The economics of health inequality in the English National Health Service

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Abstract

This thesis explores the economics of health inequalities in the English National Health Service (NHS). It consists of five applied economic studies that explore different questions regarding socioeconomic inequalities and the NHS. It is bound together by an integrative chapter that provides the historical background to, and draws conclusions across, the body of work.

The first of the five applied studies examined the financial costs that socioeconomic inequalities exact on the NHS, the second looked at socioeconomic inequalities in access to primary care, the third looked at socioeconomic inequalities in health outcomes attributable to the NHS, and the final two studies extended the established methods for the economic evaluation of health care programmes to explicitly value minimising socioeconomic health inequalities as well as maximising population health. These extended methods were termed distributional cost-effectiveness analysis.

The studies found that dealing with the excess morbidity associated with socioeconomic inequalities cost the NHS approximately a fifth of its annual budget. Socioeconomic inequalities in access to and quality of primary care significantly improved from 2004 to 2011 in response to government policy to tackle these. However, socioeconomic inequalities in health outcomes stubbornly persisted over this period, by 2011 socioeconomic inequality was still associated with over 158 000 patients experiencing one or more preventable hospital admissions and almost 40 000 patients dying from causes amenable to health care. Distributional cost-effectiveness analysis methods were shown to be practically applicable in an NHS setting. This was demonstrated using a case study comparing population health programmes in which trading off between health maximisation and health inequality minimisation was necessary.

The thesis provides an evidence base and practical new methods that should serve as a foundation to better understand the role of the NHS in tackling socioeconomic inequalities in health. In so doing, it also outlines an exciting programme of further research.

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I must also thank my co-authors on the papers that form the core of this thesis, and my generous colleagues at the Centre for Health Economics at the University of York. Many of the ideas in this thesis have been shaped in discussions with them over the years.

Finally, a special thanks to Fatema Sunderji, Khalil Hassanally, John Gardner, Andrew Mirelman, Karl Claxton, Tony Culyer and Fuad Ali for their careful proof reading of, and thoughtful comments on, my integrative chapter.

Author's Declaration

The five papers [1–5] that form the core of this thesis are listed below. Whilst I am the first author on each of the papers all the papers have been written in conjunction with co-authors. My contribution to each paper is described after the citation of the respective paper. The integrative chapter that binds these papers into the thesis is solely my own work.

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References.

1. Asaria M, Doran T, Cookson R. **The costs of inequality: whole-population modelling study of lifetime inpatient hospital costs in the English National Health Service by level of neighbourhood deprivation.** JECH 2016; doi:10.1136/jech-2016-207447
   [Contribution of the candidate: Design, development and conduct of the analyses, preparation of the manuscript and subsequent revisions]

2. Asaria M, Cookson R, Fleetcroft R, Ali S. **Unequal socioeconomic distribution of the primary care workforce: whole-population small area longitudinal study.** BMJ Open 2016; doi:10.1136/bmjopen-2015-008783
   [Contribution of the candidate: Design, development and conduct of the analyses, preparation of the manuscript and subsequent revisions]

3. Asaria, M., Ali, S., Doran, T., Ferguson, B., Fleetcroft, R., Goddard, M., Goldblatt, P., Laudicella, M., Raine, R. & Cookson, R. **How a universal health system reduces inequalities: lessons from England.** JECH 2016; doi:10.1136/jech-2015-206742
   [Contribution of the candidate: Design, development and conduct of the analyses, preparation of the manuscript and subsequent revisions]

4. Asaria M, Griffin S, Cookson R, Whyte S, Tappenden P. **Distributional cost-effectiveness analysis of health care programmes–a methodological case study of the UK bowel cancer screening programme.** Health Economics 2014; doi:10.1002/hec.3058
   [Contribution of the candidate: Design, development and conduct of the analyses, preparation of the manuscript and subsequent revisions]

5. Asaria M, Griffin S, Cookson R. **Distributional cost-effectiveness analysis: A tutorial.** Medical Decision Making 2015; doi:10.1177/0272989X15583266
   [Contribution of the candidate: Design, development and conduct of the analyses, preparation of the manuscript and subsequent revisions]

Integrative Chapter

Introduction

This thesis examines the economics of socioeconomic inequalities in health in the context of the English National Health Service (NHS).

The World Health Organization defines health inequities as:[6]

> *"differences in health which are not only unnecessary and avoidable but, in addition, are considered unfair and unjust"*

The focus of this thesis is on socioeconomic inequalities in health — the variation in health associated with differences in the social and economic environments in which people live — and hence can be viewed as unnecessary, avoidable, unfair and unjust. For the purposes of this thesis the terms health inequity and socioeconomic inequalities in health are used interchangeably.

It is widely recognised that health and its distribution are a function of more than just health care. This multifaceted nature is conceptualised by economists through the lens of the Grossman model for health production,[7–9] and understood by the wider social sciences through the lens of the social determinants of health.[10] This presents two distinct approaches for examining socioeconomic inequalities in health: (i) a broad approach considering inequalities in health outcomes such as life expectancy due to inequalities in the social determinants of health; and (ii) a narrow approach considering inequalities in access to and outcomes of health care, focusing on health outcomes that are more specifically attributable to the role of health care in producing health.

With this context in mind, the overarching aims of the thesis are: to contribute to (a) understanding the impact that socioeconomic inequalities in health have on the NHS; (b) understanding the impact the NHS itself has on socioeconomic inequalities in health; and (c) developing methods that the NHS can use to evaluate and compare proposed policy initiatives to tackle health inequalities.

The thesis begins with a section outlining the historical background of research and policy regarding socioeconomic inequalities in health in England. The four sections that follow this background describe how the papers that constitute this thesis addressed the overarching aims outlined above. Each section begins by positioning

the respective papers within the existing academic literature and policy context, then explains the contribution of the paper to knowledge and understanding about the aims it addressed, and concludes by highlighting areas for further research suggested by its findings. The chapter concludes with a summary section that picks up key themes across the studies. This summary section explains how taken together these studies provide an evidence base and a practical set of tools that will enable the NHS to identify and evaluate interventions that tackle socioeconomic inequalities in health. The full papers constituting the core of the thesis are reproduced in the appendix.

Historical background

In this section I briefly outline some of the key milestones of health inequality policy in England. I describe how socioeconomic inequalities in health, government policy towards it, and the academic literature about it, have evolved over time and in relation to each other. Whilst this historical background section is far from comprehensive, its aim is to provide sufficient context within which to interpret the work presented in this thesis.

In 1837 the national registration of births and deaths in England came into force with recording of cause of death, age at death, and occupation on every death record. This was coupled with the classification of the whole population by age and occupation in the decennial censuses. The production of these key datasets have catalysed and underpinned the wealth of research and policy that have sought to unpick and address socioeconomic inequalities in health ever since.

Amongst the earliest advocates of this research agenda was William Farr, who in 1839 was appointed as the first 'Compiler of Abstracts' at the General Register Office (GRO). Farr pioneered the field of social epidemiology with his series of 'Letters to the Registrar General' appended to the GRO annual reports.[11] These were filled with insightful observations on the social gradient in mortality, and they proposed and examined a range of hypotheses regarding the causes of this gradient.[12]

Another notable early intervention in the field was that of social reformer Edwin Chadwick. He was invited by the then government to undertake an independent inquiry on sanitation following the influenza and typhoid epidemic in London in

the 1830s.[13] In 1842 Chadwick published his response to this inquiry as: 'The Sanitary Conditions of the Labouring Population of Great Britain'.[14] He found that disease amongst the poor was largely caused by damp, filth, and overcrowded living conditions. His report was not favourably received by the Conservative government of the time, a harbinger of the recurrent tension between academic research and policy making on socioeconomic inequalities in health. After the election of the Whigs in 1847, Parliament passed the 1848 Public Health Act implementing many of the recommendations made by Chadwick. These included establishing and improving water supplies, sewage systems, and refuse collection.

A long period of sustained economic growth followed resulting in dramatic improvements in the determinants of health. These improvements, coupled with further developments in public health, resulted in what has been termed the 'epidemiological transition'.[15] Previously large numbers of people were dying at young ages from infectious diseases. As a result of the 'epidemiological transition' life expectancy increased rapidly, and instead people were dying much later in life of chronic diseases such as cardiovascular disease and cancers. Despite these huge strides in improving population health, socioeconomic gaps in health persisted.[16]

One explanation for the continued socioeconomic inequality in health, despite the 'epidemiological transition', was that the poor still had little if any access to health care when they got sick. Disease was identified as one of the five 'Giant Evils' in the seminal Beveridge report of 1942.[17] The report's recommendations were felt to be too costly to implement by the Conservative government in power at the time it was published. The opposition Labour Party on the other hand enthusiastically embraced the report. This appeared to chime with post-war public opinion, and resulted in them winning a landslide victory in the 1945 elections. The scale of their election victory gave them a strong mandate to pursue the ideas proposed by Beveridge. In doing so the English welfare state was built. One of the most ambitious goals of this welfare state was the establishment of the National Health Service (NHS), achieved in 1948. This provided universal health care free at the point of delivery — for the first time giving the poor access to health care.

