p. (12.9%)
Lack of support	5.1 p.p. (60.1%)	5.2 p.p. (63.5%)	1.8 p.p. (91.8%)
Men			
Loneliness	1.1 p.p. (7.8%)	1.5 p.p. (10.1%)	1.1 p.p. (21.6%)
Social isolation	-0.7 p.p. (-5.9%)	-0.7 p.p. (-6.6%)	0.2 p.p. (10.1%)
Lack of support	6.5 p.p. (40.8%)	7.0 p.p. (45.0%)	1.6 p.p. (60.9%)
Neighbourhood deprivation gradients			
Women			
Loneliness	1.4 p.p. (6.6%)	0.8 p.p. (4.1%)	0.4 p.p. (4.5%)
Social isolation	2.6 p.p. (47.4%)	2.2 p.p. (45.9%)	0.5 p.p. (45.1%)
Lack of support	2.0 p.p. (20.1%)	1.1 p.p. (11.5%)	0.3 p.p. (12.3%)
Men			
Loneliness	1.9 p.p. (13.6%)	1.5 p.p. (10.9%)	0.6 p.p. (11.2%)
Social isolation	3.2 p.p. (34.5%)	2.9 p.p. (34.4%)	0.5 p.p. (36.8%)
Lack of support	2.2 p.p. (12.3%)	0.8 p.p. (4.3%)	0.3 p.p. (8.5%)

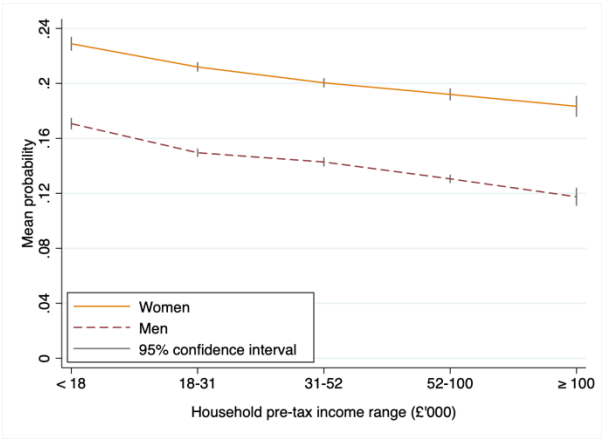
Note: Impact is expressed as a difference in percentage points (p.p.) or proportionately (%).

[a] For education gradients, this is the difference between mean probability when all sample individuals have education reset to the highest category (degree) and mean probability when all individuals are assigned to the lowest education category (no qualifications). For neighbourhood deprivation gradients, this is the difference between mean probability when all sample individuals have their Townsend Deprivation Index decile reset to the lowest category (least deprived) and mean probability when all individuals are assigned to the highest category (most deprived).

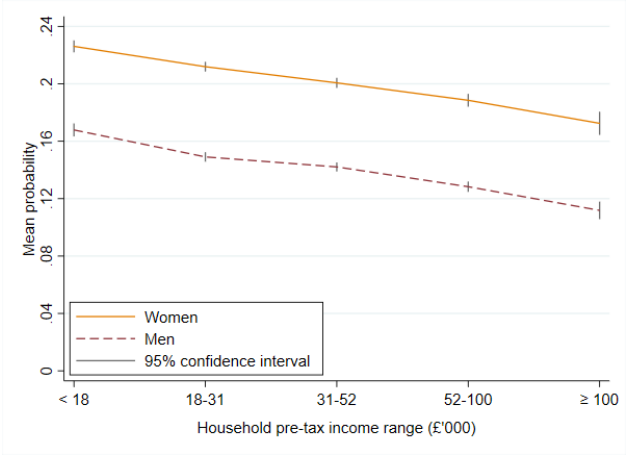
[b] Mean over subsample of individuals observed in both waves.

Figures

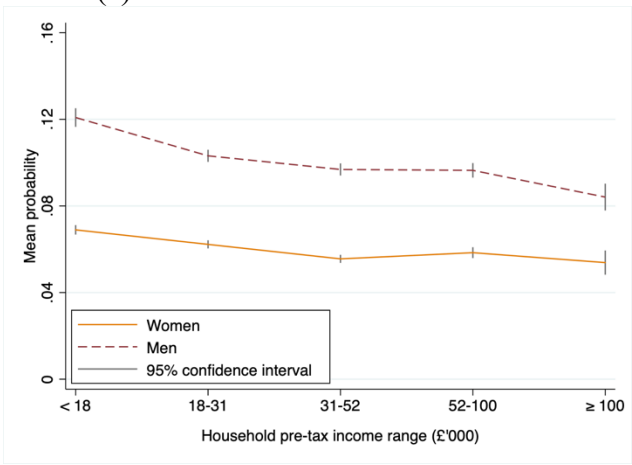
Figure 1: Income gradients at wave 1 for the cross-section linear probability model with area effects and the baseline component of the two-wave transition model



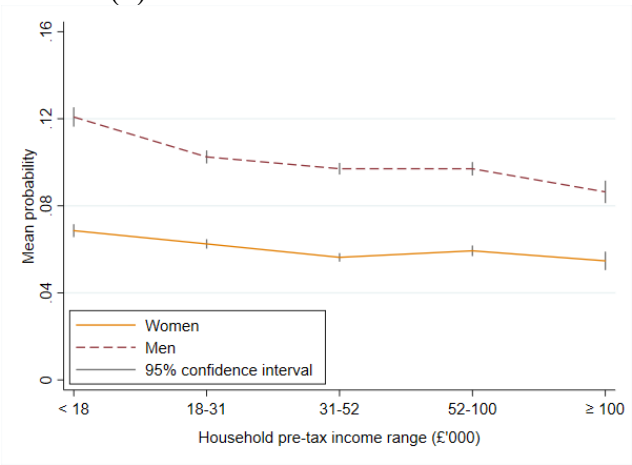
(a) Area effects model: loneliness



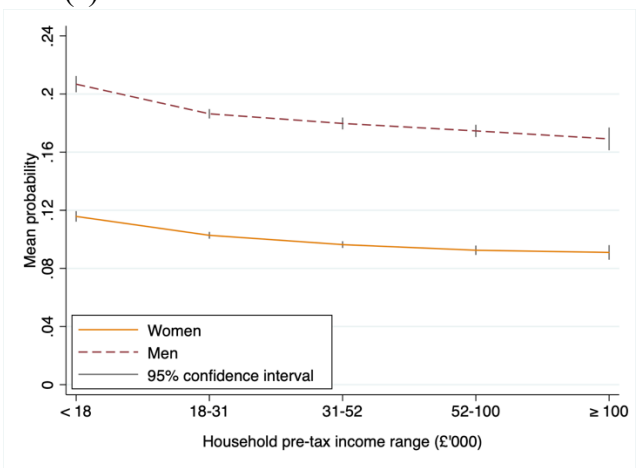
(b) Transition model: loneliness



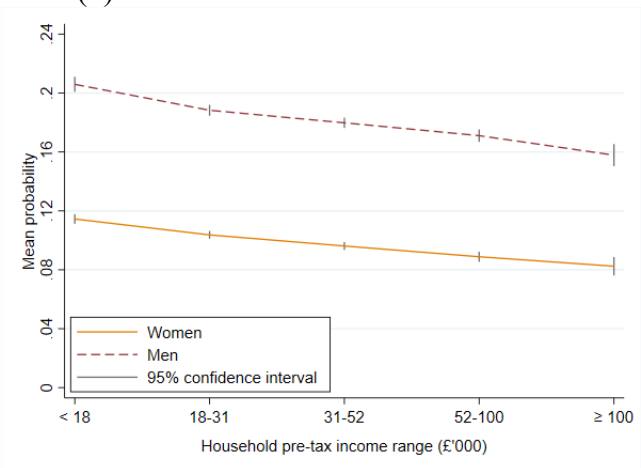
(c) Area effects model: social isolation



