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Establishing a framework of analysis for selective sorting and changing health gradients

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Abstract

Health inequalities research seeks to determine if changing health gradients may be due to the movement of differently healthy people between area types and/or social classes through a process of selective sorting. Because conclusions vary, in part because of different approaches employed, there is a need to establish an appropriate framework within which it is possible to determine whether and how spatial or social mobility contributes to changing spatial and social inequalities in health over time. In this paper, we present empirical examples demonstrating a methodological approach needed to determine aggregate changes in health, and discuss the results in terms of the impact of selective sorting on changing health gradients. Our empirical work illustrates that selective sorting through social mobility and migration can contribute to widening health inequalities in the population. We conclude that it is necessary to re-aggregate microdata at the relevant time points of interest to determine changes in the population distribution of a particular health outcome. Simply establishing whether individuals vary in health by transition status may imply an impact on aggregate changes but does not demonstrate it.

KEYWORDS
deprivation mobility, health inequality, internal migration, selective sorting

1 | INTRODUCTION

Recent statistical releases from the Office for National Statistics (e.g., ONS, 2018) paint a bleak picture of health inequalities in England. Males born in the least deprived areas between 2015 and 2017 can expect to live almost a decade more than those born in the most deprived areas, with little change by 2016–2018 (ONS, 2019). For women, the inequalities are more stark: Those living in the most deprived areas have seen a reduction in their life expectancy, whereas those in the least deprived area have seen gains. Though gaps narrow in older ages, they do not disappear. These differences in longevity are then compounded both by differences in healthy life expectancy and by significant increases in socio-economic inequalities in life expectancy at birth and at age 65. The pathways by which these varying socio-economic and spatial circumstances influence health have been widely explored: Conceptual frameworks explaining their influence help us understand how health inequalities occur. These range from theories of natural selection (see The Black Report, Department of Health and Social Security, 1980) to psycho-social (Martikainen, Bartley, & Lahelma, 2002; Wilkinson, 1997) and lifecourse (van de Mheen, Stronks, & Mackenbach, 1998) explanations. It is less clear why inequalities in health between people and places, that is, health gradients, may change over time.

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Yet an increasingly explored aspect is that over time, changing health gradients may be due to a process of selective sorting between area types and/or social classes. At the heart of these analogous bodies of research is the question of whether the movement of differently healthy groups (between area types or socio-economic statuses) contributes to changing health gradients (Darlington-Pollock, Norman, & Ballas, 2018). However, conclusions vary (e.g., Boyle, Norman, & Rees, 2004, van Lenthe et al., 2007; Gartner et al., 2018). There is thus a need to establish an appropriate framework within which we can determine whether and how spatial or social mobility contributes to changing health gradients. Further, this framework should allow researchers to account for the interdependencies between the mobility processes in question, something that is neglected in extant research. Drawing on developments in the selective migration literature (Darlington, Norman, & Gould, 2015) that highlights problems with the analytical frameworks employed in studies (Norman, 2018), this paper establishes an appropriate framework within which it is possible to isolate the effects of mobility on differences in a particular outcome at two points in time. Indeed, recent studies of migration and labour market outcomes (Rodríguez-Vignoli & Rowe, 2018) validate such a counterfactual approach that has long been in use within a subset of the selective migration literatures (e.g., Brimblecombe, Dorling, & Shaw, 1999, 2000; Norman, Boyle, & Rees, 2005). This paper first reviews the competing frameworks used to examine selection effects and health before turning to the relationship between selective sorting and changing health gradients. This section concludes by establishing the research questions guiding the framework of analysis before addressing the data and methods employed in this study. Results are discussed both in terms of the implications of selective sorting for changing health gradients as evidenced by these data and more generally in terms of the methodological approach needed to determine aggregate changes in health. This paper features in a Special Issue highlighting the value of longitudinal data for the analysis of social inequalities in health and mortality. Here, we demonstrate the significance of longitudinal data as a means to uncover the complexities of the relationships between selective sorting and population-level health inequalities.

2 | LITERATURE

The concept of socio-demographic selective sorting captures three *mobility* processes: social mobility (relating to changes in social status through occupational change), residential mobility or migration (whether or not people change address) and deprivation mobility (if an individual's residential area changes characteristics, whether or not they change address). Although a number of studies have separately explored how selective sorting through social, residential or deprivation mobility may influence health gradients, the interdependencies of these mobility processes are neglected (though see Fielding, 1992; Platt, 2005). To exemplify the interdependencies of these processes, consider how a promotion, the resultant upward social mobility and possible change in address to a differently deprived area may interact. Further, these three separate, but interrelated mobility processes may also be influenced by, or influence, health status. For example, it might be anticipated that an individual's health will benefit from a promotion and the move to a differently deprived area, but what of their health prior to the promotion or change of address? Are upwards socio-spatial trajectories as likely for someone in poor health or with fewer health-enabling behaviours? The nature of the sorting process will vary within a population and over space depending on wider social, economic and political structures. Indeed, differences in the determinants or drivers of spatial mobility, and the interrelations between individual-level and wider contextual factors in shaping mobility over the lifecourse, are well theorised in wider literature (Coulter, van Ham, & Findlay, 2016; Findlay, McCollum, Coulter, & Gayle, 2015; Mulder & Hooimeijer, 1999). The opportunities for and nature of any form of spatial or social mobility are contingent on individual-level attributes which are conditional on the context within which people live. Thus, the 'selectivity' of the sorting process should not be construed as a form of Darwinian natural selection. Rather, a complex interplay between the contextual and compositional factors well known to influence health (e.g., see Cummins, Curtis, Diez-Roux, & Macintyre, 2007; Macintyre, Ellaway, & Cummins, 2002).

Although it is generally agreed that some form of selection operates through migration or social mobility, the extent to which this selective sorting influences (changing) health gradients is unclear. Underpinning this lack of consensus are differences in the conceptual and analytical frameworks employed alongside differences in choice of health outcome, the time frame under investigation (e.g., 10 years, 20 years etc.), context (e.g., different regions or countries) and the operationalisation of social, residential and deprivation mobility in the research design (Darlington-Pollock, Norman, Exeter, & Shackleton, 2018; Gartner et al., 2018; Norman, 2018).

2.1 | Competing frameworks

2.1.1 | Individual-level models

Verheij et al.'s (1998) classic study on selective migration in the Netherlands was one of the first to effectively exploit longitudinal data. First, they compare health between mobile groups differentiated in the direction of their move defined as urban–rural and rural–urban movers. Using logistic regression and controlling for an extensive array of variables, Verheij et al. determine whether odds of either being a mover (relative to stayers) or moving into an urban area (relative to moving into a rural area) vary according to different health outcomes. Second, they compare health differences between movers and stayers. Here, urban–rural distinctions are not considered. The authors conclude that for selective migration to influence health differences between urban and rural areas, '[a]bsolute numbers of migrants need to be very high … to make this noticeable at the aggregate level' (1998, p. 487). However, although the framework that the authors adopt is adept at revealing nuances as to the complexities of the health–migration relationship, it is less able to draw conclusions at

the aggregate level. In part, this is because instead of simply establishing whether there are differences in health between differently moving groups (there are differences shown), the controls for other variables 'explain away' those differences. Thus, the influence of health selective migration on changing health gradients between rural and urban areas is not established. Notwithstanding, this framework for modelling individual-level outcomes has been widely adopted in subsequent literature examining the relationship between selective migration and health. Although such a framework can be used to simply differentiate between those who do (movers) and do not (stayers) change address, it can be broadened to capture different related mobility processes such as social (Maheswaran et al., 2018) or environmental (Tunstall, Mitchell, Pearce, & Shortt, 2014) deprivation mobility. Moves between areas defined by their trends of population change are also considered in the literature (e.g., Dijkstra, Kibele, Verweij, van der Lucht, & Janssen, 2015; Westphal, 2016), important insofar as population decline is associated with increasing deprivation, with residualised populations generally comprising, an older, less socio-economically advantaged population often in poorer health (Exeter, Feng, Flowerdew, & Boyle, 2005).