When the NHS was established in 1948 there was no explicit principle that governed how NHS resources should be geographically allocated. Resource allocation in the NHS therefore naturally followed — and so perpetuated — the

existing geographically uneven distribution of government resources. This allocation was skewed towards London and the South East — the most prosperous parts of the country. By the 1970s it was becoming apparent that richer geographical areas were benefiting more from the NHS than poorer areas, despite having less need for health care among their populations. This was famously described as the 'inverse care law' in a study by Julian Tudor Hart, published in 1971.[18]

From 1971 to 1975, NHS resource allocation began to move towards a more formal approach with the adoption of the 'Crossman Formula'. This formula took into consideration population size and composition. In 1976 the Resource Allocation Working Party (RAWP) made its first set of recommendations on how to allocate NHS funds to regions. The RAWP formula was based on the principle of 'equal opportunity of access to health care for people at equal risk'. To estimate these allocations the RAWP formula weighted the population size and composition of areas according to their health care needs, as measured by the standardised mortality ratio. This formula directly informed NHS resource allocation between 1976 and 1995, and its 'weighted capitation' principles have underpinned all subsequent funding formulae in the NHS. The key developments in the post-RAWP formulae were in the ways in which they captured health care needs more accurately as more detailed data sets and sophisticated statistical methods became available.[19]

Ideas of 'health care for all' and tackling social gradients in health were also gaining international traction during this period, as exemplified by the World Health Organisation's (WHO) declaration following the Alma-Ata conference on primary health care in 1978.[20] It was in this context that the ruling Labour government commissioned Sir Douglas Black, then Chief Scientist at the Department of Health and Social Security (DHSS), to undertake an independent inquiry into health inequalities. The resulting 'Black Report', published in 1980, found that there were large and pervasive inequalities in health across the population.[21] Furthermore, it found that these inequalities had widened rather than narrowed since the introduction of the NHS. There had been a change in government between the time that the report was commissioned, and when it was finally published. The incoming Conservative government led by Margaret

Thatcher did not acknowledge the findings of, or embrace the recommendations of, the report.[22]

Following the 'Black Report' the Health Education Council (HEC), an independent body funded by the DHSS, commissioned Dame Margaret Whitehead to update the analysis in the report using the most recently available data. This update was published as 'The Health Divide' in 1987 — reinforcing the findings and recommendations of the 'Black Report'.[23] This new report received a similarly frosty reception to that received by the 'Black Report' with the press conference organised to announce its launch being cancelled at the last minute. Few if any of the recommendations of these reports were adopted by the government at the time.

In 1997 a Labour government was elected on the back of a socially progressive political agenda. One of the first acts of this new government was to commission Sir Donald Acheson, former Chief Medical Officer (CMO), to conduct an independent inquiry into health inequalities. The 'Acheson Report' was published in 1998.[24] For the first time for a report of this kind, it was received by a sympathetic government. The report again confirmed the findings of the 'Black Report', and made a number of recommendations for inter-departmental actions to tackle the social determinants of ill-health.

In response to the 'Acheson Report' the government launched an ambitious and well-funded raft of policies to tackle socioeconomic inequalities in health. These included the 'Sure Start' programme to provide early learning opportunities for children living in poverty; the creation of 'Health Action Zones' where local strategies to improve health in deprived areas were implemented; the introduction of a national minimum wage; and a 'New Deal' to help the young and the long term unemployed into work. Alongside these, a number of more general investments were made in housing, education, urban regeneration, and healthcare.[25,26] 'Spearhead' local authority areas were identified as the areas of the country with the worst health and deprivation, and explicit targets were set to close the gap between these areas and the rest of the country.[27]

The National Institute for Clinical Excellence (NICE) was created in 1999. Part of its remit was to introduce the use of rigorous economic evaluation to decide which treatments the NHS should pay for, thus ending the 'postcode lottery' in drug

prescribing in primary care. NICE also worked to establish clinical best practice guidelines to ensure uniform standards of care across the health service. These functions were in part seen as a way to stop those better able to navigate the system getting better care in the NHS.[28] NICE merged with the Health Development Agency in 2005 to become the National Institute for Health and Clinical Excellence — taking on additional public health responsibilities. Its remit was further widened following the Health and Social Care Act (2012)[29] to include social care, and it was again renamed, this time as the National Institute for Health and Care Excellence.

A host of measures were also introduced to strengthen primary care including: the 'Quality and Outcomes Framework' (QOF) in 2004, a pay for performance programme to improve the quality of care provided by General Practitioners (GPs); and the 'Equitable Access to Primary Medical Care' programme of investment, in which £250 million was invested to increase the number of GPs in under-doctored areas between 2008 and 2012.

Despite this comprehensive and sustained assault on socioeconomic inequalities in health, by the end of the thirteen years of Labour government in 2010, their attempts at tackling inequalities were widely considered to have failed.[30,31] It was not that the policies implemented did not improve the health of the poor, rather it was that during the same period the health of the rich improved too. In fact income inequality widened over this period, and the health of the rich improved even faster than the health of the poor, thus health inequality failed to improve. Reflections on the failure of these strategies have concluded that at the time they were launched there was a wealth of research describing and explaining socioeconomic inequality in health, however, there was little evidence available on effective strategies to tackle health inequality, and still less evidence on the cost-effectiveness of such strategies.[32,33] Furthermore, it became increasingly accepted in the academic literature that action on health inequality could only succeed in conjunction with action on income inequality.[34–38] This did not appear to be a priority for the government of the time, and indeed one of the leading figures in this administration, Peter Mandelson, was notorious for his comment about being "intensely relaxed about people getting filthy rich as long as they pay their taxes".[39]

The 'Marmot Review' was published in 2010 as the final action on health inequalities by the outgoing Labour government.[40] The review confirmed that substantial health inequalities remained, and it proposed a wide programme of actions to tackle the social determinants of health. With the change of government in 2010, and the onset of the programme of austerity measures, the recommendations of the 'Marmot Review' were not as enthusiastically embraced as those of the 'Acheson Report' that preceded it.

The idea that in order to tackle socioeconomic inequality in health it is crucial to tackle the social determinants of health, 'the causes of the causes',[41] has been at the core of each of the landmark reports commissioned by the government over the years. Furthermore, the recommendations made by each of these landmark reports have shown an appreciation for the distinction between 'upstream' structural population wide strategies that have the potential to reduce socioeconomic inequality in health,[42,43] as compared to 'downstream' agentic strategies — requiring behaviour change — that are likely to increase health inequality.[44,45]

Most recently, government public health strategy has largely side-stepped making the significant structural interventions that have been advocated by the academic and clinical public health communities. Key examples include government responses to academics' recommendations on alcohol minimum pricing,[46,47] and childhood obesity.[48] Instead, the government has focused on voluntary agreements with industry partners,[49] and recommendations targeted at individuals to take responsibility for their own health.[50,51]

Socioeconomic inequalities in health

Ever since the publication of the 'Black Report' in 1980,[21] it has been widely recognised that socioeconomic inequalities in England have been associated with steep social gradients in both mortality and morbidity. These findings have been repeatedly confirmed, and health inequalities have been shown to persist through time as described in the several landmark studies that followed. The most recent of these, the 'Marmot Review'[40], found using data from 1999 to 2003, a gap in life expectancy of 7 years between the most and least deprived areas in the country, and an even larger gap of 17 years in disability free life expectancy between these areas. More recent research estimating the social distribution of health in

England[52] found that the gap in terms of quality adjusted life expectancy in 2012, between people living in the most deprived fifth and least deprived fifth of neighbourhoods in the country, to be 12 quality adjusted life years (QALYs). There are not only gaps between the richest and poorest groups in society, but there is also a consistent socioeconomic gradient in health across the population. In other words, every increase in socioeconomic deprivation, corresponds to a reduction in life expectancy and an increase in morbidity.

The founding principles of the English NHS,[53] and more recently the NHS constitution,[54] clearly state that health care should be allocated solely in accordance with clinical need, and not correspond to the ability to pay for care. Given this, we would expect the stark differences in the relative health of the different socioeconomic groups described in these landmark studies to feed through to similar differences in the level of health care use by these groups — in other words, we would expect poorer people to use more health care because they are sicker. There have been numerous studies that have confirmed that such social gradients both in morbidity and in overall use of the health service are observed in practice. These studies are summarised in the reviews by Goddard and Smith in 2001,[55] Dixon et al in 2007[56] and Cookson et al in 2016.[57] What has been lacking in the literature, however, is a rigorous translation of these socioeconomic inequalities in health care use into an estimation of the financial burden that they exact on the NHS.

Paper 1[1] of this thesis explored the financial cost to the NHS of the excess morbidity associated with socioeconomic inequality. It examined the extent to which the financial costs associated with the social gradient in the use of hospital care in any given year, were offset by the social gradient in life expectancy, when these costs were aggregated over patients' expected lifetimes.

The paper looked at the costs to the NHS of patients admitted to hospital in the financial year 2011/12. These costs totalled £22 billion, accounting for approximately one fifth of the total NHS budget for that year. Patients were attributed to deprivation groups based on the Index of Multiple Deprivation (IMD 2010) of the neighbourhood (lower layer super output area) in which they lived. A steep social gradient was observed in hospital admission rates at any given age — with those living in more deprived areas being admitted to hospital more

frequently. The gradient for the more serious emergency admissions was found to be much steeper than that for the typically better planned elective admissions. The paper explored what the impact on hospital use would have been, if people who lived in all the more deprived neighbourhoods, had had similar rates of hospital admissions to those who lived in just the most affluent fifth of neighbourhoods in the country. In such a scenario, after adjusting for differences in age and sex, the cost to the NHS for that year would have been reduced by £4.8 billion. Furthermore, the paper used differences in mortality rates at neighbourhood level, to project hospital costs over patients' lifetimes. It found that expected cumulative lifetime hospital costs increased with deprivation, despite longevity decreasing with deprivation.

Not all hospital episodes contained enough detail to both allocate costs to them and to attribute them to deprivation levels. Of the almost 19 million hospital episodes recorded for patients admitted in 2011/12 approximately 9% were excluded from the analysis. For the purposes of the paper it was assumed that these missing hospital episodes were equally distributed across the deprivation quintiles and so costs for each quintile were inflated by approximately 9% to account for these missing data. In the supplementary appendices for the paper there is a detailed breakdown of this missing data. From this appendix we can see that for those excluded hospital episodes where deprivation information was available — comprising approximately half of all excluded hospital episodes — these excluded episodes were marginally more prevalent amongst those patients living in the most affluent areas. The implication being that should all excluded episodes have been similarly distributed our interpolation will have over-inflated costs in patients from the more deprived areas and under-inflated costs in patients from the more affluent areas and hence this may have biased the estimated cost of inequality in our analysis upwards.