(d) Transition model: social isolation

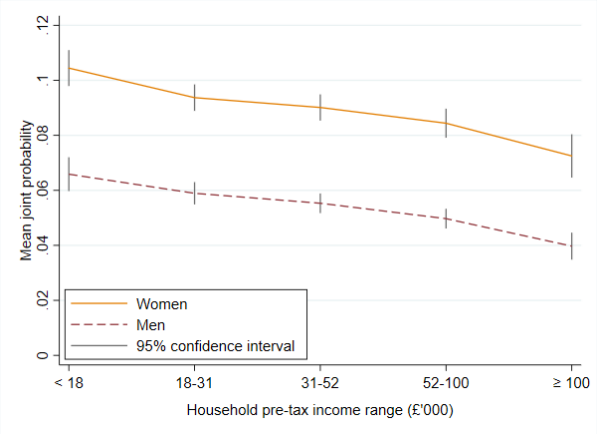


(e) Area effects model: lack of support

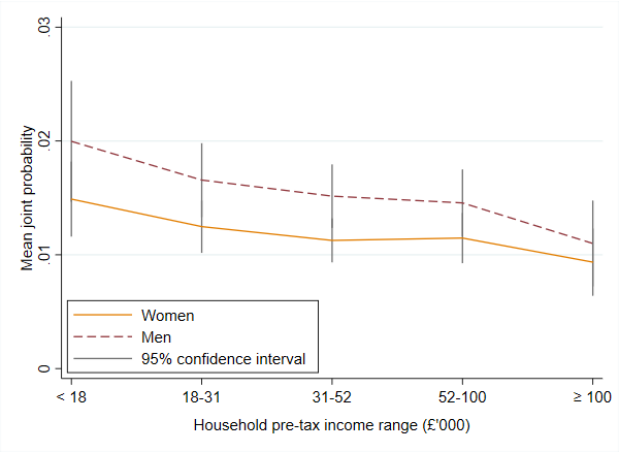


(f) Transition model: lack of support

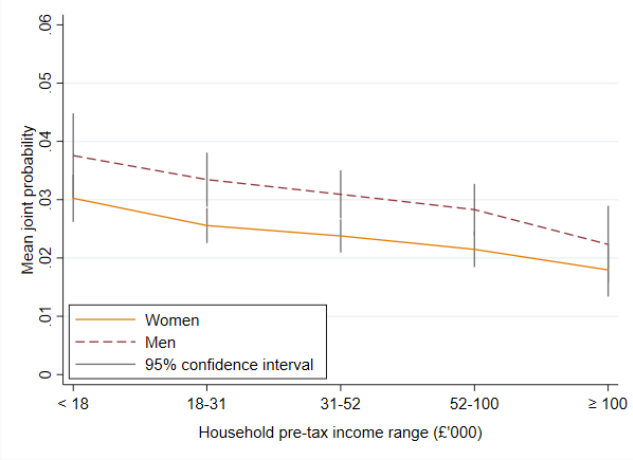
Figure 2: Income gradients in the joint probability of loneliness at both waves 1 and 2 (Transition model)



(a) Loneliness

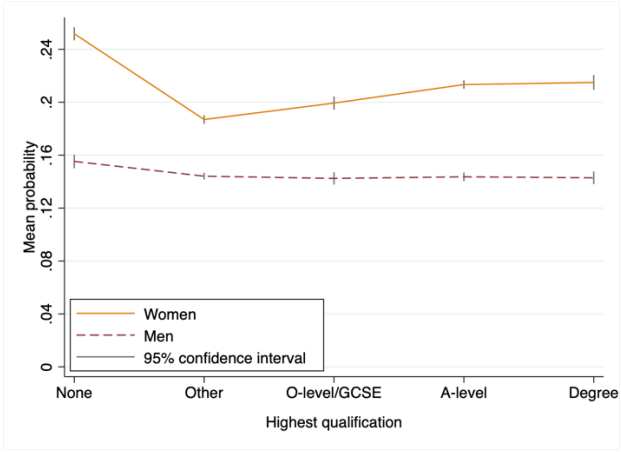


(b) Social isolation

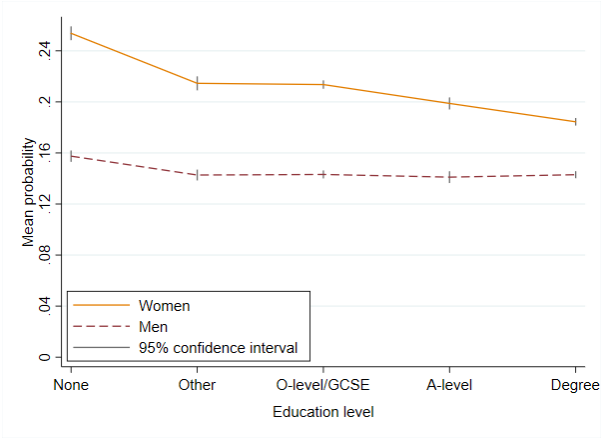


(c) Lack of support

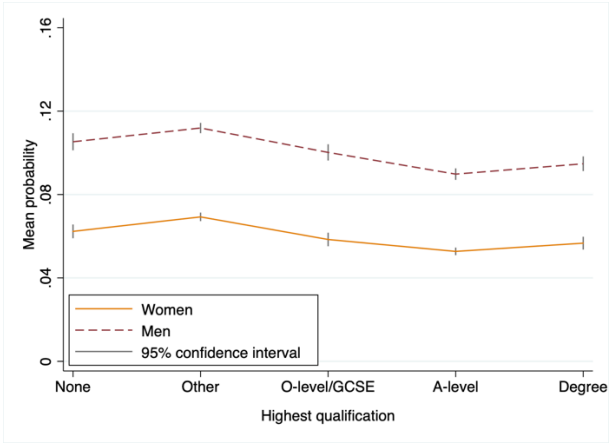
Figure 3: Transition model: Education gradients for the probabilities of loneliness, isolation and lack of support at baseline wave 1, and for their joint probabilities at both waves 1 and 2