In the United Kingdom, Tunstall et al. (2014) conclude that odds of poor mental health are elevated for movers and that those with poor mental health are more likely to move towards more socio-economically deprived areas. Yet they do not find that selective migration contributes to the poorer health observed in areas with multiple physical deprivation. Intriguingly, odds of poorer mental health are elevated amongst those moving to better physical environments. In the Netherlands, Dijkstra et al. find that though movers are healthier than stayers, the effect is larger for movers out of declining regions than for those into declining regions. Having determined that net migration between regions with population decline and elsewhere is small, the authors conclude that selective migration can only account for a small part of observed health disparities (2015, p. 949). Similar findings are reported in Germany, though using event-history analysis rather than logistic regression. Westphal (2016) demonstrate the health-selectivity of migration between federal states concluding that the positive selection of healthier, younger individuals into migration leads to a residualising and declining population who are older and in poorer health. Relatedly, though at a more local scale, Maheswaran et al. (2018) add more evidence to support one the central tenets of the health selection hypothesis. Namely, that movers away from more affluent areas in Sheffield, UK had poorer health than their immobile peers, whereas movers towards more affluent areas in that city had better health than those who remain. In addition, Maheswaran et al. find evidence of the widely observed paradoxical findings in older ages indicative of the changing nature of the health–migration relationship with increasing age (e.g., Findley, 1988; Larson, Bell, & Young, 2004).

Though informative, modelling individual-level outcomes do not demonstrate whether the movement of differently healthy groups influences (changing) health at the aggregate level. Rather, these studies which apply different models within a comparable analytical framework document the association between odds of poor health (or moving) for differently defined movers (or those in poor health) (e.g., see Moriarty et al. elsewhere in this Special Issue). More recently, a study of selective migration and health in Wales employed the sort of counterfactual approach needed to better determine the impact of mobility on health outcomes (Gartner et al., 2018). Here, the authors used Cox proportional hazard models to compare risk of mortality for different deprivation quintiles in two scenarios. The first is based on deprivation quintile at the end of the study period, whereas the second artificially 'puts people back' into their origin deprivation quintile. However, in modelling individual-level outcomes, this approach is not able to effectively determine whether movement could contribute to widening population-level health gradients. There is a strong implication that the differences between groups may affect area relationships, but this is not specifically measured.

2.1.2 | Counterfactual approaches

The 'put people back' approach exemplifies a counterfactual approach to studying the impact of mobility on change in a particular outcome. In the context of health-deprivation gradients, we are interested in whether the current distribution of poor health between deprivation quintiles varies to that which would have arisen should a population have remained in place over time. When applied to aggregate-level data, rather than when modelling individual outcomes, this method is better placed to determine the contribution of selective sorting to changing health gradients. A number of studies have employed this method in the context of different types of mobility. For example, lifetime migration at a regional level (Brimblecombe et al., 1999, 2000) or in the context of health-deprivation gradients (Boyle et al., 2004; Boyle, Norman, & Popham, 2009; Norman et al., 2005). We build on this. Though necessary, this method is not sufficient when explaining whether and how selective sorting can influence changing health gradients. As Verheij et al. (1998) rightly establish, it is important to compare health differences between mobile groups differentiated in direction of move (such as urban to rural, or from more to less deprivation). At the aggregate level, for this to be informative, comparisons must be made between the health of those joining an area or social class with the health of those leaving. Boyle et al. (2004) and Norman et al. (2005) re-aggregate linked census microdata at two points in time to establish whether health-deprivation gradients change following mobility, whether through area type change for non-movers (Boyle et al., 2004) or in combination with selective migration for movers (Norman et al., 2005). Here, the health of mobile groups (whether through a change in address [migration] or change in the level of deprivation in an area [deprivation mobility]) transitioning into and out of the most and least deprived areas are compared. Indeed, Boyle et al. (2009) later applied this method to the analogous field of social mobility, providing convincing evidence that the influence on health gradients manifests through differences between the health of those leaving a social class and those joining, rather than through differences between the health of those joining a class and the health of existing class members.

2.2 | Selective sorting and health

For spatial inequalities in health, studies tend to focus on the extent to which migration or residential mobility redistributes populations between differently deprived areas operationalised in a variety of ways. Boyle et al. (2004) and Norman et al. (2005) are notable in that they also consider deprivation change, that is, for the in situ experience whereby the level of area deprivation has changed relative to other areas between two points in time. However, the interdependencies between social mobility and residential or deprivation mobility receive less specific coverage. Notwithstanding, Boyle et al. (2009) do consider transitions between social classes alongside those between deprivation quintiles, and Malmusi, Borrell, and Benach (2010) have sought to elucidate the importance of accounting for the interaction between health, migration and social class. Establishing an analytical framework that can both demonstrate the extent to which mobility accounts for changing health gradients over time and, at least to some extent, account for the interdependencies within processes of selective sorting may be revealing.

As differently healthy individuals transition between areas or social classes, this sorting process may maintain, widen or constrain existing aggregate health gradients. Individual social determinants of health or contextual (place) influences will simultaneously maintain or exacerbate existing health gradients. Thus, those in the best health remain in (or transition between) the most advantaged circumstances, whereas those in the poorest health remain in (or transition between) the least advantaged circumstances. The health (dis)advantage of more or less advantaged circumstances is therefore maintained through transitions between these different circumstances and the subsequent (or prior) health (dis)benefits of those circumstances. This is illustrated in Figure 1.

Although the best health (continuous green lines) is afforded to those who remain in or transition between the most advantaged circumstances, the poorest health (continuous red lines) is found for those at the opposite end of the spectrum. Worsening health (red dashed lines) is observed for those moving towards more disadvantaged circumstances, whereas improving health (green dashed lines) is observed for those moving towards more advantaged circumstances. The dashed lines also denote upward (green) or downward (red) mobility. Comparing the health of the mobile and immobile groups, as shown in Figure 1, will not reveal how transitions of the mobile groups influences overall health gradients. This is key to the critique of extant research into social selection and social mobility made by Boyle et al. (2009). As Norman and Boyle (2014) further demonstrate, to identify how transitions between social classes and area types influence changing health gradients, comparisons of health must be made between the transitioning groups as shown in Figure 2, rather than the comparisons made in Figure 1 above. Moreover, rather than comparing *changing* health, we are interested in differences in health between the mobile groups at destination deprivation quintile or social class.

In Figure 2, the continuous green lines denote groups in the most advantaged circumstances with the best health, whereas the continuous red lines denote groups in the least advantaged circumstances with the poorest health. Upward mobility and possibly improving health is denoted by dashed green lines, whereas downwards mobility and likely worsening health is denoted by dashed red lines (given what is known about the wider social and spatial determinants of health). Figure 2 compares the health of the transitioning groups moving between the most and least advantaged circumstances.