Inpatient hospital care accounted for approximately a fifth of the total hospital budget in 2011/12. If similar trends were also present in the rest of the NHS, for example in primary care and specialist visits (some evidence of which can be found in the supplementary materials for the paper), then the actual total cost to the NHS associated with socioeconomic inequality in that year alone would have been in the order of £20 billion — a fifth of the total NHS budget. Furthermore, the literature

suggests that poorer people tend to under-use many types of health care relative to their level of need/morbidity. This implies that if anything, the NHS would have to spend even more than this amount in order to tackle unmet health care needs in socioeconomically disadvantaged communities.[18,58]

This study confirmed the strong association between deprivation and ill health as evidenced by patterns of health care use and mortality. Additionally, it has for the first time rigorously translated these in terms of the financial costs that they impose on the NHS. The study looked at both cross-sectional and lifetime costs. It found that healthier people cost less to the publically funded health care system over their lifetimes than less healthy people, despite living longer. The implication of this finding is that, should ill-health associated with socioeconomic inequality be reduced, then this could result in both short term and lifetime savings in terms of health care costs to the NHS.

The results give a sense of the size of potential government investment in tackling socioeconomic inequality that, if effective, may actually be cost saving for the public sector as a whole. This is particularly relevant at a time when the NHS budget is being squeezed.[59] To evaluate the financial consequences of tackling socioeconomic inequality, non-NHS financial impacts on the public sector must also be accounted for. Emerging studies on the wider impacts of reducing socioeconomic inequality support such interventions, demonstrating net positive financial impacts of reducing socioeconomic inequality across the public sector.[60]

There is a well-established causal relationship between socioeconomic inequality and health.[61] Furthermore, while the causal pathways involved are complex, the direction of causality has been shown to run predominantly from improvements in socioeconomic conditions to improvements in health.[62] Given these relationships, there is ample motivation to identify interventions to tackle socioeconomic inequalities, and evaluate them in terms of their cost-effectiveness and distributional impacts. In doing so, it is necessary to take into account the magnitude and distributions of financial and non-financial costs, opportunity costs, and benefits, across the public sector. The methods described in **papers 4 and 5**,[4,5] discussed later in this chapter, demonstrate how such evaluations can be conducted in the context of the NHS.

This study looked at hospital admissions in 2011/12; i.e. those that occurred directly following the most recent change of government. Since then the government has introduced a programme of austerity measures that have reduced public spending targeted towards some of the most vulnerable people in the country. The United Nation's Committee on Economic, Social and Cultural Rights has expressed concerns about the regressive nature of these measures. In their '6th Periodic Report on the United Kingdom' published in 2014, they note the:[63]

> *"considerable and often cumulative effects on social security, access to justice, education and healthcare, especially for vulnerable and marginalized groups, such as women, children, persons with disabilities, ethnic minorities and migrants."*

As these austerity measures start to take effect they will likely result in a widening of the underlying socioeconomic inequalities in society.[64] Hence, if the causal relationships described here hold, we will likely see a steepening of the observed social gradient in costs to the NHS. In simple terms, the reduction in government expenditure directed at the most vulnerable in society, will feedback through the deterioration of population health, to result in increased health care related costs to the NHS. These unfortunate circumstances, combined with imaginative research study design, may present further opportunities to tease out the causal relationships between changes in socioeconomic inequality and health, or at least health care use.[65,66]

It is noteworthy that private spending on health care not funded by the NHS accounts for approximately 20% of total spending on health care, with this proportion remaining stable between 2000 and 2015.[67] Data is not available about the distribution of the consumption of private health care nor about the proportion of this consumption comprising inpatient hospital admissions. However, if we assume consumption of private inpatient hospital care is skewed towards the more affluent sections of the population, the substitution of NHS funded care for private care may account for part of the observed social gradient in NHS hospital expenditure that we observed in our study.

Socioeconomic inequalities in supply of health care

The declaration made by the World Health Organisation, following the international conference on primary health care in Alma-Atta in 1978,[20] is widely recognised as bringing to the fore the ideas of 'health care for all' and — its most recent incarnation — the 'universal health coverage' movement.[68,69] Fundamental to these movements is the idea that universal access to primary health care, regardless of socioeconomic position, is a basic right and a necessary pre-requisite to tackling health inequality.

The scale of the financial impact of socioeconomic inequalities on the NHS found in **paper 1**[1] illustrate that substantial socioeconomic inequalities in health in England remain, despite the NHS' founding principles to provide health care for all. To a large extent these may be attributable to inequalities in the wider social determinants of health. However, there is value in ensuring that the NHS is doing all it can to ameliorate these health inequalities, and is not exacerbating these inequalities in any way. To this end the Health and Social Care Act (2012) stipulates:[70]

> *'In exercising functions in relation to the health service, the Secretary of State must have regard to the need to reduce inequalities between the people of England with respect to the benefits that they can obtain from the health service.'*

This thesis begins to explore the NHS' role in contributing to health inequalities by examining socioeconomic inequalities in the supply of health care. Primary care is at the heart of keeping people healthy. In the English NHS general practitioners (GPs) play the crucial role of managing patients with chronic conditions, engaging patients in preventative health care initiatives, and planning and coordinating elective hospital procedures as and when patients need them. Having an adequate supply of GPs is a critical prerequisite to ensuring adequate access to primary care which in turn in essential for the effective management of ill health. Hence, any socioeconomic inequalities in the supply of primary care constitute the first step in the patient pathway in which the NHS can have an impact on socioeconomic inequalities in health.

Previous studies have found substantial and persistent variations in the concentration of GPs across large administrative geographies. These studies did

not explicitly link the variations they found to socioeconomic inequalities.[71,72] However, the potential social gradient in GP supply had been noted by policy makers. Expanding primary care provision in under-doctored areas was highlighted as a key challenge in tackling health inequality in the 2006 Department of Health White Paper 'Our Health, Our Care, Our Say'.[73] This led to the subsequent roll out of the 'Equitable Access to Primary Medical Care' programme, where £250 million was invested in opening new GP practices in under-doctored areas between 2008 and 2012.[74] Prior to our work, the most recent previous study in this area used data up until 2008.[71] There had not been any studies examining how the socioeconomic distribution of access to GPs had changed over the key period since 2008, a period during which significant investments in addressing supply issues in primary care were made.

Paper 2[2] looked at the socioeconomic distribution of GPs in England between 2004/05 and 2013/14. The paper examined how the socioeconomic inequalities in the geographical distribution of GPs responded to the increasing government attention to inequalities in access to primary care.

The paper found substantial inequalities in the distribution of GPs at the beginning of the study period. In 2004/2005 the most socioeconomically deprived fifth of neighbourhoods had approximately 4 fewer GPs per 100 000 of population (adjusted for need) than the most affluent fifth of neighbourhoods. By 2013/2014 this socioeconomic gradient in GP supply appeared to have been eliminated. The number of full time equivalent GPs per 100 000 population serving the most socioeconomically deprived fifth of neighbourhoods increased over this period from 54 to 60. A smaller increase, from 57 to 60 GPs per 100 000 population, was observed over the same period in the most affluent fifth of neighbourhoods in the country. The increase in GP supply in the most deprived fifth of neighbourhoods was larger in areas that received targeted investment for establishing new practices under the 'Equitable Access to Primary Medical Care' programme than in similar areas that did not receive this funding.

This paper brought the existing literature up to date by including the latest data on GP supply. It also extended the existing literature by explicitly focusing on socioeconomic variations in GP supply. It did this by first attributing GP supply to neighbourhood level. It then used this to describe the trends in the relationship

between the level of socioeconomic deprivation of neighbourhoods and their level of GP supply. The study found that the targeted government policy to open new GP practices in under-doctored areas reduced inequalities of access to primary care. This demonstrates that sustained policy commitment to clearly defined and measurable objectives can be effective in addressing socioeconomic inequalities.

It was observed that socioeconomic inequality in GP supply had been eliminated by the end of the study period. This finding was contingent on the adjustment for the differing needs for primary care being adequately reflected in the standard need adjustment formulae.[75] A key driver of the need for health care is having one or more chronic conditions.[76] There are clearly observed socioeconomic gradients in rates of multi-morbidity amongst the population.[77–79] Existing need adjustment formulae do not explicitly account for multi-morbidity and hence are likely to be underestimating need in socioeconomically deprived populations.

The Carr-Hill need adjustment formula, used by the NHS to adjust for need in primary care and applied in this study, estimates that in 2013/14 the need for primary care was 3.8% higher for those people in the most deprived fifth of the population as compared to those in the most affluent fifth of the population (see the supplementary appendices of this paper for detailed exploration of the various need adjustment formulae used by the NHS). Data from the NHS Quality and Outcomes Framework attributed to deprivation quintiles indicate that in 2011/12 prevalence of cardiovascular disease, severe mental illness and diabetes were 71%, 67% and 28% higher respectively in the most deprived fifth of the population as compared to their prevalence in the most affluent fifth of the population.[80] These figures suggest that the current need adjustment formulae may be dramatically underestimating the social gradient in need for primary care.

Further research is required to improve current need adjustment formulae to reflect patterns of need for health care more accurately, particularly in relation to multi-morbidity and socioeconomic deprivation.