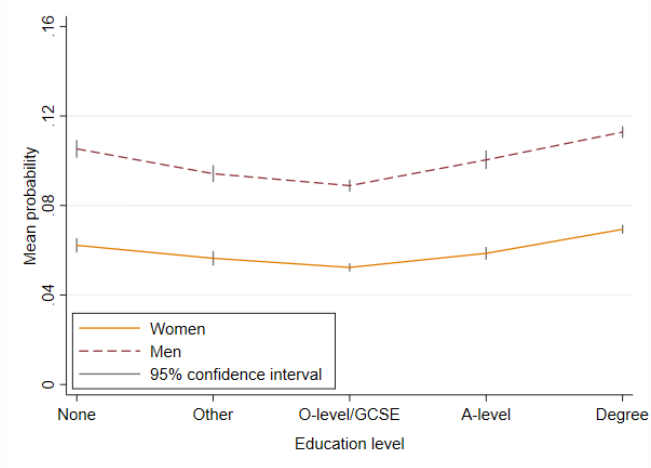
(a) Linear model: loneliness



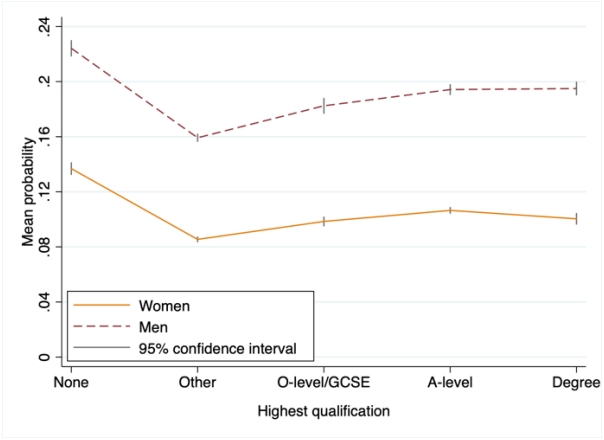
(b) Transition model: loneliness



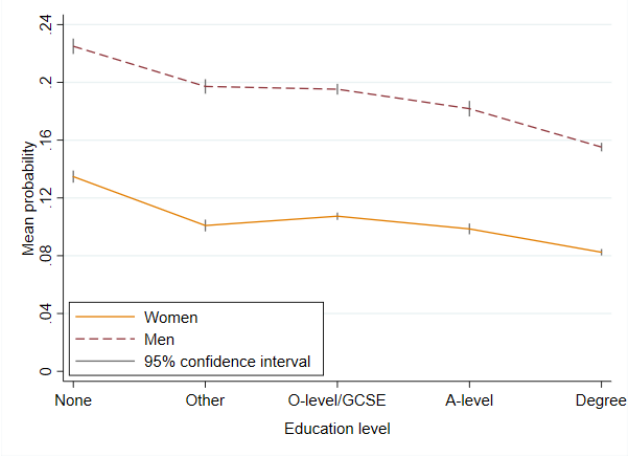
(c) Linear model: social isolation



(d) Transition model: social isolation

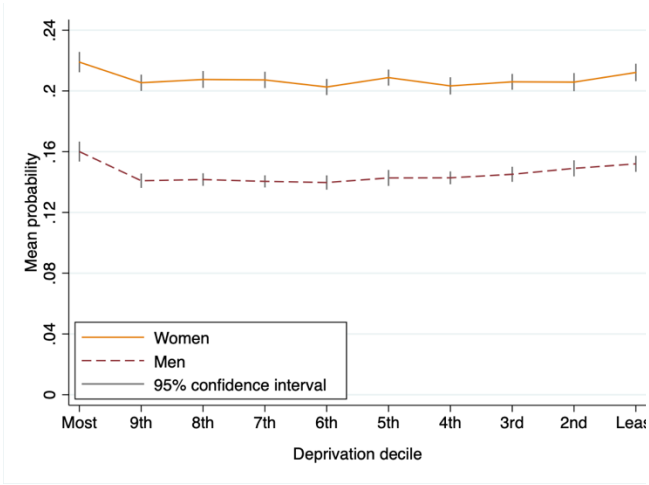


(e) Linear model: lack of support

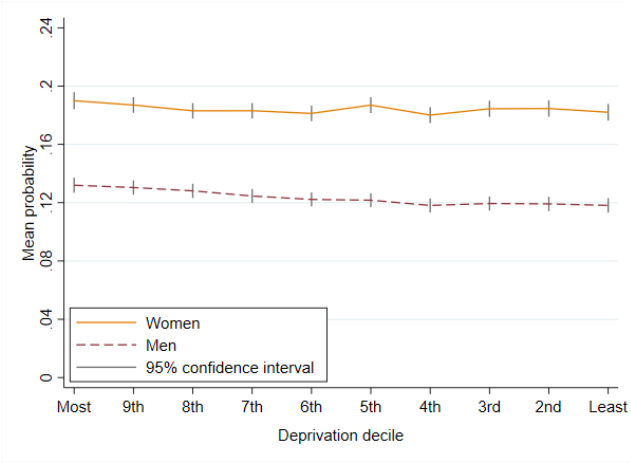


(f) Transition model: lack of support

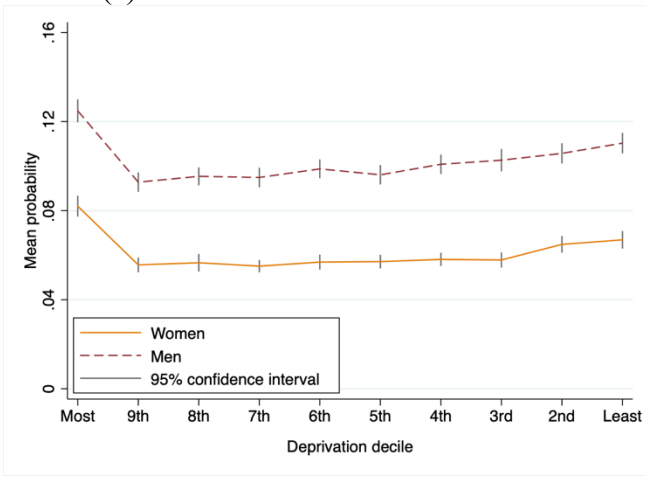
Figure 4: Neighbourhood deprivation gradients at wave 1 for the cross-section linear probability model with area effects and the baseline component of the two-wave transition model



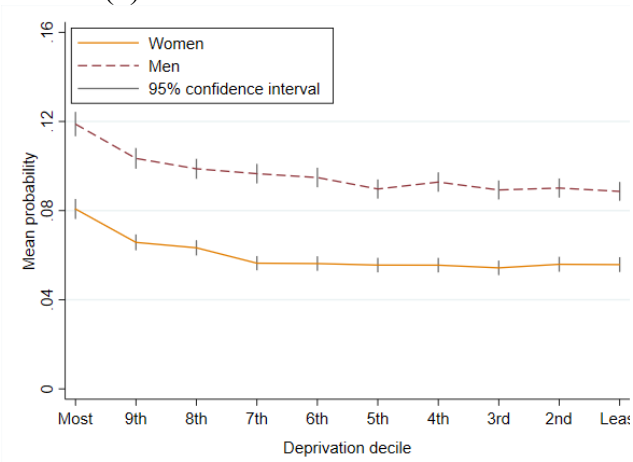
(a) Area effects model: loneliness



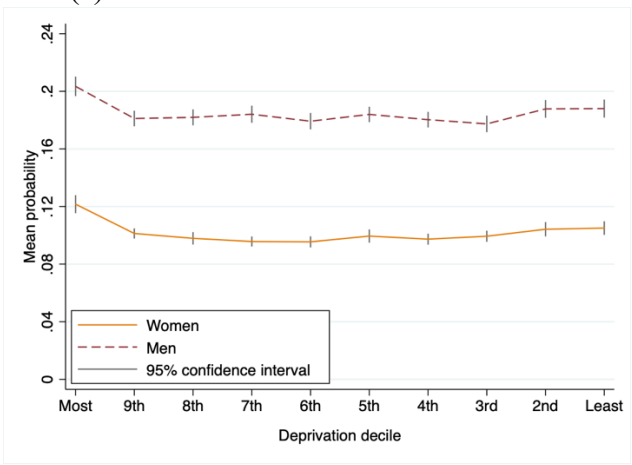
(b) Transition model: loneliness



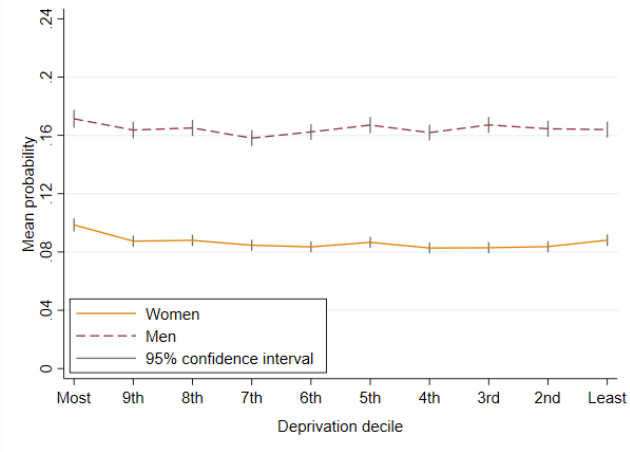
(c) Area effects model: social isolation



(d) Transition model: social isolation



(e) Area effects model: lack of support



(f) Transition model: lack of support

Appendix

Appendix Info 1: Literature review

Although not extensive, there is an existing literature that has examined the link between various measures of socioeconomic status including educational attainment, employment status, income and wealth, and measures of social health, although not all studies have this as their primary focus. Moreover, studies have rarely adopted an inequalities lens (Niedzwiedz et al. 2016). However, most studies tend to find that better socioeconomic status is a protective factor against the risk of experiencing loneliness (Aylaz et al. 2012; Bosma et al. 2015; Bu et al. 2020; Cohen-Mansfield et al. 2016; Fokkema et al. 2012; Fokkema and Naderi 2013; Hansen and Slagsvold 2016; Kung et al. 2021; Lasgaard et al. 2016; Luhmann and Hawkley 2016; Menec et al. 2019; Niedzwiedz et al. 2016; Pinquart and Sorensen 2001; Victor and Yang 2012). Further, a greater risk of loneliness has been found for individuals in lower-status occupations (Finlay and Kobayashi 2018), for those receiving a disability pension (Lasgaard et al. 2016), those with low satisfaction with their living situation (Fokkema and Naderi 2013; Scharf and de Jong Gierveld 2008), and for those facing a worsening of their financial situation (de Jong Gierveld et al. 2015). Loneliness is also generally higher in areas of socioeconomic deprivation (Beere et al. 2019).

However, not all studies find consistent economic gradients, and several do not find loneliness to differ by levels of education, income (Zebhauser et al. 2015) or social class (Wenger et al. 1996). Moreover, Lasgaard et al. (2016) found that education predicted loneliness only during young adulthood. Luhmann and Hawkley (2016) found that after controlling for income, that higher educated people are lonelier, perhaps because they may have higher standards for evaluating their relationships or have fewer high-quality relationships. While among middle-aged adults full-time employment is associated with lower loneliness, this has been found not to be significant for older adults (Hansen and Slagsvold 2016; Luhmann and Hawkley 2016). In contrast, among younger adults, full-time employment has been found to be associated with higher loneliness (Hansen and Slagsvold 2016). Deeg and Thomése (2005) found that neighbourhood comparisons matter: low-income individuals in high-status neighbourhoods, and high-income individuals in low-status neighbourhoods, are lonelier than their respective neighbourhood counterparts. Some studies have also found individuals in rural areas to be less lonely than urban dwellers (Beere et al. 2019).