For selective sorting to widen health gradients, the health of those *entering* the most advantaged circumstances must be *better* than the health of those leaving. Similarly, the health of those *entering* the least advantaged circumstances must be *poorer* than the health of those leaving (this is the patterning to health depicted in Figure 2). Thus, the health-deprivation gradient or social gradient to health would be steeper if migration, residential mobility, deprivation mobility or social mobility occurs over a given time period compared with if the population had remained in place. For selective sorting to maintain existing health gradients, the health of the downwardly mobile must be better than the health of the upwardly mobile for either those transitioning around the most advantaged circumstances or for those transitioning around the least advantaged. If the health of the downwardly mobile is consistently better than the health of the upwardly

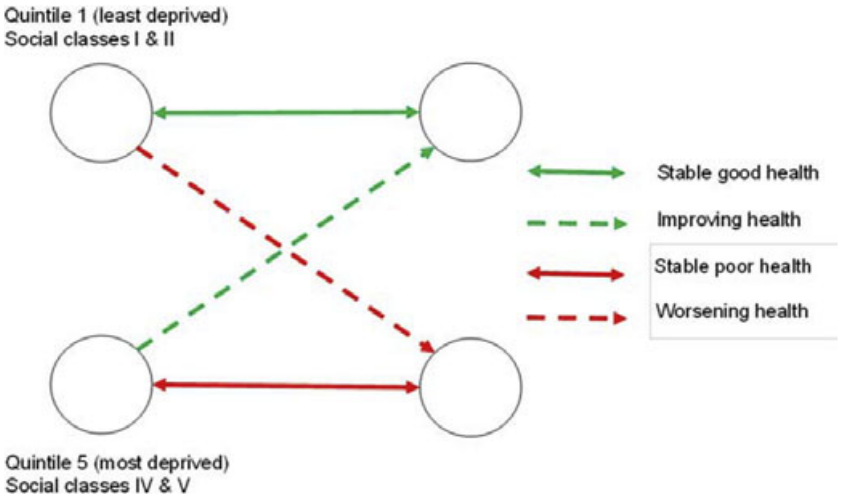

FIGURE 1 Transitions between (dis) advantaged circumstances and health change

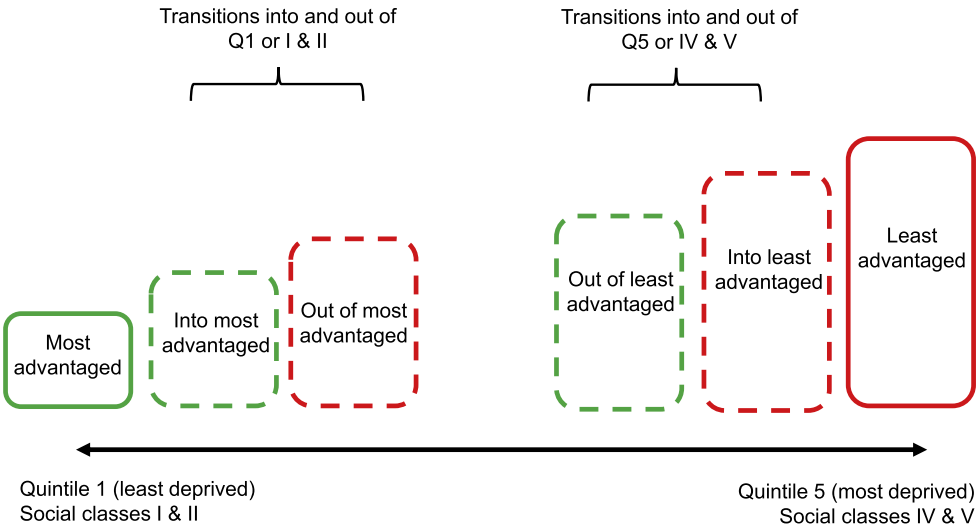

FIGURE 2 Transitions and widening health gradients

mobile, it is possible that selective sorting narrows rather than widens or maintains existing health gradients. Thus, the framework for analysis must establish all three of the following:

a To what extent do health gradients vary when populations are able to move between area types and social classes compared with those arising when populations are *put back* into their area type or social class of origin?
b To what extent does the health status of those entering the most and least advantaged areas or highest and lowest social classes differ from those leaving these areas or classes?

Finally, given the strength of the selectivity of migration and the extent to which this interacts with either social mobility (e.g., see Fielding, 1992) or deprivation mobility (e.g., Darlington-Pollock et al., 2016; Exeter, Sabel, Hanham, Lee, & Wells, 2015; Norman et al., 2005);

c To what extent does the patterning to health by transitions into and out of differently deprived areas or social classes (as depicted in Figure 2) vary by migrant status?

3 | DATA

This paper exploits linked census data from the Office for National Statistics (ONS) Longitudinal Study. Linking census data and life event information, the Longitudinal Study comprises a 1% sample of the population of England and Wales. Starting from 1971, individuals are sampled based on four birth dates. Life event information, including births and immigration (entry events), and death and emigration (exit events), is updated between censuses for those with relevant birth dates (Hattersley & Creeser, 1995; Shelton et al., 2018). At the household level, information is also recorded for all those enumerated in the same household as a Longitudinal Study member, but only information about the Longitudinal Study members are linked over time. For any one census, the Longitudinal Study has data on around 500,000 members. Between successive censuses, approximately 400,000 Longitudinal Study members are linked. Since its inception and to date, the Longitudinal Study holds data on more than 1 million sample members. By linking census data to life event information, the Longitudinal Study covers the full range of census topics with the added benefit of data on cancer registrations and mortality. External data can also be linked, such as measures of deprivation. Thus, the Longitudinal Study are an invaluable resource within which to establish whether and how selection effects may contribute to changing health gradients between area types or social classes over time.

The sample for this study comprises an extract of Longitudinal Study members present at two successive censuses (2001 and 2011). Re-aggregating linked census data from two points in time defines a closed cohort of included LS members, capturing change (and continuity) in socio-economic status; health status; area of residence (though this is subject to relevant disclosure controls); and through linking to external data, area deprivation. It is worth noting that the closed cohort aggregated into start and end groups will not necessarily emulate the area data collected in successive censuses due to sampling strategies and population entries and exits for areas not accounted for in the closed cohort. The Longitudinal Study may be differently affected by non-response than the censuses as a whole (e.g., attrition compared with underenumeration). Figure 3 details the selection criteria for the closed cohort defined in this analysis.