Socioeconomic inequalities in health outcomes attributable to health care

In 2003 the UK government made tackling socioeconomic inequalities in health a priority for the NHS in England. It embarked on a sustained programme of investment in the health service, and set explicit national inequality targets for key health indicators such as life expectancy and infant mortality.[27] As part of this investment flagship programmes were launched to strengthen primary care, including the world's largest primary care pay for performance programme.[81] Much of what is required to improve performance on indicators such as those targeted is however, outside the scope of the NHS. Hence, even where these interventions were successful in reducing inequalities in the quality and delivery of primary care,[82] the government's broad health outcome based inequality indicators failed to improve.[83,84]

In order to hold the NHS accountable for inequalities in health, the health outcomes selected to measure inequality performance against must be those over which the health service has some direct influence. One such outcome is the rate of emergency hospitalisation for chronic ambulatory care sensitive conditions.[85] This captures hospitalisations for conditions such as asthma and diabetes. Such hospitalisations can largely be avoided if the conditions are managed properly in primary care. For these conditions there is evidence demonstrating that the investments made in primary care described above did lead to improvements for the average patient.[86] However, substantial socioeconomic inequalities between patients in these hospitalisation rates stubbornly persisted.[87] Another important outcome that the NHS could and should be held accountable for is premature mortality from conditions amenable to health care.[88] These also improved on average following the investments in the health service, with some evidence suggesting that even the socioeconomic gradient in such deaths began to flatten.[89]

There has been research looking at how some of these outcomes responded during this period in which the NHS invested heavily to tackle socioeconomic inequality in health.[87,89] However, prior to our work in this area, there has not been work to describe what happened in terms of socioeconomic inequality across the patient pathway in a unified framework. Such an approach is useful when evaluating what may or may not have worked to reduce inequality.

Paper 3[3] of the thesis examined the evolution of socioeconomic inequalities in the supply of primary care, quality of primary care, emergency hospitalisations for chronic ambulatory care sensitive conditions and mortality amenable to health care. It constructed indicators at these four points in the patient pathway, and tracked the trends in these indicators between 2004/2005 and 2011/2012. The study found that socioeconomic inequalities in supply and quality of primary care were more or less eliminated over the study period. However, only modest improvements were observed in both the levels and the socioeconomic distribution of the emergency hospitalisation and mortality outcomes. By the final year of the study period socioeconomic inequality was still associated with 158 396 patients experiencing one or more preventable hospitalisations and 37 983 patients dying from causes amenable to health care.

This study was the first of its kind measuring socioeconomic inequality in the NHS by bringing together input, process and outcome indicators in a unified framework. In order to do this all the key national administrative health data sets were assembled and linked. A common methodology was applied across all measures to produce a suite of comparable indicators that could be computed consistently over time at neighbourhood, local, and national levels. Analytic tools were developed with a focus on communicating results in a meaningful and easily interpretable manner to policy makers. Health care inequality indicators based on this work and the wider study within which it was conducted have since been adopted by the NHS as part of the 'CCG Improvement and Assessment Framework'.[90–92]

The study computed deprivation gradients across the four outcomes measured using linear regression methods. In the supplementary appendix to this study we compared the deprivation gradients computed using linear regression with more sophisticated negative binomial models. We found that in some cases the more sophisticated regression models had a marginally better fit to the data resulting in smaller confidence intervals around the estimated deprivation gradients. However, measures of the level of inequality and the trends observed in this inequality over time were almost indistinguishable between the simple and more sophisticated models. Therefore, to make our indicators as easy to compute and interpret as possible and hence maximise the likelihood of them being adopted by the NHS we opted for the simple linear regression based models to present in the main analysis.

The primary care quality outcome used in this study was based on data from the NHS Quality and Outcomes Framework (QOF). QOF data is collected by GP practices and measures the degree of compliance with a set of pre-defined disease specific patient management protocols. GPs receive financial rewards for performing well on the QOF. Given the inherent conflict of interest, with GPs both measuring their own performance and being financially rewarded for good performance on the QOF, some have questioned the reliability of the data and its susceptibility to gaming.[93] One such mechanism that can be exploited for gaming the QOF is excluding patients from the measures, who are deemed by the clinical judgement of their GP, to not be clinically suitable candidates for treatment according to the standard pre-defined protocol. In the supplementary appendices to this study we explore the impact of recalculating our QOF based primary care quality indicator when these excluded patients are re-included. We find that approximately 5% of patients are excluded from the QOF calculations per year, and that whilst this does inflate QOF performance scores we find that these exclusions occur almost uniformly across the deprivation gradient and hence have negligible impact on the levels of or trends in socioeconomic inequality in primary care quality.

The somewhat perplexing conclusion to be drawn from this paper was that eliminating inequalities in primary care access and quality was not sufficient to substantially address inequalities in outcomes amenable to health care. There are a number of hypotheses that can be explored in further research as to why this may have been the case: (a) This study did not control for differences in the prevalence of the underlying conditions or the prevalence of the risk factors leading to the conditions that result in the potentially avoidable emergency hospitalisations and deaths. It may well be the case for example, that the NHS treats each patient with one of these conditions equally regardless of their socioeconomic background. The inequalities that we observe may instead be an artefact of a greater prevalence of these conditions in more deprived populations. Recent studies suggest that while some risk factors such as smoking, blood pressure and cholesterol have improved over time others such as obesity and diabetes have got worse over time. However, these studies have indicated that regardless of these trends there are substantial socioeconomic gradients in all of these risk factors and that these gradients have

persisted or even widened over time.[94–96] This relationship between social gradients in risk factors and health outcomes does not alleviate the NHS of the responsibility to tackle the inequalities in health care outcomes observed. Rather, it locates the responsibility for tackling these inequalities in the setting of clinical priorities and the allocation of resources towards tackling those conditions that are more concentrated in deprived populations. (b) On a related note, it is known that wider social determinants of health, such as the prevalence of unhealthy behaviours, were becoming more unequally distributed over this period.[97] It may have been the case that the primary care strengthening interventions implemented over this period worked to prevent these growing inequalities in unhealthy behaviours feeding through into growing inequalities in health outcomes. (c) It is likely that the need adjustment in the primary care supply indicator was inadequate, and that inequality in fact still remained in GP supply at the end of the study period. Additionally, socioeconomic inequalities in other aspects of NHS delivery that influence health care outcomes, other than GP supply — including GP quality not captured by the quality and outcomes framework (QOF), practice nurse supply and quality, hospital supply and quality, as well as the coordination of care — may also have been driving the socioeconomic inequalities in health outcomes observed. (d) Finally, it is possible that the primary care strengthening measures have not been given sufficient time to work their way through the system, and that the beneficial impacts on outcomes amenable to health care are yet to be reaped.

Whilst this study presented health inequality indicators at a national level, the same indicators can also be computed for local levels of geography, such as at local authority or clinical commissioning group level. These are levels at which local commissioning decisions about public health, primary, and secondary care investment are made. Examining such indicators over time, at local levels, can highlight those local areas performing particularly well at tackling health inequalities as well as those performing particularly badly. This information can then be used, in conjunction with historical information about local level investment decisions, to learn lessons about the kinds of initiatives to encourage and/or avoid when tackling socioeconomic inequalities in health.[92,98] To this end, as an extension of this work, we have developed an interactive tool (accessible at www.ccg-inequalities.co.uk) to allow CCGs to view their performance at

reducing socioeconomic inequalities amenable to health care as measured by the indicators developed in this study. The tool also allows CCGs to compare their performance at tackling socioeconomic inequalities in health with other similar CCGs. Using such indicators for policy evaluation and lesson learning are key areas of further research.

Economic evaluation of interventions tackling socioeconomic inequalities in health

Ever since the establishment of the National Institute for Clinical Excellence (NICE) in 1999, cost-effectiveness analysis (CEA) has played a prominent role in decisions regarding whether or not the NHS should fund new health care interventions. In response to being given this central role, CEA methods for evaluating health technologies have been rigorously formalised and standardised.[99] These methods however, largely focus on what happens on average across the NHS, with only cursory regard to distributional issues.[100]

Methods for evaluating public health interventions, where reducing socioeconomic inequalities in health is often a top level objective alongside improving population health, are less well developed.[101,102] In low and middle income country settings Extended Cost-effectiveness Analysis (ECEA) has recently emerged as a methodology for disaggregating the benefits of health care programmes. This disaggregation by socioeconomic group presents the impacts of health care programmes in terms of both the health gains they deliver and the financial risk protection they provide.[103] This approach provides useful information about socioeconomic inequalities in health, however, it does not suggest a course of action where trade-offs exist between health improvement and health inequality reduction. In addition to this, the applied studies that have followed this approach have not thus far incorporated opportunity costs or their distributions into their analyses.[104–107]

The wider literature on the economics of inequalities, particularly the literature around evaluating income inequalities, uses social welfare functions to evaluate the trade-offs between increasing average income and reducing income inequality.[108–113] Various forms of social welfare function have also been applied to evaluate health distributions,[114–116] and these have been used to underpin approaches such as equity weighting of health gains.[117]

These theoretically grounded social welfare function based approaches have, however, rarely if ever been applied to choose between alternative interventions in a health care context. Instead, ad-hoc multi-criteria decision analysis (MCDA) based approaches, in which various dimensions of the alternative interventions being compared are identified and prioritised by stakeholders, have proved more popular in applied studies.[118,119] This gap in the literature, showing how a social welfare function based approach can be applied in the context of the English NHS, is the focus of the final two papers in the thesis.

Paper 4 and 5 [4,5] show how to extend the mature methods of CEA as used by NICE in the NHS. They do this by using the theoretically grounded social welfare function based approach to incorporate distributional concerns. This enhanced CEA approach was termed distributional cost-effectiveness analysis (DCEA). The studies went on to explore the challenges of operationalising these methods in the NHS using an applied example.