Fewer studies have examined the extent of economic gradients in social isolation and perceived social support, and findings on the direction of associations have been mixed. With regard to isolation, studies have documented a gradient with regard to social class (Wenger et al. 1996), low income (Bosma et al. 2015; Eckhard 2018; Menec et al. 2019), material deprivation (Mood and Jonsson 2016;

Scharf et al. 2005) and education (Ajrouch et al. 2005; Van Groenou and Van Tilburg 2003). For unemployment, men show an initially reduced risk of isolation, but this risk increases with the duration of unemployment; whereas women have a reduced risk of isolation throughout (Eckhard 2018). Interestingly, Menec et al. (2019) found that lower income, but higher educational attainment, correspond to greater social isolation, perhaps due to migration and thus less contact with the family network, among the higher educated. However, higher education is predictive of larger social networks (Ajrouch et al. 2005; Van Groenou and Van Tilburg 2003), but not necessarily frequency of contact or number of very close friends (Ajrouch et al. 2005). Paúl et al. (2003) found social networks to be larger among rural elderly individuals, who show lower levels of educational attainment and income, than among their urban counterparts.

The literature on socioeconomic inequalities in social support is again considerably smaller than for loneliness, and worth discussing in the context of the measures used and types of support. Overall, there appears to be two overarching types of support: instrumental, which refers to the provision of tangible help such as personal care or financial resources; and emotional, which reflects the ability to share feelings and problems, affection, feeling loved and a sense of belonging. Van Groenou and Van Tilburg (2003) found that educational attainment and occupational prestige are associated with greater availability of instrumental (e.g. help with chores and transport) and emotional support (e.g. sharing of personal experiences and feelings) from non-family relationships. Greater instrumental, but not emotional, support from kin is seen among lower educated individuals, perhaps stemming from their own cultural preferences, or that they have fewer financial resources and are thus less able to purchase instrumental support from other sources.

Shields and Wheatley Price (2005) found that individuals with higher educational attainment and household income are more likely to report having supportive family or friends who, can be relied upon no matter what, will see that they are taken care of if needed (instrumental); give them support and encouragement, make them feel loved, and accept them just as they are (emotional). The authors further discussed that higher educated individuals could be more likely to practice enhanced communication and conflict resolution skills in their relationships, and that higher income increases opportunities for social interactions and activities, via ownership of a telephone, car or other technology. Being out of the labour force due to long-term sickness is also related to lower perceived social support (cf. Lasgaard et al. 2016), but this association is not seen for unemployment or neighbourhood-level deprivation.

More recently, Mood and Jonsson (2016) found small negative effects of perceived material deprivation, but not absolute or relative income poverty, on whether individuals have a close friend who can help if they get sick (instrumental), or if they need company or someone to talk to about their

troubles (emotional). Eckhard (2018) also found income poverty to be associated with having nobody to ask for help if they were to "need long-term care" (instrumental), or with whom they discuss "important matters" (emotional).

Taken overall, we believe that there remains considerable uncertainty about the extent of economic gradients in these key measures of social health, which motivates our study. The following table provides the sample size, age of sample, and country focus, for each of the above studies. It is clear that the sample available in the Biobank is large by comparison, which allows for more precise estimates of the independent associations between the various measures of socioeconomic status and social health. However, it is also worth noting that the studies (including this one) are mostly based on samples from Europe, including the UK.[7] The Table below provides a summary of the main studies. As such the economic patterns of social health reviewed here may, to an extent, be specific to these societies. Fewer studies have examined whether these patterns differ between cultures. This may be an important consideration, given that the prevalence of loneliness has been shown to differ by country (Fokkema et al. 2012; Hansen and Slagsvold 2016) and immigrant status and identity (Fokkema and Naderi 2013; Niedzwiedz et al. 2016), at least partially due to differences in socioeconomic status (Fokkema et al. 2012; Fokkema and Naderi 2013).

[7] Fewer studies are based on data from, for example, Turkey (Aylaz et al. 2012), Israel (Cohen-Mansfield et al. 2016), Northern America (Ajrouch et al. 2005; Menec et al. 2019) and Australasia (Beere et al. 2019; Kung et al. 2021).

Characteristics of key studies

Study	Sample size	Sample age	Country
Aylaz et al. (2012)	17,080	60+	Turkey
Bosma et al. (2015)	24,978	17-65y	Netherlands
Bu et al. (2020)	60,341	18+	UK
Cohen-Mansfield et al. (2016)	Review of quantitative studies, sample sizes between 137 and 13,812. Qualitative study sample size 25	60-85	Israel
Fokkema et al. (2012)	12,248	50+	14 European countries
Fokkema and Naderi (2013)	3,742	50-79	Germany
Hansen and Slagsvold (2016)	33,832	60-80	11 European countries
Kung et al. (2021)	30,824	15-85	Australia
Lasgaard et al. (2016)	33,285	16–102	Denmark
Luhmann and Hawkley (2016)	16,132	18-103	Germany
Menec et al. (2019)	48,330	45-85	Canada
Niedzwiedz et al. (2016)	31,639	65+	14 European countries
Pinquart and Sorensen (2001)	meta-analysis, sample sizes between 100 and 31,247		
Victor and Yang (2012)	2393	15-97	UK
Scharf and de Jong Gierveld (2008)	4009	60+	England, Netherlands
de Jong Gierveld et al. (2015)	3,799	65+	Canada
Beere et al. (2019)	52,973	65+	NZ
Zebhauser et al. (2015)	1079	64-94	Germany
Wenger et al. (1996)	532	65+	Wales
Deeg and Thomése (2005)	2,540	55-85	Netherlands
Finlay and Kobayashi (2018)	124	55-92	US
Eckhard (2018)	26,961	mean 45	Germany
Mood and Jonsson (2016)	3,089	18-75	Sweden
Scharf et al. (2005)	600	60+	UK
Ajrouch et al. (2005)	840	40-93	US
Van Groenou and Van Tilburg (2003)	2,285	55-89	Netherlands
Shields and Price (2005)	11,241	16-64	England
Paúl et al. (2003)	234	mean 75, sd 6.4	Portugal

Appendix Info 2: Baseline Biobank Assessment Centres, dates of operation and recruitment

Assessment centre	Dates of operation	Total recruitment
Birmingham	29/10/2009 - 21/07/2010	25,506
Bristol	09/07/2008 - 28/11/2009	43,020
Bury	14/01/2008 - 20/12/2008	28,326
Cardiff	08/10/2007 - 31/05/2008	17,885
Cheadle (revisit)	01/08/2012 - 06/06/2013	20,348
Croydon	24/09/2009 - 09/07/2010	27,392
Edinburgh	07/11/2007 - 07/06/2008	17,202
Glasgow	16/07/2007 - 19/04/2008	18,653
Hounslow	17/06/2009 - 26/06/2010	28,881
Leeds	27/02/2008 - 11/07/2009	44,220
Liverpool	28/01/2009 - 01/04/2010	32,825
London Barts	27/08/2008 - 29/08/2009	12,584
Manchester	16/04/2007 - 22/12/2007	13,943
Middlesbrough	29/04/2009 - 06/02/2010	21,290
Newcastle	23/01/2008 - 28/03/2009	37,011
Nottingham	30/07/2008 - 12/09/2009	33,883
Oxford	30/04/2007 - 27/10/2007	14,063
Reading	14/05/2008 - 02/05/2009	29,426
Sheffield	05/08/2009 - 13/07/2010	30,399
Stockport (pilot)	13/03/2006 - 13/06/2006	3,799
Stoke	05/12/2007 - 26/07/2008	19,441
Swansea	11/03/2010 - 03/07/2010	2,284
Wrexham	16/08/2010 - 01/10/2010	649

Source: www.ukbiobank.ac.uk

Appendix Table A1: Baseline and panel statistics

	Baseline sample		Observed at both waves	
	Women	Men	Women	Men
Loneliness (often feel lonely)	0.208	0.145	0.165	0.116
Social isolation (visits less than once a month)	0.061	0.102	0.058	0.094
Lack of social support (never able to confide)	0.102	0.185	0.083	0.161
Age	55.7 (8.0)	56.6 (8.1)	53.9 (7.4)	55.7 (7.6)
Married	0.689	0.784	0.721	0.820
Child(ren) in household	0.368	0.359	0.427	0.401
Household size	2.4	2.5	2.5	2.6
Number of own children	1.8	1.8	1.7	1.8
Mother no longer alive	0.565	0.598	0.486	0.553
Father no longer alive	0.741	0.764	0.685	0.734
Number of brothers	1.1	1.1	1.1	1.0
Number of sisters	1.1	1.0	1.0	1.0
Long term illness	0.290	0.343	0.211	0.258
White	0.958	0.960	0.975	0.975
Mixed race	0.006	0.004	0.005	0.003
Black	0.014	0.011	0.006	0.005
Bangladeshi / Indian / Pakistani	0.010	0.014	0.005	0.010
East Asian	0.005	0.005	0.004	0.004
Other	0.007	0.007	0.005	0.004
Degree	0.351	0.368	0.488	0.509
‘A’ Level	0.126	0.108	0.146	0.117
‘O’ Level	0.288	0.242	0.237	0.206
Other qualification	0.099	0.134	0.082	0.113
No qualifications	0.135	0.148	0.047	0.055
Employed or self-employed	0.597	0.634	0.713	0.713
Unemployed	0.009	0.019	0.007	0.014
Retired	0.319	0.305	0.222	0.257
Disabled	0.024	0.033	0.009	0.009
Other employment status	0.051	0.009	0.049	0.008
HH income > £100,000	0.051	0.064	0.075	0.093
HH income £52,000-£100,000	0.193	0.231	0.267	0.316
HH income £31,000-£51,999	0.258	0.273	0.302	0.305
HH income £18,000-£30,999	0.262	0.241	0.229	0.197
HH income < £18,000	0.235	0.190	0.126	0.089
Serious own illness	0.084	0.103	0.056	0.069
Serious illness relative	0.143	0.091	0.163	0.105
Death of close relative	0.221	0.202	0.209	0.197
Death of spouse	0.019	0.010	0.016	0.009
Marital separation	0.035	0.031	0.036	0.029
Financial stress	0.126	0.122	0.097	0.092
N	201,473	179,032	18,040	18,113