At the individual-level, modelling either health outcomes or mobility, these data can contribute to our understanding of the risk of either poor health or mobility for different subgroups of the population. At the aggregate level, these data reveal whether and how migration, social mobility or deprivation mobility contribute to changes in either the health-deprivation gradient or social gradient to health. For the purposes of this study, the sample is restricted to household residents of England aged between 16 years and older. In line with extant literature on selection effects and health, we exclude recent international migrants according to the 10-year migration indicator (discussed below) and those reporting limiting long-term illness

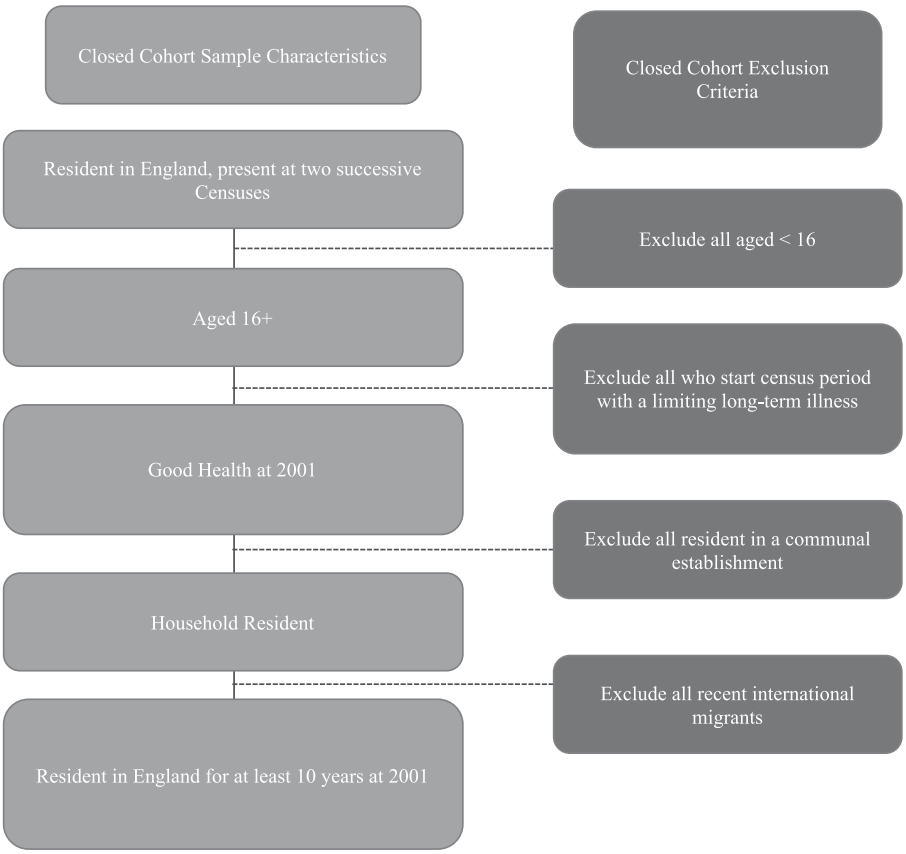

FIGURE 3 Population eligibility flow chart

at the start of the study period (see Norman et al., 2005). In restricting the sample to a relatively healthy baseline group who must survive to the next census, we focus on selection processes contributing to the maintenance of good health or deteriorating health. Given the health-selectivity of migration, our results may underestimate the strength of the relationship between sorting processes and wider health inequalities. Those already in poor health are much less likely to move (as shown in the literature) and more likely to remain in more disadvantaged circumstances. Future work must extend our proposed framework to account for the selection processes operating amongst those already experiencing poor health.

Deprivation is defined according to the Carstairs Index (Morris & Carstairs, 1991). This index is a composite measure based on four census variables capturing male unemployment, overcrowding, non-car ownership and low social class. The index scores are grouped into quintiles with equal numbers of the population for each census year. These quintiles are then linked to the Longitudinal Study members in the extract (Norman & Boyle, 2014). This measure of deprivation is relative to the census year: Thus, although an area may be in the same quintile at two points in time, this does not necessarily mean the area is experiencing the same level of deprivation between census years. However, as we are interested in the deprivation experience of an individual at two time points relative to other areas in the same year, the lack of comparability over time is not a problem (other studies have similarly concluded that the Carstairs Index can be used to explore deprivation change over time in terms of selective sorting; e.g., Norman et al., 2005).

Social class is defined by the Registrar General's Social Class scheme, identified by converting the National Statistics Socio-economic Classification (NS-SeC) provided for 2001 and 2011. This measure was chosen for two key reasons: First, the NS-SeC is not technically hierarchical, though it has been used in social mobility research (Fry, Alhamad, & White, 2012); and second, for comparability with wider research into social selection and health. All groups not assigned to a social class are grouped as 'Unclassifiable'. To increase sample size, the top and bottom two social classes in the Registrar General's scheme are combined. Notwithstanding, future research may apply the framework established here to alternative measures of socio-economic status. Health is measured by the presence or absence of limiting long-term illness (LLTI). In 2011, the census allows respondents to indicate the extent to which their day-to-day activities are limited by their health, distinguishing between limited a little and limited a lot. Here, we combine both responses. Migrant status is captured by a 10-year migrant indicator, comparing the address of the Longitudinal Study member to that recorded at the previous census. As noted above, we are only interested in moves within England between two censuses. Thus, recent international migrants are excluded as the Longitudinal Study members must be resident in England for at least 10 years. Differentiating between movers and stayers, according to their migrant status, is crucial to the holistic analysis of selective sorting between area types and social classes presented in this framework. Transition categories, capturing movement between area types and social classes, are defined for movers (who are identified by the change of address between 2001 and 2011) and stayers. These groups may transition between deprivation

quintiles either through migration (via a change of address) or deprivation mobility (as their location becomes more or less deprived relative to the other areas) but may also transition between social classes. The transition categories identified are well-established in the literature on selection effects (e.g. Exeter, Boyle, & Norman, 2011; Norman et al., 2005) but not without their limitations. First, these mask rarer transitions between the extremes of either the social class hierarchy or the deprivation quintiles. For example, of the 71,620 people living in the least deprived quintile in 2001 (based on our Longitudinal Study sample), 1.9% (1,355) were living in the most deprived quintile in 2011. A slightly higher proportion experienced a more favourable move, with 3.9% (2,246) of the 57,551 living in the most deprived quintile in 2001 residing in the least deprived quintile by 2011. Second, and specific to the deprivation transition categories, these potentially mask differences in the magnitude of moves *within* quintiles. A move between the 99th and 81st percentile is a bigger change in deprivation than a move between the 81st and the 79th, yet both are within the same quintile. Though risking smaller sample sizes, future research may benefit from expanding the framework proposed here to capture more detail in the transitions, whether expanding to deprivation deciles rather than quintiles, or considering a more disaggregated breakdown of the transition categories themselves. The availability of longitudinal register data, such as that used by Neels and Wood in this Special Issue (though over a longer time frame), would also permit more detailed analysis of the nature of deprivation or social class transitions over time. Table 1 summarises the study population in respect of the variables used in this analysis.

TABLE 1 Study population by variables included in the analysis

Variables			2001–2011, count (prop, %)	
Label	**Categories**	**Description**	**2001**	**2011**
Limiting long-term illness	LLTI	Presence of LLTI at each census	321,697 (100%)	42,875 (13.3%)
	No LLTI			278,822 (86.7%)
Age	—	10-year age groups		
Social Class	I & II	Registrar General's schema of social class derived from the NS-SeC	81,516 (25.3%)	94,993 (29.5%)
	IIIN		55,823 (17.4%)	71,151 (22.1%)
	IIIM		44,339 (13.8%)	54,232 (16.9%)
	IV & V		40,288 (12.5%)	21,188 (8.8%)
	Unclassifiable		99,731 (31.0%)	73,133 (22.7%)
Social mobility	Stable I & II	Social class transitions (excludes unclassifiable)[a]	56,025 (27.6%)	
	IIIN–IIIM to I & II		19,749 (9.7%)	
	I & II to IIIN–IIIM		20,514 (10.1%)	
	Stable IIIN–IIIN		67,271 (33.1%)	
	IV & V to I–IIIM		18,338 (9.0%)	
	I–IIIM to IV & V		8,400 (4.1%)	
	Stable IV & V		12,684 (6.2%)	
Deprivation	Q1–least deprived	Deprivation quintiles based on Carstairs Index score at each census	71,620 (22.3%)	74,418 (23.1%)
	Q2		68,906 (21.4%)	71,949 (22.4%)
	Q3		64,587 (20.1%)	65,882 (20.5%)
	Q4		59,033 (18.4%)	58,869 (18.3%)
	Q5–most deprived		57,551 (17.9%)	50,579 (15.72%)
Deprivation mobility	Stable Q1	Deprivation transitions	47,913 (14.9%)	
	Q2–Q4 to Q1		24,259 (7.5%)	
	Q1 to Q2–Q4		22,352 (6.9%)	
	Stable Q2–Q4		154,281 (48.0%)	
	Q5 to Q1–Q4		22,313 (6.9%)	
	Q1–Q4 to Q5		15,341 (4.8%)	
	Stable Q5		35,238 (11.0%)	
Migrant status	Mover	Moved between 2001 and 2011	132,501 (41.2%)	144,772 (45.0%)
	Stayer		189,196 (58.8%)	176,925 (55.0%)

Source: ONS LS.