The two papers, paper 4 outlining the methods and paper 5 discussing how to apply them to NHS interventions in detail, used the DCEA methods to compare two alternative approaches to augment an existing NHS cancer screening programme. The first approach resulted in better population health on average but also greater health inequality as compared to the second approach. The DCEA methods were applied to quantify where in the population the health opportunity costs and health benefits of the two alternative approaches fell. Population health distributions associated with each alternative were estimated and standardised to reflect the equity relevant characteristics of the population. These standardised distributions were evaluated in the DCEA framework to resolve the equity-efficiency trade-offs inherent in the NHS choosing one of these approaches over the other. This process was applied iteratively to determine which alternative should be pursued by the NHS under a range of different plausible social value judgements. Alternative social value judgements were made in the selection of equity relevant characteristics used for standardisation, the form of the social welfare function used, and the level of inequality aversion applied within the chosen social welfare function to evaluate equity efficiency trade-offs.

These papers built on the well-established methods of cost-effectiveness analysis as used in health technology assessment by NICE in the NHS. They demonstrated

how these methods could be extended in practice using social welfare analysis, and illustrated how these extended methods could be applied to NHS population health programmes. The methods were found to be particularly relevant for evaluating programmes in which reducing health inequalities was identified as an important objective. The case study demonstrated the application of the proposed methods in the NHS using publicly available data. In so doing, it highlighted the social value judgements needed in order to evaluate the equity-efficiency trade-offs observed.[4]

Many of the methods comprising the DCEA approach including CEA, standardisation for fairness, inequality measurement, and social welfare analysis, have already been extensively explored in the literature. The contribution of these papers was to demonstrate how these various methods can be combined and applied in practice in the context of the NHS. In so doing, these studies have produced the first rigorous applied quantitative economic evaluation of a public health programme in the NHS that accounts for both health improvement and health inequality reduction objectives using methods underpinned by a clear theoretical framework.

The DCEA work has shown that applied social welfare analysis is possible in the NHS. It highlighted the key role played by social value judgements in underpinning the resolution of equity efficiency trade-offs that may arise when reconciling these potentially competing objectives. Further work is required to develop the methods to meaningfully elicit such judgements in the NHS.[120,121]

Other distributional weighting methods, not specifically dealing with socioeconomic inequality, such as the burden of illness based weights in the Department of Health's value based pricing proposals, can also be captured by the general social welfare function based DCEA approach.[122] Burden of illness weights would require a social welfare function that maximises health whilst expressing a level of inequality aversion over remaining quality adjusted life expectancy in the absence of disease. The DCEA framework ensures that the social welfare function is applied to both the direct beneficiaries of the proposed health policy as well as those impacted by the resources consumed to deliver the proposed policy. Using the DCEA framework ensures that the weights used in evaluating policy options are a function of the inequality of interest in the

population and hence are automatically updated as this underlying inequality changes.

The DCEA approach developed in these methodological studies are best suited to evaluate interventions that are large enough in scale so as to have a discernible impact on the population health distribution. Additionally, DCEA methods only provide useful insights over and above traditional CEA methods in situations where decision makers are explicitly concerned about the distribution of health. DCEA in its current form only evaluates interventions from a health sector perspective, that is to say it only considers health sector costs, health sector outcomes and health sector opportunity costs when comparing interventions.

This sole focus on the health sector is the main limitation of the DCEA methods proposed, particularly as distributional economic evaluation is most obviously applicable to evaluate large scale public health programmes. Public health programmes often comprise of complex interventions, funded from a number of different public sector budgets, and have distributional impacts on multiple outcomes, including but not necessarily limited to health. Another important limitation of the approach is that DCEA requires explicit social value judgements to be made. The requirement to make such potentially politically sensitive judgements explicit may be deemed undesirable by some decision makers. Additionally, DCEA evaluations combine context specific social value judgements with context specific population health distributions to arrive at conclusions. This degree of context specific information embedded in the analysis makes it non-trivial to generalise conclusions across different contexts. Finally given that the particular specification of the social welfare function used and social value judgements applied may alter the conclusions reached by the analysis, as with any framework used to make resource allocation decisions, it is vital that robust processes are implemented to hold decision makers accountable for the reasonableness of their decisions.[123–125]

Further research is required to develop methods to extend cost-effectiveness analysis to be able to evaluate interventions where cost and benefits accrue across different parts of the public sector, and to evaluate the resulting inter-sectoral distributional issues.[126–128]

Summary of the thesis as a whole

Undertaking the research that comprises this thesis has given me an appreciation of how national policies can be effective at tackling inequality whilst also providing me with an understanding of the limitations of such policies. This endeavour has allowed me to explore a range methodological approaches and helped me to hone the discipline of distilling the results of complex economic and statistical analysis into concise and rigorous policy relevant conclusions suitable for publication in academic journals.

This integrative chapter began by describing the history of policy to tackle socioeconomic inequality in health in England, paying particular attention to the most recent concerted effort to tackle health inequality in the 2000s. There is a degree of consensus in the academic literature that this effort had limited success, in part due to a lack of evidence on proven strategies to tackle socioeconomic inequalities in health.[32,33]

The overarching aims of the thesis were: to contribute to (a) understanding the impact that socioeconomic inequalities in health have on the NHS; (b) understanding the impact the NHS itself has on socioeconomic inequalities in health; and (c) developing methods that the NHS can use to evaluate and compare proposed policy initiatives to tackle health inequalities.

The first paper in this thesis outlined the scale of the impact of socioeconomic inequality on the NHS. It translated this impact into financial costs, and demonstrated how socioeconomic inequality is exacerbating the financial crisis currently faced by hospitals in the NHS. The analysis indicated that reducing the excess morbidity and mortality associated with socioeconomic inequality would result in both immediate savings and savings over patients' lifetimes accruing to the NHS. If this could be done, the study suggested that the health care cost savings to be reaped due to decreases in morbidity would outweigh the additional health care costs incurred due to the associated increases in longevity. Of course, reducing health inequality is easier said than done, and an effective programme for doing this would likely have costs of its own. However, our findings form the foundation of a compelling financial case for the government to tackle socioeconomic inequalities in general, as well as for the NHS to tackle the impact of health care on socioeconomic inequalities in health specifically.

With this in mind the next two studies looked at the impact of the NHS on socioeconomic inequality in health. A suite of indicators were developed for monitoring inequality performance at key points in the patient pathway in order to quantify the scale of the inequalities that the NHS could plausibly reduce. These indicators were designed to make them easily computable using data available to the NHS, and easily interpretable by and meaningful to NHS policy makers. The studies found that whilst significant progress had been made from 2004/5 to 2011/12 in reducing the social divide in supply and quality of primary care, substantial socioeconomic inequalities in health remained, even when focus was restricted to those health outcomes that the NHS should have had a direct impact on.

The thesis proposed a number of possible hypotheses to explain why socioeconomic inequalities in health care outcomes failed to improve in line with the inequality in supply and quality measures. To investigate these hypotheses further and identify where best to focus resources to reduce these inequalities, a finer grained natural experiment based approach is recommended. Monitoring health care outcome indicators over time, across the country, and comparing inequality performance on these at a local level, will highlight local NHS policies that have and have not worked to reduce health inequalities. Those policies that are observed to work at a local level can then be evaluated in order to explore whether or not they are worthwhile to pursue across the country.

In order to evaluate such policies, the final two studies in the thesis proposed methods to extend the cost-effectiveness analysis methods already widely adopted within the NHS. These methods were extended to explicitly incorporate concern for distributional issues. Using these methods, and a suitable set of social value judgements, policies can be chosen that optimally combine the potentially conflicting goals of maximising health gains while minimising socioeconomic inequalities in health across the population.

The work in this thesis has a number of implications for policy. Firstly it helps with the agenda setting task of highlighting the financial importance of socioeconomic inequalities in health for health care, social care and other public services. Secondly it helps with the quality assurance task of ensuring that health equity is firmly embedded in the performance assessment of health care delivery organisations.

Finally it helps with the priority setting task of designing and implementing 'proportional universal' policies. Some of this potential policy impact is already being realised as demonstrated by the NHS' adoption of the health inequality indicators developed in this work as part of the 'Clinical Commissioning Group Improvement and Assessment Framework'.[91] Various aspects of the work have also featured in the national media.[129,130]

The work in this thesis also has implications for health economics. The first of these is that it provides tools for equity informative quality monitoring of NHS organisations. These can be used routinely when comparing organisations and conducting research to retrospectively evaluate the impact of policy on these organisations. Secondly it provides tools to perform equity informative CEA. Such enhanced CEAs can be performed routinely when prospectively evaluating public health interventions to ensure that health inequality concerns are meaningfully addressed in these analyses.

The work presented in this thesis suggests an exciting programme of further research. Such a programme may include: (1) Extending the scope of the costs of inequality work beyond hospital admissions to also examine the costs of inequality in primary, specialist and social care. (2) Examining the impact of the government's programme of 'austerity' on socioeconomic inequality and using this to infer the causal impacts of changes in inequality on changes in NHS spending. (3) Improving the primary care need adjustment formulae used in the NHS. The formulae currently in use suggest implausibly small social gradients in need for primary care when compared to the social gradients observed in the prevalence of chronic diseases. These formulae need to be updated to better account for multi-morbidity and deprivation. (4) Using the inequality monitoring tools developed in the thesis to identify interesting natural experiments at the local level and then using these natural experiments to evaluate the effectiveness of policies to tackle health inequalities. (5) Extending the DCEA methods to enable them to evaluate the distributional impacts of cross sector interventions having costs and consequences that extend beyond the NHS. This will allow them to be applied to a much broader range of public health interventions.

The historical background section, at the start of this chapter, described how political windows of opportunity for tackling health inequality come and go in

cycles. This thesis provides tools to identify and gather evidence of local policies that are successful in reducing socioeconomic inequalities in health. It also provides methods to evaluate the cost-effectiveness and distributional impacts of such policies once identified. Using these tools and methods, an evidence base can be amassed on policies that the NHS can pursue to successfully tackle socioeconomic inequalities in health. When the next political window of opportunity opens, this evidence base can help the NHS to dent the stubbornly persistent link between socioeconomic conditions and avoidable sickness and premature death.