Appendix Table A2: Baseline and panel geographical statistics

Assessment centre	Baseline sample		Observed at both waves	
	Women	Men	Women	Men
Baseline (W1)				
Stockport (pilot)	1,280	0	219	0
Manchester	5,419	5,092	1,105	1,056
Oxford	6,113	4,924	373	378
Cardiff	7,305	6,671	17	17
Glasgow	7,910	6,796	378	398
Edinburgh	7,415	6,175	751	726
Stoke	6,755	7,606	657	812
Reading	11,831	10,869	718	766
Bury	10,556	10,180	1,445	1,548
Newcastle	15,285	13,486	2,355	2,169
Leeds	17,689	15,867	1,857	1,911
Bristol	18,191	15,424	70	66
London Barts	5,074	4,251	386	307
Nottingham	13,381	12,070	1,406	1,442
Sheffield	12,334	11,320	1,524	1,605
Liverpool	13,130	11,755	1,682	1,727
Middlesbrough	8,403	7,793	1,021	1,074
Hounslow	11,411	9,677	788	750
Croydon	11,192	9,059	447	448
Birmingham	9,673	9,003	810	872
Swansea	889	788	3	3
Wrexham	237	226	28	38
	201,473	179,032	18,040	18,113
Imaging (W2)				
Stockport			10,578	10,860
Newcastle			4,744	4,595
Reading			2,693	2,632
Bristol			25	26
			18,040	18,113

Appendix Table A3: Social isolation measures

Study	Measure	Setting
(Eckhard 2018)	**Social isolation [0,1].** Single indicator for (1) living alone; (2) no partner; (3) meet socially with friends, relatives, and neighbours less than monthly; and (4) give help to friends, relatives, and neighbours less than monthly.	17y+ from the German Socio-economic Panel (*N*=26961)
(Menec et al. 2019)	**Social isolation [0,1].** Single indicator for scoring positive to at least three of (1) living alone and not married or in a common law relationship; got together within the past 6 months or less frequently with, or reported having none of, (2) friends/neighbours, (3) relatives/siblings, and (4) children; and (5) retired and over the past year had less than monthly social participation in only one or none of family or friendship based activities, church or religious activities, sports or physical activities, and educational and cultural activities. **Loneliness [0,1].** "How often do you feel lonely?" over the past week, using an indicator for "all of the time [5-7d]" and "occasionally [3-4d]" vs. "some of the time [1-2d]" and "rarely/never [<1d]".	45-85y from the Canadian Longitudinal Study on Aging (*N*=48330)
(Wenger et al. 1996)	**Social isolation [0,8].** One point for each of living alone; no close relatives; never visits relatives or friends; no contact with neighbours; no telephone; alone for >9hr a day; lives more than 50km from the nearest neighbour; and is housebound. **Loneliness A [0,8].** One point for each of feeling lonely much of the time; does not see enough of friends and relatives; does not meet enough people; has no one to confide in; wishes for more friends; has no one to ask favours of; has no real friends in the area; and spent the previous Christmas alone and lonely. **Loneliness B [0,1].** Self-assessment of loneliness, using an indicator for "most of the time", "often", and "sometimes" vs. "never" and "rarely".	65y+ from North Wales (*N*=498)
(Bosma et al. 2015)	**Social isolation [0,1].** Single indicator for scoring 11+ for frequency of contact where response choices range from 1 for "more than once per week" to 6 "seldom/never" for each of (1) family members, (2) friends, and (3) neighbours. **Loneliness [0,1].** Using an indicator for scores of 9+ on the 11-item de Jong Gierveld loneliness scale (de Jong-Gierveld and Kamphuls 1985)	17-65y from the Netherlands (*N*=24978)
(Mood and Jonsson 2016)	**Social isolation A [0,1].** On how often one meets (1) relatives and (2) friends, either (i) at ones' home or (ii) at the home of those one meets, where response choices being "yes, often", "sometimes", and "no, never"; using a single indicator for having at least one "yes, often" of the four possible and no "never". **Social isolation B [0,1].** Indicator for having actively participated (held an elected position or was at a meeting) in a trade union or a political party **Social isolation C [0,1].** Indicator for being a member of an organization and actively participate in its activities at least once in a year. **Social support [0,1].** Single indicator for having a close friend who can help if one gets sick, if one needs someone to talk to about troubles, and if one needs company.	18-75y from Swedish Level-of-Living Survey (*N*=3089)
(Scharf et al. 2005)	**Social isolation [0,1].** Single indicator for scoring positive to any one of the following three measures: **(1) Social isolation A [0,1].** Single indicator for scoring positive to at least two of (i) no relatives or children or see them less than weekly; (ii) no friends in neighborhood or chat/do something with a friend less than weekly; and (iii) chat/do something with a neighbour less than weekly. **(2) Social isolation B [0,1].** Single indicator for inability to participate in 2+ of seven common activities perceived as necessities by majority of adults e.g. having friends/family around for a meal, celebrating special occasions. **(3) Loneliness [0,1].** Using an indicator for scores of 9+ on the 11-item de Jong Gierveld loneliness scale.[a]	60-96y from deprived areas in England (*N*=581)
(Ajrouch et al. 2005)	**Social isolation.** Several different measures are used: network size represents total number of people named in one's social network [0,10]; inner circle size represents number of people named in one's inner circle (with whom they feel "so close and important it is hard to imagine life without them") [0,10]; contact represents the average frequency with which respondents have contact with their network; and proportion of friends indicates percentage of network members they consider as friends.	40-93y from Detroit, MI (*N*=840)
(Van Groenou and Van Tilburg 2003)	**Social isolation.** Several different measures are used: network size represents total number of people named as persons with whom they have frequent contact and who are important to them (adults 18y+ who are household members including spouse/children and their partners, other kin, neighbours, work and school contacts, members of voluntary organisations, and others); and for all relationships frequency of contact is asked. **Social support [0,44].** For each of a maximum of 11 network members with highest contact frequency, "How often in the past year did … help you with daily chores?" and "How often in the past year did you tell … about your personal experiences and feelings?" are asked, with response choices of "never [1]" to "often [4]".	55-89y from the Netherlands (*N*=2543)
(Paúl et al. 2003)	**Social isolation and social support.** The Lubben Social Network Scale comprises 10 items with 5 categories, with indices for family, friends, confidants, and global network. Measures for quantity of relatives, friends, and confidants; the "helping others" behaviour; and quality of the relationships are used.[b]	75y on average, (*SD*=6.4y) from Portugal (*N*=234)

Appendix Table A4: Linear Probability Regression with Postcode Fixed Effects for Women