[a]Unclassifiable excluded from social class transitions, n = 118,716 (36.9%).

4 | METHODS

The framework of analysis established here draws on two different methods variously employed in existing studies of selective sorting and health. The first part builds on the use of the 'put people back' method to establish whether mobility has influenced the distribution of the health outcome in question. The second part examines whether transitions into and out of the most and least advantaged circumstances can contribute to widening health gradients. In all cases, the individual microdata are aggregated into the differently defined population subgroups at relevant time points to assess whether changes in group membership by individuals leads to changes when the aggregates are compared.

Standardised illness ratios (SIRs) and 95% confidence intervals are used to compare health between population groups (see Norman et al., 2005). We employ the indirect method of standardisation, which is more robust with small numbers: Observed counts of poor health (here defined as the presence of LLTI) are compared with the expected counts, based on the application of a set of age-specific illness rates (ASIRs) to the population age structure. Here, the standard population is all LS sample members contained within the closed cohort defined for this study.

SIRs provide a summary of the extent of illness (however defined) in a population subgroup, indicating whether there are higher or lower than expected levels of poor health in a population given their age structure. Values great than 100 indicate greater than expected levels of poor health, whereas values of less than 100 indicate lower than expected levels of poor health. For the 'put people back' approach, SIRs are calculated based on health status at the end of the study period by destination deprivation quintile and social class and also by origin deprivation quintile and social class. Two summary measures can be calculated to describe the influence of mobility, whether between area types or social classes, on the steepness of either the health-deprivation gradient, or social gradient to health. These compare the extent of the health-deprivation or social gradient to health under the two scenarios: (a) the extent of the health gradient at the end of a study period assuming that some of the population will have experienced social or spatial mobility over that time period and (b) the extent of the health gradient that would have arisen had none of the population experienced any mobility during that time period. First, extremal quotients between either the most and least deprived quintiles, or the top and bottom social classes, are compared in either scenario to summarise the steepness of the gradient. If mobility does influence (changing) health gradients, the health gradient would be steeper than that observed when the population are essentially 'put back' into the area (or deprivation quintile)/social class in which they began the study period. This closely aligns to a recently developed measure assessing the impact of migration on the composition of areas (Rodríguez-Vignoli & Rowe, 2018) by quantifying the change in a given measure attributable to migration. Extremal quotients are calculated as the ratio between the most and least deprived, or top and bottom social classes. To account for movement across the breadth of the deprivation quintiles or social classes, the steepness of the gradient can be summarised by calculating the Slope Index of Inequality (SII) and Relative Index of Inequality (RII) (see also McMinn et al. in this Special Issue).

The SII summarises absolute inequalities in health for given population groups (e.g., social classes or area types), whereas the RII summarises relative inequality. Amongst others (e.g., Preston, Haines, & Pamuk, 1981), Pamuk (1988) developed the measure, noting that the SII enables 'trend[s] in inequality … [to be] assessed [more] legitimately by using a summary indicator that incorporates the [health] experiences of all classes [or indeed population subgroup more generally] and their relative shares of the population' (p. 4). By extension, the RII enables the analysis of relative differences in health supplementing the summary of absolute differences by the SII. The SII is calculated by regressing the mean health of a group on the relative rank of that group (Shaw et al., 2007, p. 182), with the regression equation expressed as

$$\bar{y}_j = \beta_0 + \beta_1 \bar{R}_j$$

where j = indexes the social class or area type; $\bar{y}_j$ = average health status; $\bar{R}_j$ = average relative ranking of social class or area type in the cumulative distribution of the population; β_0 = estimated health status of hypothetical individual at bottom of the ranked groups (e.g., class V or deprivation quintile 5); and finally, β_1 = difference in average health status between hypothetical individual at the bottom of the ranked groups and hypothetical individual at the top (e.g., class I or deprivation quintile 1).

In the case of social class, the classes are ranked from highest (I and II) to lowest (IV and V) (see Table 1). The population in each class is one part of the cumulative distribution of the entire population. Each group is given a single score based on the mid-point of their range in the cumulative distribution of the ranked population. Here, the mean health of each group is based on SIRs calculated by social class and area type. The SII can therefore be understood as a summary of the hypothetical absolute differences between the top and bottom of the ranked population, that is, the top and bottom of the social class structure, according to results of the regression model. Where the SII is typically expressed as differences in rates, the RII which summarises relative differences is often expressed as rate ratios (Mackenbach & Kunst, 1997). In the above regression equation, the β_1 coefficient is the SII value.

The RII is similarly based on a regression model. However, to obtain the RII value, the SII can be divided by the mean value of the outcome measured (the health outcome) (as proposed by Pamuk, 1988). It can also be obtained by calculating the ratio of the difference in the rate between those at the top of the ranked hierarchy and those at the bottom of the ranked hierarchy. Thus, it is the rate ratio of the theoretical extremes of the ranked hierarchy under investigation (e.g., social class or deprivation). This method, developed by Mackenbach and Kunst (1997), is therefore similar to other widely used measures of health inequality such as the calculation of rate ratios or extremal quotients used. In the regression equation, this equates to the rate for those at the bottom of the ranked hierarchy

(intercept + slope) divided by the rate for those at the top of the ranked hierarchy (intercept):

$$RII = \frac{(\beta_0 + \beta_1)}{\beta_0}.$$

The value of the SII and RII over simply calculating extremal quotients rests in the fact that these measures account for the total (study) population when estimating absolute and relative differences in health between population groups rather than only accounting for those at the top and bottom of the hierarchy. In accounting for differences in the proportion of the population within each category (deprivation