Appendices

These appendices contain full reproductions of the five papers that this thesis is built around. Each paper is reproduced in its own section and followed by all supplementary materials published alongside the paper.

Appendix A: Paper 1 - The costs of inequality: whole-population modelling study of lifetime inpatient hospital costs in the English National Health Service by level of neighbourhood deprivation

OPEN ACCESS

The costs of inequality: whole-population modelling study of lifetime inpatient hospital costs in the English National Health Service by level of neighbourhood deprivation

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ABSTRACT

Background There are substantial socioeconomic inequalities in both life expectancy and healthcare use in England. In this study, we describe how these two sets of inequalities interact by estimating the social gradient in hospital costs across the life course.

Methods Hospital episode statistics, population and index of multiple deprivation data were combined at lower-layer super output area level to estimate inpatient hospital costs for 2011/2012 by age, sex and deprivation quintile. Survival curves were estimated for each of the deprivation groups and used to estimate expected annual costs and cumulative lifetime costs.

Results A steep social gradient was observed in overall inpatient hospital admissions, with rates ranging from 31 298/100 000 population in the most affluent fifth of areas to 43 385 in the most deprived fifth. This gradient was steeper for emergency than for elective admissions. The total cost associated with this inequality in 2011/2012 was £4.8 billion. A social gradient was also observed in the modelled lifetime costs where the lower life expectancy was not sufficient to outweigh the higher average costs in the more deprived populations. Lifetime costs for women were 14% greater than for men, due to higher costs in the reproductive years and greater life expectancy.

Conclusions Socioeconomic inequalities result in increased morbidity and decreased life expectancy. Interventions to reduce inequality and improve health in more deprived neighbourhoods have the potential to save money for health systems not only within years but across peoples' entire lifetimes, despite increased costs due to longer life expectancies.

INTRODUCTION

Healthcare systems in most high-income countries aspire to provide equitable care, adopting the principle of equal access to services for equal need,[1] even when this is difficult to define and implement in practice.[2] Some, such as the National Health Service (NHS) in England go further, and aim for equal use of healthcare or even equal outcomes.[3] However, health status is powerfully influenced by socioeconomic factors, with lower income associated with greater healthcare needs.[4] So for a system to be equitable it must de-couple use of healthcare services from individual income and contributions towards system costs. This is usually achieved through social insurance schemes, or—as in the case of the English NHS—by funding system costs through progressive income taxation. Through the use of such funding arrangements, healthier people subsidise care for those who fall ill, and more affluent sections of society subsidise the more deprived.

There is a widespread assumption that over the life course such systems disproportionately favour people lower down the socioeconomic scale, in terms of the imbalance between their contribution to the costs of health services and their use of those services.[5] Lower socioeconomic status is associated with lower incomes, and therefore, smaller income tax and social insurance contributions, but also with greater healthcare need, in particular, the earlier development of multiple chronic morbidities.[6 7] However, evidence on actual use of services is more nuanced. More deprived populations tend to make greater use of unplanned (emergency) services than affluent populations, and are slightly more likely to visit the GP,[8] but are less likely to visit a medical specialist or to use many types of planned and preventative services.[9]

Most studies, to date, on the costs and use of healthcare services by different socioeconomic groups have been cross-sectional. This is an important limitation, because morbidity and mortality may have opposing impacts on lifetime healthcare costs—greater morbidity will tend to increase lifetime costs, whereas dying younger will tend to reduce them. After early childhood, average current-year healthcare costs for individuals increase throughout life, rising dramatically from the age of 50.[10] These higher healthcare costs for poorer people in life may be partially offset by a shorter lifespan. Alternatively, given that the rising costs in older age are largely driven by the onset of chronic disease, earlier onset of these diseases in poorer populations may simply shift the healthcare costs to younger age groups.

Consideration of these longitudinal relationships is necessary in order to determine the impact of socioeconomic factors on health system costs. Measuring the size of this impact is important not just to quantify the relative healthcare benefits received by different social groups, but to understand the costs borne by the health service as a consequence of social inequality. In this study, we aimed to measure the costs to the NHS of socioeconomic inequality, by estimating the lifetime inpatient hospital costs of the whole English population by socioeconomic status.

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METHODS

Data

This study focuses on socioeconomic differences in inpatient hospital costs across the life course. Hospital admissions in England are recorded in the Hospital episode statistics (HES) data set used to reimburse hospitals for provided care. This data set contains details on every episode of care, and a new finished consultant episode (FCE) record is created for every new admission, and every time responsibility for the care of a patient passes from one consultant to another. The HES FCE records data about the patient (age, sex, place of residence) and their hospital stay (diagnoses, procedures, length of stay). Using this information the FCE is allocated to a healthcare resource group (HRG), which collates hospital stays that use similar levels of resources—this is the English version of diagnosis related groups used in the USA. Hospitals are reimbursed by the NHS through the payments by results (PbR) system based on the HRG, adjusted for the specifics of the case—for example, a more complicated case with longer than usual length of stay attracts additional reimbursement. Reimbursement is also adjusted for local cost variations (termed 'market forces factors'). Costs attached to each HRG for each year, and variations for more complex cases, are given in the NHS national reference costs.[11] Details of how to derive costs from HES data are available in the PbR documentation,[12] and their use in health economic analysis is discussed in Asaria *et al*.[13] We use HES inpatient data for 2011/2012 and associated reference costs in this study.

The basic geographical unit of analysis in this study is the lower-layer super output area (LSOA). The country is divided into 32 482 LSOAs each containing, on average, 1500 people (range 1000–3000). Population data for 2011/2012 are taken from Office for National Statistics (ONS) midyear population estimates split by LSOA, sex and age (ages 0–84 in single-year estimates, and then 85+). This data estimates the total resident population, including homeless people and people living in institutions. Mortality data for 2011/2012 are taken from the ONS, split by LSOA, sex and age (ages 0–84 in 5-year age bands, and then 85+). Area deprivation for LSOAs is measured using the index of multiple deprivation (IMD) for 2010. The IMD includes seven domains: (1) income; (2) employment; (3) health deprivation and disability; (4) education skills and training; (5) barriers to housing and services; (6) crime; and (7) living environment. These domains are combined to produce an overall deprivation rank for each LSOA. We grouped LSOAs into deprivation quintiles based on this rank ranging from Q1 (the most deprived fifth of LSOAs) to Q5 (the least deprived fifth of LSOAs).

Analysis

We grouped HES inpatient data into age, sex and IMD quintile categories. Of the 18 808 903 episodes in our 2011/2012 HES data set, 1 659 295 episodes (8.8%) could not be grouped due to missing data on either age, sex or LSOA of residence, and were dropped from the analysis. We then calculated the total cost for each age, sex and IMD quintile group using the HRGs and the relevant reference costs. Market forces factors adjustments were not made as we are interested in the variation in resource use by deprivation group rather than local cost variations. We then inflated these costs by 8.8% to account for the missing data (we assumed that missing data were equally distributed across all patient groups and HRGs). Finally, we divided by the population in each age, sex and IMD quintile group using ONS population estimates to estimate average costs for each group:

$$\text{average\_cost}_{\text{age, sex, imd}} = \frac{\sum \text{hospital\_costs}_{\text{age, sex, imd}} \times 1.088}{\sum \text{population}_{\text{age, sex, imd}}}$$

We used these average costs to calculate the total cost associated with inequality in 2011/2012 by comparing the costs as observed in the data with the costs calculated, by assuming that each individual experienced the average costs (split by age and sex) experienced in the least deprived fifth of areas:

$$\begin{aligned}\text{cost\_of\_inequality}_{\text{imd, age, sex}} = \sum [\,&\text{population}_{\text{age, sex, imd}} \\ &\times (\text{average\_cost}_{\text{age, sex, imd}} \\ &- \text{average\_cost}_{\text{age, sex, imd=Q5}})]\end{aligned}$$

Next we used the mortality data to calculate mortality rates by age, sex and IMD quintile group and used these in turn to calculate survival curves for each group:

$$\text{mortality\_rate}_{\text{age, sex, imd}} = \frac{\sum \text{deaths}_{\text{age, sex, imd}}}{\sum \text{population}_{\text{age, sex, imd}}}$$

$$\text{survival}_{\text{age, sex, imd}} = \begin{cases} 1, & \text{age} = 0 \\ \text{survival}_{\text{age}-1,\text{sex,imd}} \times & \\ (1 - \text{mortality\_rate}_{\text{age}-1,\text{sex, imd}}) & \text{age} > 0 \end{cases}$$

We used these survival curves to calculate expected cost at each age split by sex and IMD quintile group by adjusting the average cost for the probability of an individual from each group being alive to incur that cost. Finally, we summed across these age groups to get an expected lifetime cost for an individual in each sex and IMD quintile group (assuming mortality experience and hospital costs remained constant at 2011/2012 level):

$$\begin{aligned}\text{expected\_cost}_{\text{age, sex, imd}} &= \text{survival}_{\text{age, sex, imd}} \\ &\times \text{average\_cost}_{\text{age, sex, imd}}\end{aligned}$$

$$\text{expected\_lifetime\_cost}_{\text{sex,imd}} = \sum^{\text{age}} \text{expected\_cost}_{\text{age, sex, imd}}$$

We repeated this analysis for emergency and elective hospitalisations, and also compared rates of outpatient hospital use among the different groups.