	(1) Loneliness		(2) Social isolation		(3) Lack of support	
	Coeff	|*t*-stat|	Coeff	|*t*-stat|	Coeff	|*t*-stat|
Age/10	-0.036	18.10	-0.001	1.13	0.018	12.11
$(Age/10)^2$	-0.012	7.54	-0.006	6.20	-0.001	0.55
Married	-0.114	31.52	-0.005	2.31	-0.013	4.75
Has child(ren) in household	0.017	3.72	0.002	0.60	0.005	1.51
People in household = 2	-0.045	11.27	0.022	8.96	-0.009	2.86
People in household = 3	-0.066	9.96	0.036	9.01	-0.009	1.70
People in household = 4	-0.074	10.13	0.057	12.68	-0.002	0.30
People in household > 4	-0.093	11.49	0.071	14.33	0.003	0.41
Num of own children	0.007	7.35	-0.020	35.51	-0.006	7.93
Mother no longer alive	0.021	9.98	0.026	20.69	0.003	1.91
Father no longer alive	0.009	4.04	0.013	9.04	0.007	3.75
Brothers = 1	-0.007	3.23	0.001	0.60	-0.003	2.07
Brothers > 1	0.001	0.32	0.003	1.80	-0.002	0.86
Sisters = 1	-0.005	2.30	-0.001	0.51	-0.001	0.65
Sisters > 1	-0.001	0.43	0.002	1.70	-0.002	1.20
Long term illness	0.052	25.46	0.010	7.82	0.011	6.72
Mixed race	-0.009	0.76	0.021	3.08	0.027	3.09
Black	-0.015	1.88	0.090	18.84	0.039	6.46
Bangl / Ind / Pak.	0.095	10.22	0.039	6.77	0.033	4.61
East Asian	-0.023	1.79	0.092	11.98	0.070	7.13
Degree	-0.065	20.26	0.007	3.55	-0.051	20.76
'A' Level	-0.052	14.40	-0.004	1.75	-0.038	13.61
'O' Level	-0.038	12.67	-0.010	5.19	-0.030	12.93
Other qualification	-0.037	9.92	-0.006	2.49	-0.036	12.70
Unemployed	0.056	6.10	0.020	3.58	0.032	4.55
Retired	-0.011	3.89	-0.020	11.98	-0.004	2.07
Disabled	0.124	20.47	0.010	2.70	0.047	9.92
Other employment status	0.041	9.95	-0.003	1.01	0.007	2.24
HH income > £100,000	-0.017	6.34	-0.007	4.11	-0.013	6.30
HH income £52,000-£100,000	-0.028	9.52	-0.013	7.33	-0.019	8.40
HH income £31,000-£51,999	-0.037	10.55	-0.011	4.93	-0.023	8.61
HH income £18,000-£30,999	-0.046	9.05	-0.015	4.92	-0.025	6.37
Serious own illness	0.020	6.30	0.002	1.25	-0.009	3.52
Serious illness relative	0.006	2.47	-0.015	10.02	-0.017	8.58
Death of close relative	0.013	6.25	-0.010	7.52	-0.006	3.69
Death of spouse	0.200	30.64	-0.009	2.29	-0.013	2.51
Marital separation	0.086	17.50	-0.011	3.70	-0.030	7.88
Financial stress	0.120	42.88	0.015	8.61	0.032	14.77
Townsend Deprivation Index Decile						
Least deprived	-0.014	2.86	-0.026	9.09	-0.020	5.53
2nd	-0.011	2.43	-0.025	8.85	-0.024	6.52
3rd	-0.012	2.53	-0.027	9.49	-0.026	7.21
4th	-0.016	3.55	-0.025	8.92	-0.026	7.34
5th	-0.010	2.24	-0.025	8.95	-0.022	6.28
6th	-0.016	3.49	-0.024	8.71	-0.024	6.99
7th	-0.013	2.94	-0.024	8.96	-0.022	6.51
8th	-0.013	3.04	-0.017	6.48	-0.017	5.19
9th	-0.007	1.64	-0.015	5.93	-0.017	5.14

Notes: N = 201,473. Omitted categories are not married, cohabiting or partnered; no children living in household; one person living in household; mother alive; father alive; no brothers; no sisters; no long-standing illness, disability or infirmity; white; no qualifications; employed or self-employed; household income less than £18,000 per annum; no illness, injury, bereavement or stress events in last 2 years; and most deprived Townsend Deprivation Index decile. The models include postcode and assessment centre fixed effects.

Appendix Table A5: Linear Probability Regression with Postcode Fixed Effects for Men

	(1) Loneliness		(2) Social isolation		(3) Lack of support	
	Coeff	|*t*-stat|	Coeff	|*t*-stat|	Coeff	|*t*-stat|
Age/10	-0.031	18.72	0.001	0.35	0.011	5.85
$(Age/10)^2$	-0.005	3.78	-0.012	9.37	-0.006	4.09
Married	-0.136	35.55	-0.024	6.83	-0.104	23.54
Has child(ren) in household	0.017	3.74	0.008	1.92	0.015	2.93
People in household = 2	-0.045	10.93	0.004	1.05	-0.035	7.32
People in household = 3	-0.056	9.10	0.025	4.53	-0.034	4.73
People in household = 4	-0.061	9.17	0.053	8.85	-0.024	3.09
People in household > 4	-0.066	9.22	0.080	12.29	-0.014	1.71
Num of own children	0.001	1.23	-0.029	40.00	-0.009	9.36
Mother no longer alive	0.012	6.18	0.045	25.59	0.003	1.24
Father no longer alive	0.006	2.55	0.013	6.67	0.008	3.04
Brothers = 1	-0.002	1.15	0.000	0.13	-0.002	1.14
Brothers > 1	-0.000	0.02	0.007	3.68	0.001	0.45
Sisters = 1	0.000	0.13	0.003	1.55	-0.001	0.38
Sisters > 1	0.005	2.28	0.006	2.98	0.003	1.28
Long term illness	0.045	25.48	0.011	7.18	0.011	5.63
Mixed race	-0.006	0.48	0.021	1.87	-0.004	0.30
Black	-0.054	6.93	0.057	8.13	0.015	1.71
Bangl / Ind / Pak.	0.069	9.65	0.000	0.03	0.024	2.94
East Asian	0.014	1.24	0.033	3.25	0.049	3.75
Degree	-0.011	3.97	0.007	2.60	-0.065	20.09
'A' Level	-0.013	3.81	-0.005	1.68	-0.042	10.79
'O' Level	-0.012	4.17	-0.016	6.18	-0.030	9.37
Other qualification	-0.012	4.04	-0.011	3.82	-0.029	8.31
Unemployed	0.031	5.18	0.004	0.70	0.019	2.77
Retired	-0.009	3.60	-0.029	13.30	-0.006	2.02
Disabled	0.117	23.98	0.000	0.06	0.014	2.41
Other status	0.028	3.26	-0.008	1.01	-0.022	2.19
HH income > £100,000	-0.021	7.96	-0.018	7.39	-0.020	6.68
HH income £52,000-£100,000	-0.028	9.65	-0.024	9.21	-0.027	8.15
HH income £31,000-£51,999	-0.040	12.28	-0.024	8.28	-0.032	8.56
HH income £18,000-£30,999	-0.053	12.05	-0.037	9.24	-0.038	7.43
Serious own illness	0.028	10.45	-0.001	0.57	-0.009	2.90
Serious illness relative	0.006	2.00	-0.025	10.17	-0.030	9.54
Death of close relative	0.004	2.06	-0.015	8.13	-0.015	6.63
Death of spouse	0.238	30.20	-0.032	4.58	-0.011	1.18
Marital separation	0.134	28.57	0.002	0.48	-0.001	0.26
Financial stress	0.104	40.51	0.021	8.91	0.042	14.19
Townsend Deprivation Index Decile						
Least deprived	-0.019	4.47	-0.032	8.28	-0.022	4.52
2nd	-0.018	4.33	-0.029	7.68	-0.022	4.41
3rd	-0.020	4.66	-0.030	7.89	-0.019	4.01
4th	-0.020	4.85	-0.026	6.90	-0.024	5.02
5th	-0.017	4.17	-0.029	7.67	-0.019	4.08
6th	-0.017	4.21	-0.024	6.50	-0.023	4.91
7th	-0.015	3.70	-0.022	6.08	-0.026	5.61
8th	-0.011	2.79	-0.019	5.35	-0.016	3.44
9th	-0.008	2.12	-0.014	4.22	-0.015	3.52

Notes: N = 179,032. Omitted categories are not married, cohabiting or partnered; no children living in household; one person living in household; mother alive; father alive; no brothers; no sisters; no long-standing illness, disability or infirmity; white; no qualifications; employed or self-employed; household income less than £18,000 per annum; no illness, injury, bereavement or stress events in last 2 years; and most deprived Townsend Deprivation Index decile. The models include postcode and assessment centre fixed effects.