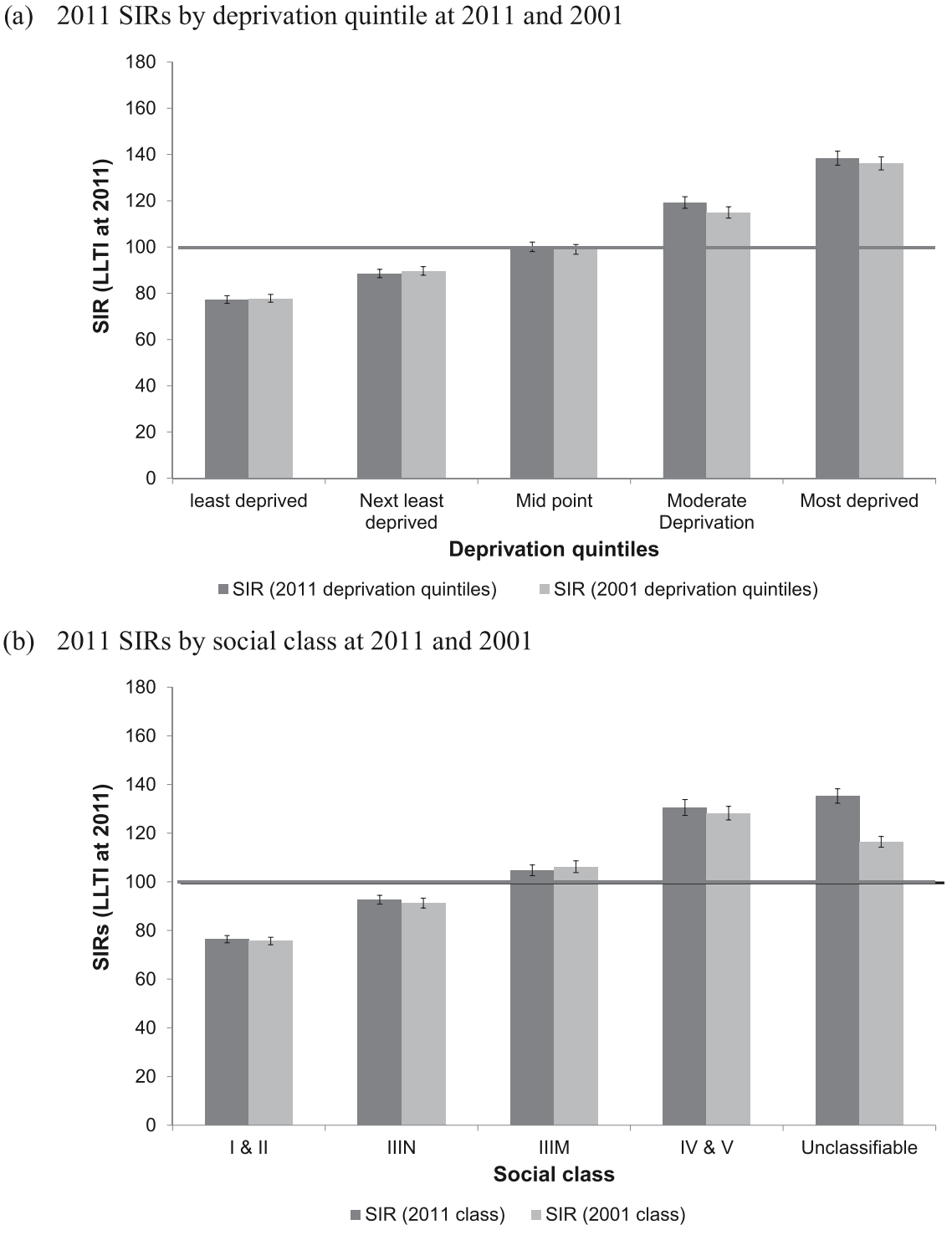

FIGURE 4 Standardised illness ratios by origin and destination deprivation quintile and social class, 2001–2011. Source: ONS LS

quintile or social class), these measures also allow comparison of health inequalities between different population groups (Shaw et al., 2007). This is the main strength of these measures. Notwithstanding, it should be noted that as groups are ranked hierarchically, these measures necessarily assume that everyone in the bottom group (the lowest social class or most deprived area type) is worse off than all groups above them (Mackenbach & Kunst, 1997; Shaw et al., 2007). Although this *is* often the case, it is not universal. These measures are underused in research into selection effects, though Boyle et al. (2009) is a notable exception.

The second part of the analyses utilises SIRs based on aggregations of individuals into transition categories within and between the most and least deprived quintiles and the top and bottom social classes. This includes those who remain in the same deprivation quintile or social class for the duration of the study period and those whose area type or social class changes. Here, we are able to account for the interdependencies between the mobility processes examined in this study. Calculating SIRs for transition categories, whether between social classes or deprivation quintiles, illustrates whether movement exacerbates health gradients at the extremes. For simplicity, transitions within and between either the middle deprivation quintiles or social classes are grouped leaving seven transition categories (e.g., see Boyle et al., 2004; Boyle et al., 2009; Exeter et al., 2011; Norman et al., 2005). For mobility, whether through deprivation mobility or migration, to contribute to widening health gradients, the health of those entering the most deprived areas or bottom social classes must be poorer than the health of those they replace, whereas the health of those entering the least deprived areas and top social classes must be better (as depicted in Figure 2). As with the 'put people back' approach, the standard population comprises all LS members in the closed cohort defined for this study.

5 | RESULTS

Figure 4 illustrates the 'put people back' approach, first by deprivation and second by social class. The light bars are based on deprivation and class of origin, that is, individual sample members are 'put back' by being aggregated into their origin deprivation quintile or social class. The dark bars are based on deprivation and class of destination. The dark bars thus assume mobility has occurred and the population has been able to transition within and between deprivation quintiles and social classes. The light bars assume no mobility has occurred. Here, no distinction is made between movers and stayers. Both plots are illustrative of the graded nature of health: SIRs for more deprived areas and lower social classes are significantly higher than SIRs for less deprived areas and higher social classes. Increasing deprivation or declining social class each return successively higher SIRs and therefore increasingly higher levels of LLTI. Differences between deprivation quintiles and social classes are generally significant. The extremal quotients and the SII and RII all summarise the extent to which health gradients vary when populations are able to move between area types and social classes compared with those arising when populations are *put back* into their area type or social class of origin. Here, we focus on relative differences summarised in the extremal quotients and RII. These are presented in Table 2. Table 2 considers the change to the social gradient to health including and excluding those not assigned to a class (i.e., the unclassifiable group).

Calculating the extremal quotients and RII indicates that the social gradient to health and health-deprivation gradient are steeper assuming mobility occurs in a population. When the populations are 'put back' into their area type or social class of origin, the health gradients that emerge are shallower than those after mobility occurs. This is exemplified by the lower values for the extremal quotients and RII under the no mobility scenario than the mobility scenario.

Figure 5 plots SIRs for movers and stayers by deprivation transition category for movers and stayers between 2001 and 2001, alongside the SIRs for movers and stayers by social class transition category. As noted in Figure 3, poor health is positively associated with increasing deprivation and declining social class. Those remaining in the least deprived areas or highest social classes have the best health, whereas those remaining in the most deprived areas and lowest social classes have the poorest health. Differences in health between the most and least deprived areas and the highest and lowest social classes are significant for movers and stayers. Although the health-deprivation gradient is consistent for movers and stayers, it is more pronounced for movers. For example, the extremal quotient (Q5:Q1) is 2.33 for movers compared with 1.75 for stayers.

Transitions into successively more deprived quintiles for movers return higher (though not always significantly so) SIRs with each downward transition. Importantly, movers transitioning into Q1 (from Q2 to Q4) have better health than the movers they replace, those transitioning out of Q1 (into Q2–Q4). Similarly, movers transitioning into Q5 (from Q2 to Q4) have poorer health than those they replace, those transitioning out of Q5 (into Q2–Q4). Conversely, stayers who become more deprived through deprivation mobility (i.e., their area type changes without a change of address) consistently have better health than stayers whose area becomes less deprived. Movers churning with the most deprived areas have significantly poorer health than stayers who remain in these areas, whereas movers churning

TABLE 2 Extremal Quotients and Relative Index of Inequality

	2001–2011	
	No mobility	**Mobility**
Extremal quotients		
Q5:Q1	1.75	1.79
IV & V: I & II	1.54	1.77
Unclassifiable: I & II	1.69	1.71
RII		
Deprivation quintiles	2.10	2.23
Social classes		
Excludes unclassifiable	2.40	2.22
Includes unclassifiable	1.80	2.48

Source: Authors own calculations, based on ONS LS.