The analysis was performed using Oracle 11g and R 3.2.3—the analysis code is available at https://github.com/miqdadasaria/cost-of-inequality

RESULTS

Social patterning of hospital episodes

In 2011/2012, there were 11 477 435 elective episodes and 7 914 736 emergency episodes to hospitals in England (19 392 171 total episodes). Numbers of episodes decreased between the ages of 0 years and 10 years in both sexes, then, for men, increased up to the age of 70 years, before declining in the oldest age groups, and for women, spiked sharply between adolescence and the age of 40 years —reflecting admissions relating to reproduction—before gradually increasing up to the oldest age groups (figure 1A). For ages 0 years–60 years, there was a clear social gradient in both sexes, with episodes increasing with area deprivation. After the age of 60 years, this trend began to reverse until in the over 75 years age group the most deprived areas had the fewest episodes. The greatest gap between social groups occurred in women during the peak reproductive years.

Figure 1B shows the rate of episodes after adjusting for the different demographic structures of population groups. After

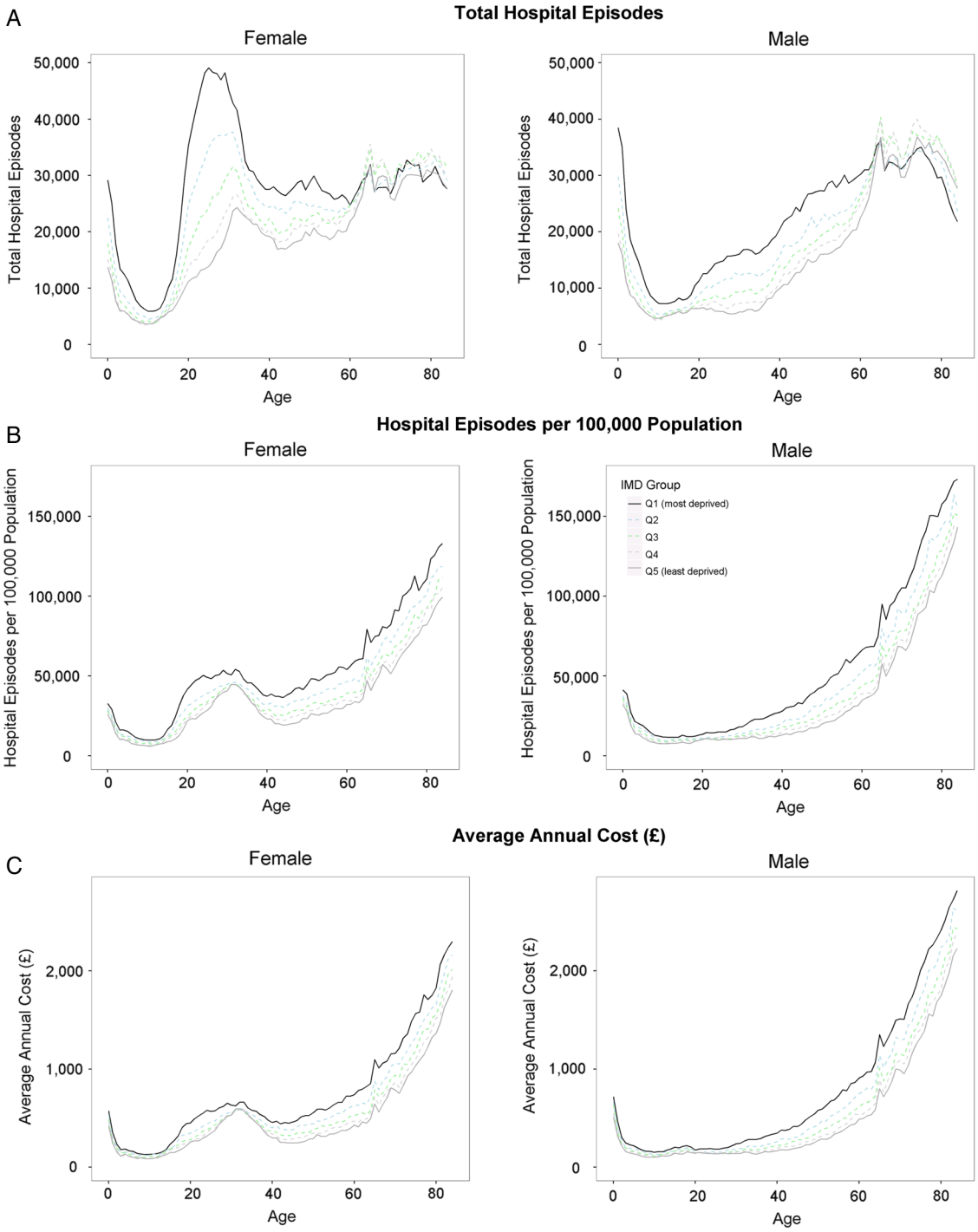

Figure 1 All hospital inpatient admissions split by age, sex and deprivation. Graphs are based on hospital episode statistics for year 2011/2012 and are broken down by sex (female on the left male on the right), deprivation (different line colours) and are plotted against age. (A) Shows the total number of hospital episodes. (B) Shows the hospitalisation rate that is, adjusts for the demographic structure of the population. (C) Translates from hospital episodes to average annual costs due to these hospitalisations.

early childhood, rates of hospital episodes generally increased with age, and were higher in women than in men between the ages of 20 years and 40 years, and higher in men after the age of 70 years. A social gradient was again evident with a higher rate of episodes in more deprived areas, but in the case of episode rates, the gradient persisted across the entire age range. This indicates that the relative fall in the number of episodes for older age groups in more deprived areas was due to a relative decline in population, with fewer people in deprived areas surviving into old age (figure 2A).

The trends for average annual costs per head of population (figure 1C) closely mirrored the patterns for hospital episode rates, suggesting that costs associated with different population groups were primarily driven by volumes of hospital usage rather than differences in types of hospital usage across the life course.

The social gradient in hospital episodes was evident for elective and emergency admissions, but the gaps were greater for emergency admissions (table 1). Compared with residents in the most affluent fifth of areas, residents of the most deprived fifth

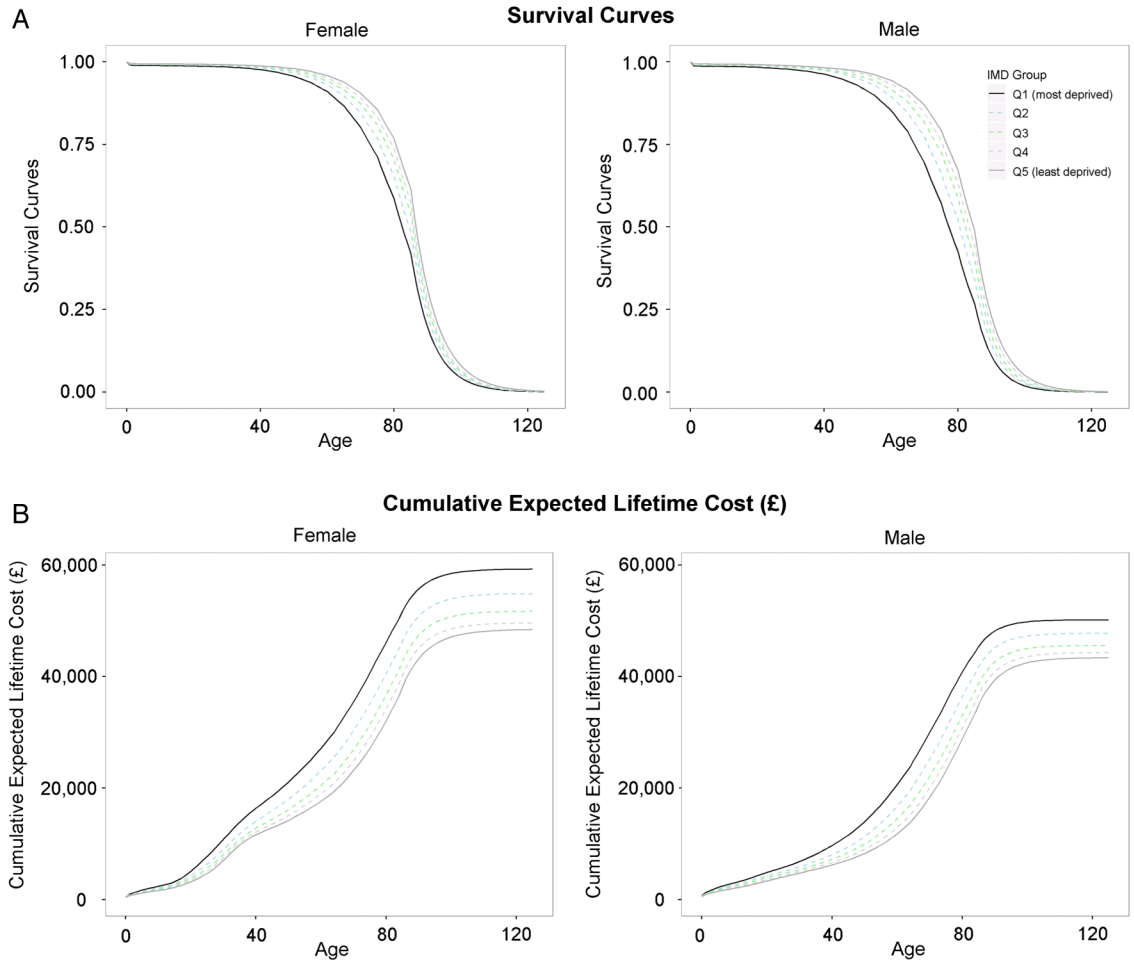

Figure 2 Survival curves and cumulative lifetime costs split by age, sex and deprivation. Graphs are based on mortality data and hospital episode statistics for year 2011/2012, and are broken down by sex (female on the left male on the right), deprivation (different line colours) and are plotted against age. (A) Shows the probability of surviving against age. (B) Shows the cumulative expected hospital costs calculated by adjusting hospital costs by the probability of being alive at any given age and cumulating these adjusted costs over all previous years.

of areas had a 20% higher rate of elective episodes, a 71% higher rate of emergency episodes, and a 39% higher rate of episodes overall. Detailed age, sex and deprivation breakdowns of the different types of admissions are given in the online supplementary appendix figure A1.