Appendix Table A6: Transition model (correlation parameters)

	Women		Men	
	Coeff	**|*t*-stat|**	**Coeff**	**|*t*-stat|**
Wave 1				
Loneliness and isolation (ρ_{12})	0.171	26.34	0.148	22.96
Loneliness and lack of support (ρ_{32})	0.327	56.30	0.288	50.27
Isolation and lack of support (ρ_{23})	0.236	30.15	0.196	30.79
Wave 2				
Loneliness and isolation (φ_{12})	0.156	5.65	0.061	2.31
Loneliness and lack of support (φ_{13})	0.283	11.38	0.316	14.24
Isolation and lack of support (φ_{23})	0.192	6.06	0.141	5.93

Appendix Table A7: Transition model parameter estimates (wave 1 and attrition estimates)

	Women								Men							
	(1) Loneliness		**(2) Social isolation**		**(3) Lack of support**		**(4) Attrition coefficients**		**(1) Loneliness**		**(2) Social isolation**		**(3) Lack of support**		**(4) Attrition coefficients**	
	Coeff	|*t*-stat|	Coeff	|*t*-stat|	Coeff	|*t*-stat|	Coeff	|*t*-stat|	Coeff	|*t*-stat|	Coeff	|*t*-stat|	Coeff	|*t*-stat|	Coeff	|*t*-stat|
Current socio-demographic state																
Age/10	-0.133	17.92	-0.011	1.09	0.104	12.09	0.094	9.54	-0.145	18.14	0.000	0.02	0.038	5.22	0.007	0.75
$(Age/10)^2$	-0.044	7.37	-0.047	5.58	-0.014	1.96	0.127	15.89	-0.032	4.66	-0.060	8.13	-0.025	4.07	0.121	15.78
Married	-0.399	31.08	-0.033	1.87	-0.076	4.76	0.058	3.24	-0.547	34.22	-0.118	6.37	-0.360	22.78	-0.010	0.44
Child(ren) in household	0.054	3.41	0.048	2.25	0.024	1.21	0.010	0.45	0.079	4.11	0.067	2.96	0.053	2.77	-0.015	0.58
Household size = 2	-0.152	10.86	0.175	8.84	-0.040	2.30	0.018	0.89	-0.166	9.74	0.022	1.09	-0.108	6.41	0.070	2.85
Household size = 3	-0.213	9.25	0.282	8.88	-0.038	1.32	0.050	1.51	-0.189	7.22	0.136	4.57	-0.095	3.68	0.127	3.43
Household size = 4	-0.240	9.19	0.449	12.76	-0.007	0.21	0.004	0.11	-0.201	6.98	0.291	9.11	-0.061	2.16	0.124	3.13
Household size > 4	-0.314	10.64	0.577	14.75	0.014	0.38	-0.042	1.03	-0.219	6.89	0.440	12.68	-0.032	1.03	0.132	3.11
Number of own children	0.021	6.08	-0.181	37.20	-0.031	7.87	0.010	2.09	0.000	0.04	-0.168	40.90	-0.030	8.62	-0.006	1.24
Mother no longer alive	0.080	10.18	0.217	19.57	0.018	1.93	0.024	2.45	0.058	6.09	0.256	24.44	0.009	1.09	0.018	1.73
Father no longer alive	0.034	3.88	0.100	8.14	0.042	3.93	0.004	0.41	0.022	2.07	0.069	5.84	0.029	2.89	0.004	0.34
Brothers = 1	-0.026	3.30	0.006	0.55	-0.022	2.42	-0.046	4.58	-0.009	0.96	0.002	0.23	-0.008	0.97	-0.031	3.01
Brothers > 1	0.003	0.35	0.022	1.81	-0.011	1.09	-0.046	4.10	0.004	0.42	0.042	3.93	0.007	0.77	-0.016	1.39
Sisters = 1	-0.020	2.59	-0.004	0.36	-0.007	0.72	-0.027	2.71	0.004	0.40	0.016	1.65	-0.002	0.21	-0.012	1.16
Sisters > 1	-0.005	0.57	0.021	1.78	-0.011	1.09	-0.025	2.24	0.025	2.42	0.035	3.16	0.015	1.56	-0.001	0.08
Long term illness	0.193	25.76	0.085	8.04	0.060	6.72	0.139	13.31	0.220	25.48	0.067	7.18	0.045	5.78	0.144	14.39
Mixed race	-0.033	0.80	0.149	2.93	0.142	2.96	0.067	1.17	-0.018	0.31	0.127	2.13	-0.012	0.22	0.140	1.86
Black	-0.059	2.19	0.498	16.75	0.204	6.56	0.284	6.03	-0.202	5.71	0.286	8.42	0.060	1.86	0.218	4.06
Bangladeshi / Indian / Pakistani	0.331	10.63	0.268	6.98	0.202	5.34	0.255	4.87	0.304	9.98	0.017	0.51	0.101	3.33	0.126	3.02
East Asian	-0.094	1.86	0.485	10.06	0.370	7.56	0.133	2.03	0.083	1.62	0.168	3.27	0.199	4.15	0.107	1.50
Economic characteristics																
Degree	-0.257	21.93	0.058	3.52	-0.290	21.99	-0.592	32.18	-0.071	5.32	0.042	2.94	-0.267	22.40	-0.586	32.87
'A' Level	-0.199	14.77	-0.031	1.61	-0.189	12.34	-0.502	24.75	-0.081	4.95	-0.029	1.65	-0.158	10.90	-0.459	22.15
'O' Level	-0.143	12.86	-0.090	5.49	-0.139	11.35	-0.313	16.99	-0.070	5.24	-0.100	6.91	-0.107	9.03	-0.324	17.63
Other qualification	-0.139	10.19	-0.051	2.55	-0.175	11.39	-0.340	15.80	-0.072	4.84	-0.066	4.09	-0.099	7.64	-0.306	15.42

Unemployed	0.154	5.01	0.110	2.62	0.159	4.35	0.059	1.18	0.073	2.98	-0.005	0.16	0.052	2.08	-0.031	0.89
Retired	-0.050	4.59	-0.190	12.00	-0.027	2.22	0.024	1.76	-0.064	5.06	-0.185	13.68	-0.027	2.46	-0.021	1.61
Disabled	0.309	15.47	0.053	1.85	0.202	8.57	0.248	6.26	0.287	14.35	-0.025	1.07	0.026	1.27	0.263	6.88
Other status	0.153	10.13	-0.018	0.86	0.038	2.02	0.040	2.03	0.096	2.52	-0.043	1.03	-0.087	2.25	-0.060	1.25
HH income > £100,000	-0.209	10.38	-0.120	4.74	-0.190	7.88	-0.320	13.91	-0.286	12.72	-0.200	8.84	-0.189	9.34	-0.444	18.84
HH income £52,000-£100,000	-0.143	10.82	-0.077	4.26	-0.148	9.54	-0.277	16.18	-0.193	12.18	-0.133	7.83	-0.133	9.33	-0.408	21.96
HH income £31,000-£51,999	-0.095	8.57	-0.105	6.59	-0.103	7.98	-0.231	15.25	-0.122	8.79	-0.133	8.79	-0.099	7.87	-0.313	18.42
HH income £18,000-£30,999	-0.052	5.34	-0.050	3.49	-0.059	5.28	-0.140	9.78	-0.087	6.95	-0.101	7.24	-0.066	5.79	-0.178	10.81
Events in previous two years																
Serious own illness	0.068	5.83	0.019	1.15	-0.049	3.40	0.157	8.92	0.113	9.17	-0.006	0.45	-0.035	2.91	0.137	8.40
Serious illness relative	0.026	2.70	-0.144	10.23	-0.106	8.95	-0.055	4.61	0.028	2.06	-0.163	10.41	-0.131	10.09	-0.054	3.64
Death of close relative	0.051	6.38	-0.084	7.36	-0.033	3.51	0.036	3.35	0.018	1.87	-0.085	7.95	-0.059	6.55	0.007	0.65
Death of spouse	0.547	25.69	-0.139	3.41	-0.060	2.21	-0.037	1.09	0.711	23.13	-0.191	4.23	-0.027	0.85	-0.005	0.10
Marital separation	0.247	15.26	-0.091	3.44	-0.177	7.72	-0.023	0.95	0.425	23.04	0.020	0.83	-0.003	0.13	0.005	0.18
Financial stress	0.371	38.88	0.114	8.40	0.174	14.90	0.101	6.92	0.381	34.93	0.105	8.36	0.149	13.77	0.052	3.45
Area characteristics: Townsend Deprivation Index Decile																
Least deprived	-0.032	1.97	-0.198	8.86	-0.064	3.40	-0.167	7.68	-0.075	3.93	-0.174	8.67	-0.030	1.76	-0.199	8.77
2nd	-0.022	1.34	-0.197	8.85	-0.093	4.93	-0.174	8.04	-0.069	3.67	-0.165	8.23	-0.028	1.64	-0.212	9.37
3rd	-0.022	1.41	-0.211	9.53	-0.098	5.25	-0.187	8.72	-0.067	3.65	-0.170	8.59	-0.017	1.01	-0.182	8.03
4th	-0.040	2.54	-0.200	9.18	-0.099	5.35	-0.187	8.74	-0.075	4.06	-0.148	7.50	-0.039	2.31	-0.164	7.24
5th	-0.012	0.78	-0.200	9.26	-0.074	4.03	-0.162	7.52	-0.055	3.02	-0.167	8.51	-0.018	1.05	-0.187	8.25
6th	-0.035	2.30	-0.194	9.08	-0.094	5.19	-0.131	6.08	-0.052	2.90	-0.135	7.01	-0.037	2.22	-0.140	6.16
7th	-0.028	1.84	-0.192	9.20	-0.087	4.84	-0.157	7.40	-0.039	2.23	-0.125	6.59	-0.055	3.33	-0.126	5.52
8th	-0.028	1.88	-0.132	6.51	-0.065	3.70	-0.129	6.04	-0.020	1.19	-0.112	6.05	-0.026	1.59	-0.133	5.85
9th	-0.012	0.82	-0.112	5.70	-0.068	3.98	-0.090	4.25	-0.008	0.50	-0.084	4.71	-0.032	2.00	-0.119	5.34
Wave 1 outcome (reference category not lonely, not isolated, had support (state 000)																
Lonely, not isolated, had support (state 100)							0.095	7.37							0.028	1.63
Not lonely, isolated, had support (state 010)							0.029	1.26							0.002	0.13
Not lonely, not isolated, no support (state 001)							0.023	1.16							-0.004	0.28
Not lonely, isolated, no support (state 011)							0.030	0.54							0.020	0.61
Lonely, not isolated, no support (state 101)							0.081	3.08							0.083	3.31
Lonely, isolated, had support (state 110)							0.024	0.60							0.006	0.14
Lonely, isolated, no support (state 111)							0.117	1.93							0.101	2.16