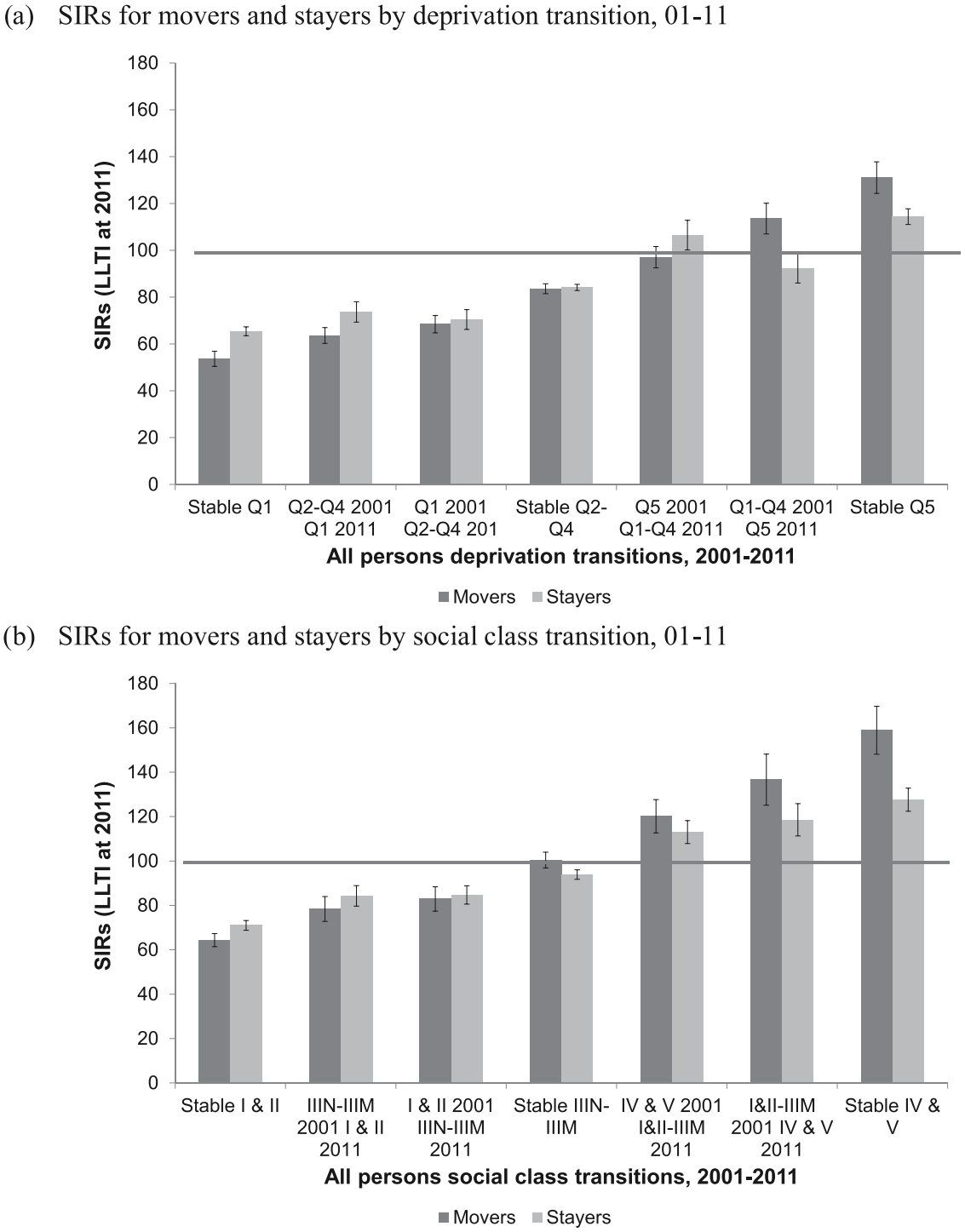

FIGURE 5 Standardised illness ratios by deprivation and social class transition for movers and stayers, 2001–2011. Source: ONS LS

within the least deprived areas have significantly better health than their immobile peers in Q1. This emphasises the significance of the association between a change of address and health status.

Health differences between movers and stayers by social class transition are similar to those observed by deprivation transition. Movers towards the top of the class structure are in better health than their stable counterparts, evident in the lower SIRs. Conversely, movers around the bottom of the class structure have poorer health. Moreover, the magnitude of inequality between the top and bottom of the class structure is greater for movers than stayers.

The extremal quotient for movers (here taken as the ratio between IV&V vs. I&II) is 2.47 for movers compared with 1.80 for stayers. For movers, poorer health is found for those entering the lowest social classes relative to those they replace, with health found for those entering the highest social classes relative to those they replace. For stayers, though a similar pattern is observed differences between

the transitioning groups at the top of the social class hierarchy are negligible.

The collective influence of movers and stayers on (changing) health gradients can be evaluated by examining the SIRs for movers and stayers combined, thus accounting for both the interrelationships between migration *and* deprivation mobility, or migration *and* social mobility. These are summarised in Table 3 by transition category (statistically significant SIRs are starred). The SIRs demonstrate a clear gradient to health with the best and worst health consistently observed for those at the extremes of either the deprivation quintiles or social class hierarchy.

6 | DISCUSSION

This paper has sought to highlight a framework within which it is possible to determine whether and how selective sorting between area types and social classes can contribute to changing population-level health gradients. It has been shown that for such mobility to lead to widening health gradients, the health gradient must be steeper after it is assumed populations can experience mobility than observed should populations be 'put back' into their area type or social class of origin. Further, for transitions into and out the most and least deprived deprivation quintiles, or highest and lowest social classes, the health of the upwardly mobile must be better than that of the downwardly mobile they replace. To identify such change, comparisons of health status must be made by summing individual microdata for relevant population subgroups to the aggregate level. In the examples given, using linked microdata from the ONS Longitudinal Study, these results suggest that selective sorting can contribute to *widening* health gradients in the population. Further, these gradients are exacerbated for movers relative to stayers, both in terms of the health-deprivation gradient and social gradient to health. We demonstrate that movers in better health (at the end of the time period) are more likely to be sorted into less deprived areas, whereas movers in poorer health are more likely to be sorted into more deprived areas. The pronounced health (dis) advantage afforded to those churning within the most and least deprived areas or remaining in the highest and lowest social classes for movers relative to stayers is demonstrative of the extent to which selective migration can exaggerate health gradients by social class and deprivation. Indeed, this is one of the key tenets of the health selection hypothesis (e.g., compare with Maheswaran et al., 2018).

TABLE 3 Standardised illness ratios by transition category for movers and stayers combined, 2001–2011

Deprivation transition	SIR	Social class transition	SIR
Stable/churn within Q1	62.8*	Stable I & II	68.77*
Q2–Q4 into Q1	67.8*	IIIN–IIIM into I & II	81.98*
Q1 into Q2–Q4	69.3*	I & II into IIIN–IIIM	84.06*
Stable/churn within Q2–Q4	84.0*	Stable IIIN–IIIM	95.73*
Q5 into Q1–Q4	100.5	IV & V into I–IIIM	115.44*
Q1–Q4 into Q5	103.4	I–IIIM into IV & V	124.30*
Stable/churn within Q5	118.0 *	Stable IV & V	134.58*

Source: Authors own calculations, based on ONS LS.
*Statistically significant.