Notes: Omitted categories are not married, cohabiting or partnered; no children living in the household; one person living in the household; mother still alive; father still alive; no brothers; no sisters; no long-standing illness, disability or infirmity; white; no qualifications; employed or self-employed; household income less than £18,000 per annum; no illness, injury, bereavement or stress events in last 2 years; and most deprived Townsend Deprivation Index decile. The models control for assessment centre fixed effects.

Appendix Table A8: Transition model parameter estimates (wave 2 component)

	Women						Men					
	(1) Loneliness		(2) Social isolation		(3) Lack of support		(1) Loneliness		(2) Social isolation		(3) Lack of support	
	Coeff	|*t*-stat|	Coeff	|*t*-stat|	Coeff	|*t*-stat|	Coeff	|*t*-stat|	Coeff	|*t*-stat|	Coeff	|*t*-stat|
Current socio-demographic state												
Age/10	-0.110	2.30	-0.222	3.66	0.072	1.22	-0.204	3.87	-0.108	2.05	0.003	0.06
$(Age/10)^2$	0.030	1.39	0.131	4.85	-0.017	0.65	0.035	1.52	0.067	2.97	-0.001	0.03
Married	-0.212	3.68	0.077	0.97	0.023	0.31	-0.184	2.40	0.027	0.30	-0.048	0.65
Child(ren) in household	0.037	0.53	0.200	2.16	-0.019	0.20	0.159	1.68	0.244	2.13	0.136	1.68
Household size = 2	-0.143	2.33	0.113	1.28	-0.115	1.43	-0.276	3.46	0.008	0.09	-0.170	2.22
Household size = 3	-0.136	1.32	0.079	0.55	-0.095	0.68	-0.309	2.33	-0.008	0.05	-0.246	2.07
Household size = 4	-0.137	1.16	0.255	1.57	-0.150	0.95	-0.342	2.36	0.216	1.28	-0.212	1.64
Household size > 4	-0.267	1.97	0.361	1.93	-0.134	0.75	-0.354	2.23	0.391	2.17	-0.136	0.95
Number of own children	-0.006	0.49	-0.185	10.52	-0.004	0.28	-0.007	0.52	-0.195	13.93	-0.015	1.27
Mother no longer alive	0.044	1.33	0.231	4.98	0.005	0.13	0.093	2.37	0.233	5.55	-0.006	0.19
Father no longer alive	0.004	0.11	0.139	2.42	0.000	0.00	0.023	0.49	0.096	1.91	0.013	0.32
Brothers = 1	0.002	0.07	-0.036	0.87	-0.062	1.79	-0.033	0.98	0.048	1.41	0.060	2.12
Brothers > 1	0.071	2.14	-0.013	0.28	-0.070	1.81	-0.075	2.00	-0.011	0.28	0.027	0.84
Sisters = 1	-0.018	0.59	0.053	1.31	0.000	0.01	-0.031	0.93	0.048	1.44	0.000	0.01
Sisters > 1	0.009	0.26	0.107	2.36	-0.049	1.23	0.005	0.14	0.050	1.29	0.005	0.15
Long term illness	0.167	5.76	0.118	2.94	0.087	2.51	0.145	4.54	0.033	1.02	0.010	0.35
Economic characteristics												
Degree	-0.056	0.88	0.072	0.79	-0.190	2.86	-0.097	1.44	-0.012	0.18	-0.218	4.21
'A' Level	-0.087	1.24	0.033	0.34	-0.161	2.18	0.005	0.07	-0.151	1.96	-0.069	1.15
'O' Level	0.031	0.48	-0.013	0.14	-0.103	1.50	-0.039	0.55	-0.070	1.00	-0.073	1.35
Other qualification	0.048	0.66	-0.065	0.61	-0.067	0.87	-0.067	0.88	-0.077	1.04	-0.114	1.98
Unemployed	0.013	0.06	-0.380	0.97	0.425	2.10	-0.067	0.38	-0.271	1.45	-0.162	1.04
Retired	-0.115	3.10	-0.217	4.31	-0.002	0.04	-0.084	2.06	-0.182	4.39	-0.008	0.23
Disabled	0.163	1.16	-0.009	0.05	0.071	0.45	0.347	2.24	0.073	0.40	0.342	2.32
Other status	0.238	3.31	-0.159	1.59	0.249	3.16	0.234	1.85	-0.147	0.94	0.147	1.14
HH income > £100,000	-0.103	1.49	-0.200	2.13	-0.140	1.71	-0.097	1.22	-0.215	2.85	-0.084	1.25
HH income £52,000-£100,000	-0.028	0.56	-0.063	0.89	-0.048	0.87	-0.002	0.04	-0.160	2.57	0.006	0.12
HH income £31,000-£51,999	-0.028	0.64	-0.076	1.19	-0.060	1.22	0.000	0.01	-0.121	2.11	-0.005	0.11
HH income £18,000-£30,999	-0.052	1.27	-0.016	0.27	-0.108	2.37	0.015	0.27	-0.094	1.67	0.051	1.11

Events in previous two years												
Serious own illness	0.119	2.29	0.004	0.06	-0.042	0.65	-0.023	0.42	0.043	0.77	-0.093	1.89
Serious illness relative	0.055	1.61	-0.169	3.22	-0.054	1.29	0.053	1.10	-0.150	2.74	-0.202	4.33
Death of close relative	0.074	2.37	0.037	0.89	-0.018	0.50	0.020	0.55	-0.022	0.58	-0.020	0.66
Death of spouse	0.665	8.55	0.004	0.03	-0.072	0.70	0.726	7.28	-0.256	1.62	-0.069	0.59
Marital separation	0.283	3.59	-0.050	0.38	-0.012	0.11	0.486	6.32	0.190	1.90	-0.040	0.44
Financial stress	0.272	5.83	0.139	2.07	0.158	2.72	0.341	6.31	0.105	1.77	0.139	2.62
Time between waves 1 & 2 (years)	0.014	1.83	-0.003	0.25	-0.001	0.12	0.028	3.24	0.000	0.03	-0.003	0.40
Wave 1 outcome state (reference category not lonely, not isolated, had support: state 000)												
100	1.278	40.24	0.150	2.74	0.263	5.89	1.352	32.73	0.104	1.78	0.272	5.90
010	0.002	0.03	1.292	22.52	0.413	5.78	0.268	4.33	1.183	26.71	0.177	3.34
001	0.233	3.98	0.352	4.60	1.380	28.73	0.254	5.43	0.199	4.27	1.245	37.83
011	-0.013	0.07	1.762	13.57	1.669	12.99	0.343	3.59	1.432	18.54	1.393	18.77
101	1.515	24.18	0.591	6.75	1.598	25.51	1.578	26.57	0.270	3.21	1.288	21.92
110	1.271	13.35	1.241	12.11	0.720	6.38	1.404	14.06	1.233	12.34	0.387	3.37
111	1.517	10.40	1.670	11.49	1.841	12.90	1.499	13.58	1.394	12.47	1.667	14.55

Notes: Omitted categories are not married, cohabiting or partnered; no children living in the household; one person living in the household; mother still alive; father still alive; no brothers; no sisters; no long-standing illness, disability or infirmity; white; no qualifications; employed or self-employed; household income less than £18,000 per annum; no illness, injury, bereavement or stress events in last 2 years; and most deprived Townsend Deprivation Index decile. The models control for assessment centre fixed effects.