It is beyond the scope of this paper to explore the mechanisms by which different opportunities or propensities for either social mobility or migration arise or why these vary by health. However, there are a couple of points worth noting, particularly as the analytical framework proposed here is important for how we conceptualise the relations between selective sorting, mobility processes and health inequality. First, health is socially determined through a complex interplay between compositional and contextual factors (Cummins et al., 2007) and macro political and economic structures (Bambra, Smith, & Pearce, 2019). Second, as we outlined in the literature review, opportunities for and nature of any form of social or spatial mobility are contingent on individual-level attributes which are conditional on the context within which people live. Opportunities for social or spatial mobility will also vary according to wider political and economic structures. The analytical framework proposed offers insights into the nature and extent of inequalities within the population, by identifying mechanisms that may contribute to changing inequalities while also illustrating differences in opportunities for and nature of social or spatial mobility. Further work into the complex interplay between people, places and politics is then needed to better unpack the injustices in differences in opportunities for social and spatial mobility, particularly where this contributes to changing health gradients at the aggregate level.

The framework adopted in this paper combines established approaches to the study of selective migration and health gradients (the 'put people back' approach) with revised methods according to the critiques made by Boyle et al. (2009). Given the proliferation of research into selection effects and health gradients, which continues to draw conclusions about the relationship between selective migration (and social mobility) on area-level differences in health based on individual-level outcomes, summarising the framework established here is necessary. We extend existing studies by accounting for the interdependencies of the mobility processes examined through differentiating between deprivation mobility for movers and stayers and social mobility for movers and stayers. By first identifying how health would be distributed in the population *should no transitions occur* and comparing this with the distribution of health *once transitions have occurred*, it is possible to establish whether transitions do in fact contribute to changes in health gradients. Further, by then comparing the health of transitioning groups differentiated by migrant status, it is possible to determine the nature of the influence of transitions into or out of the most or least deprived areas on deprivation-health gradients and transitions into or out of the top and bottom classes on social class-health gradients.

Thus, we examined the health of groups of movers (migrants) and stayers (non-migrants) transitioning between area types (defined by deprivation quintile) and social classes between 2001 and 2011. The extremal quotients calculated to compare the distribution of health by

destination social class and deprivation quintile relative to the distribution that would arise should the population have remained in their origin social class and deprivation quintile suggest that selective sorting is contributing to widening health gradients. The extremal quotients are higher, suggesting a steeper health gradient, by destination quintile and social class than at origin. Extending this 'put people back' approach, the RII was calculated at origin and deprivation social class and deprivation quintile to account for differences across the whole population, rather than simply summarising differences between the extremes. Higher RII values (and SII values, though not reported) demonstrate that relative inequalities in health (and absolute differences) are larger at destination than by origin.

The conclusions drawn from the counterfactual 'put people back' approach are further validated when comparing health between mobile groups moving into and out of the most and least deprived areas and the highest and lowest social classes. When differentiating between movers and stayers, transitions between area types for movers appear to contribute to widening health gradients as the health of those moving out of Q1 is poorer than the health of those moving into Q1, whereas the health of those moving out of Q5 is better than the health of those moving in. Conversely, the patterning to health by transition category for stayers suggest deprivation mobility may constrain health gradients over the 10-year period. Thus, deprivation-health gradient appears to be exacerbated through migration, with no evidence that area type change can contribute to widening health gradients as found by Norman et al. (2005) who used a 20-year rather than 10-year period. It is possible that over a 20-year period area type change through deprivation mobility may similarly widen health gradients. Length of residency is evidently important in terms of accruing health (dis)benefits associated with differently deprived areas. Transitions between social classes for both movers and stayers both appeared to contribute to widening health gradients, though the gradient is steeper for movers than for stayers.

To determine the *overall* influence of selective sorting on deprivation-health gradients and social class-health gradients, SIRs by transition categories are compared for movers and stayers combined: Successively increasing SIRs for transitions into more deprived areas and lower social classes suggests that overall, selective sorting does contribute to widening deprivation-health gradients.

Our approach is not without limitation. First, we define deprivation change relatively rather than in absolute terms. Though this reveals whether and how selective sorting between deprivation quintiles influences health-deprivation gradients, any area-based policies designed in response to this must be supported by additional evidence as to absolute changes in deprivation. Second, in putting people back to their previous circumstances, this approach does not take into account any (dis)benefit accrued from the subsequent circumstances. To address this would need annual increment transitions to re-aggregate the individual microdata to fill in the 10-year gap in the ONS Longitudinal Study. There would be potential in the British Household Panel Survey/Understanding Society to carry out annual re-aggregations. The Longitudinal Study sample is itself selective of healthy people at the start of the time period and of survivors to the end of the decade. However, in using a closed cohort who begin the study period in good health, it is possible to isolate the influence of migration, area type change or social class on a change in health gradients. Moreover, this helps to address a noted limitation of the 'put people back' approach, which assumes that health outcomes after a change in address, deprivation quintile or social class are only determined by experiences prior to that mobility (Lee, 2019). Prior health status is important, particularly insofar as it is associated with propensity to migrate at the individual-level (e.g., see Larson et al., 2004). In combining approaches (as this framework does), the cumulative picture that emerges can tell us much of the influence of selective sorting on changing health gradients. Although this framework may not allow for the sorting processes operating which may exacerbate health gradients through the residualisation of typically less advantaged groups already experiencing declining health, it is likely that through the strength of the health-selectivity of migration, this exclusion means we underestimate the strength of the association between selective sorting and changing health gradients. Further work with more temporal detail would be better placed to unpack these issues (as indeed the use of quarterly data and sequence analysis has shown elsewhere; Shackleton, Darlington-Pollock, Norman, Jackson, & Exeter, 2018).

Finally, the approach adopted here does not control for additional individual attributes. In addition to health status, it is likely that individuals transitioning to better or less good circumstances will be equivalently advantaged or disadvantaged by educational achievement, housing tenure, car ownership, health related behaviours and so forth. An individual-level model of health by mover status plus these kinds of attributes may well find that the crude differences between groups reduce substantially once other variables are included because these too are related to health outcomes. In reality, (dis)advantages of groups will be across a range of associated attributes, not just health. Indeed, the significance of a change of address in terms of the health-deprivation relationship is likely a reflection of the wider (dis)advantages associated with differing propensities to move.

We have demonstrated that health inequalities appear to change over time between area types and social classes between 2001 and 2011 through processes of socio-demographic selective sorting. To conclude, thus, it is necessary to re-aggregate microdata to establish change in the distribution of a particular health outcome between two time points. Simply establishing whether individuals vary in health by transition status, as is often the case in studies of selection effects, may imply an impact on aggregate changes but does not demonstrate it. Indeed, modelling health outcomes for individuals differentiated by (non-) mobility statuses and then drawing conclusions about health for groups or areas risks committing the atomistic fallacy. This paper extends existing work on selective sorting, increasingly focussed on selective migration, establishing a framework which captures the influence of the sorting process on changing health inequalities at the aggregate level. Further, the framework presented begins to account for the interdependencies between these mobility processes. In developing this framework, it offers an important conceptual contribution to wider literature on mobilities, selection effects and the relation with inequalities. Indeed, its application extends beyond health to

wider inequalities in social and economic outcomes associated with uneven opportunities for mobility.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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