The potential savings for the NHS if the costs associated with the age and sex-specific episode rates in the most affluent quintile in 2011/2012 were achieved in the other deprivation groups are given in table 2. The total cost associated with socioeconomic inequality in 2011/2012 was £4.8 billion, and there was a clear social gradient across the entire deprivation

Table 1 Number and rate of hospital episodes by admission type

IMD quintile	Elective		Emergency		All	
	Total	Rate*	Total	Rate*	Total	Rate*
Q1 (most deprived)	2 481 014	23 727	2 055 481	19 658	4 536 495	43 385
Q2	2 355 297	22 338	1 706 833	16 188	4 062 130	38 526
Q3	2 310 208	21 811	1 546 013	14 596	3 856 220	36 408
Q4	2 235 779	21 254	1 390 347	13 217	3 626 126	34 472
Q5 (most affluent)	2 095 137	19 804	1 216 063	11 495	3 311 200	31 298
Overall	11 477 435	21 783	7 914 736	15 021	19 392 171	36 804

This table shows the total numbers and rates of hospital episodes split by type of hospital admission and deprivation group. All data are based on hospital episode statistics for year 2011/2012.
*Rate per 100 000 population.
IMD, index of multiple deprivation.

Table 2 Estimated cost of social inequality

IMD quintile	Female (£)	Male (£)	Total (£)
Q1 (most deprived)	1 127 006 663	1 065 236 932	2 192 243 595
Q2	706 629 004	671 287 893	1 377 916 897
Q3	410 841 645	405 654 922	816 496 567
Q4	198 794 943	19 012 169 9	388 916 642
Q5 (most affluent)*	–	–	–
Overall	2 443 272 255	2 332 301 446	4 775 573 701

This table shows the difference in inpatient hospital costs between those in the most affluent group and each of the other deprivation groups assuming everybody in the other groups would have the same average hospital costs as those in the most affluent groups adjusted for the different demographic profiles of the groups. All data are based on hospital episode statistics for year 2011/2012.
*Comparator group—costs in this group are £2 608 800 295, £2 208 982 887 and £4 817 783 181 for women, men and total, respectively.
IMD, index of multiple deprivation.

spectrum, with the largest cost observed in the most deprived group (£2.2 billion). Costs were broadly similar in men and women.

Estimates of lifetime costs

Survival curves for men and women by deprivation quintile are shown in figure 2A. People who lived in more affluent areas were expected to live longer than those who lived in more deprived areas, and women were expected to live longer than men at any given deprivation level.

Combining data on survival and average costs, we calculated expected costs of hospital admission over the life course for each deprivation group, assuming survival and costs remained constant at 2011/2012 levels. Cumulative lifetime costs are shown in figure 2B. Average lifetime costs for men ranged from £43 358 for the most affluent group to £50 163 for the most deprived, and the respective costs for women ranged from £48 409 to £59 255. Overall, women had 14% higher expected lifetime hospital costs than men, largely due to the increased costs associated with the reproductive years, but also due to their longer life expectancy. Despite having longer life expectancy, people living in the most affluent fifth of areas had lower lifetime hospital costs than those living in more deprived areas.

Analyses for emergency and elective admissions are presented in the online supplementary appendix figures A1 and A2. Results were broadly similar to those for all admissions, but expected cumulative lifetime costs for elective episodes in men converged and were highest for people living in the most affluent fifth of areas. Results for outpatient appointments are also given in the online supplementary appendix figure A3. Very similar trends were apparent to those for inpatient admissions, with outpatient hospital use increasing with greater deprivation level and age, and spiking for women between the ages of 20 years and 40 years.

DISCUSSION

Summary of key findings

In this study, we aimed to quantify the hospital care costs to the NHS of socioeconomic inequality. As expected, we found that hospital admission rates generally increased with age, and were higher in women during the reproductive years and higher in men at most other ages. For all ages, there was a clear socioeconomic gradient, particularly for emergency admissions, with the rate of admissions increasing with neighbourhood deprivation. The costs to the NHS associated with this inequality were partially offset by lower life expectancy in more deprived groups, but remained substantial: £4.8 billion per year at 2011/2012 levels.

Strengths and limitations

This is the first study based on comprehensive whole-population data in England to explore the relationship between lifetime hospital costs to the NHS and socioeconomic inequality. We used data at small-area level to minimise, as far as possible, the risk of ecological fallacy that may have masked inequality at larger and coarser geographical levels. Mortality data were used to extrapolate the results of the analysis across the patient lifetime to allow conclusions to be drawn on both cross-sectional and lifetime costs of inequality to the NHS.

The study is subject to several limitations. First, we did not control for differing need for healthcare among the different groups, and so do not make any judgements on whether the different levels of healthcare use are 'fair' or appropriate, given differences in need. For example, it may be the case that for any given level of morbidity, poorer patients use less healthcare than richer patients, and hence, our estimate of the cost of inequality to the NHS, while representing current practice, underestimates ideal practice where patients receive equal treatment for equal need. Second, the focus of our analysis was inpatient care, but healthcare costs are also incurred through outpatient appointments and in primary care. In 2011/2012, inpatient costs and primary care costs each constituted 22% of the total NHS budget of £101.42 billion.[14] In our supplementary analyses, we found that outpatient healthcare use followed trends similar to those for inpatient use. This suggests that our estimates represent a lower bound on the total cost of inequality to the NHS. Third, our lifetime extrapolation assumes that hospitalisation rates and costs observed in 2011/2012 will remain constant into the future, and that mortality rates in 2011/2012 can be used to predict survival rates in future years. The extrapolation also assumes that deprivation levels are fixed over individuals' lifetimes. While these assumptions may not hold in practice we feel they give a reasonable indication of the relative magnitudes and directions of future trends. Fourth, the underlying population and mortality data breakdowns that we use in this study are truncated at 85 years of age, so mortality and hospitalisation rates for older age groups are assumed to be constant and not to increase further with age. Finally, while we use small-area-level deprivation in our analysis, to fully guard against ecological fallacy, individual-level deprivation data would be required. Such data are not available in a form that can be linked to health data in England. This remaining potential for ecological fallacy is likely to bias our estimate of the costs of inequality downwards.

Comparison with other studies

As far as we know, this is the first published analysis of the inpatient costs of socioeconomic inequality in England. The 2010 Strategic Review of Health Inequalities (the Marmot Review) estimated the cost of inequality to the NHS to be £5.5 billion per year,[4] but the basis for this calculation and the detailed findings were not described. ONS estimated that overall NHS spending in 2011/12 was 25.3% higher for those in the lowest income quintile compared with those in the highest (spending of £1836 and £1465 respectively).[15] However, this is an estimate based only on variation in the age and sex make-up of respondents from neighbourhoods with different levels of deprivation. By contrast, we used comprehensive national data to calculate the actual variation in healthcare costs by area deprivation, and to model lifetime costs. Our approach found that inpatient hospital costs in 2011/2012 were 31% higher for people living in the most deprived quintile of neighbourhoods compared with people living in the least deprived quintile (average annual inpatient hospital costs per resident of £597 and £455, respectively). Forget *et al*[16] modelled lifetime healthcare costs based on the population of Manitoba, finding costs for women were 40% higher than for men. As with our study, this gap between the sexes developed during the peak childbearing years and widened at the end of life. However, while the authors described wide variations in healthcare costs between individuals, the contribution of socioeconomic factors was not assessed. Finally, Hanratty *et al*[17] modelled socioeconomic inequalities in public expenditure on healthcare in the last year of life in Stockholm County Council. They used individual-level income data as their socioeconomic variable and found that after controlling for age, sex, diagnosis group and healthcare utilisation there was substantially greater public expenditure on higher income patients than on lower income patients. This

suggests that if we were able to adjust for need and to use individual-level deprivation data in our analysis, our estimate of the cost of inequality to the NHS would be higher.

Policy/clinical implications

Socioeconomic inequalities in the determinants of health result in both increased morbidity and decreased life expectancy. We found that the substantially higher healthcare costs accrued by residents of deprived areas throughout their lives are only slightly offset by their lower life expectancy. Evidence suggests that even in a country with universal access to healthcare, more affluent groups benefit more,[8 18 19] and healthcare is not entirely equitable. If healthcare provision were to adequately meet need, the cost disparities we describe could be even greater, although better prevention and early intervention could also result in a net reduction in the costs associated with inequality, as has been found in social and educational interventions.[20 21]

Rising healthcare costs in older age are largely driven by the onset of chronic disease, and the earlier onset of these diseases in poorer populations shifts the healthcare costs to younger age groups. Better primary and secondary prevention, progressively weighted towards more deprived populations, is an obvious response, but one that has proved hard to achieve. Anticipatory interventions to tackle the onset of chronic conditions in deprived neighbourhoods can result in significant patient benefit,[22] potentially generating net savings for the health system in any given year, as well as across the lifetimes of these patients. However, while there is scope for health professionals to do more to tackle health inequalities as providers and commissioners,[23 24] the root causes of these inequalities are socioeconomic, and the healthcare system—however, equitable—can only partially alleviate their impact.[25 26] A range of recent national social and health system programmes (eg, Health Action Zones, the Quality and the Outcomes Framework) have been associated with more equitable access to high-quality care,[26 27] and in some cases, with improvements in educational and health outcomes,[28 29] but for the most part inequalities in health outcomes have persisted—or have actually worsened.[30–32]

What is already known on this subject

- Poorer people tend to use more healthcare at any given age, because they are sicker, but also tend to have shorter lives.
- It is not known how these two sets of inequalities interact to produce lifetime healthcare costs for different socioeconomic groups.

What this study adds

- There is a social gradient in both current and lifetime hospital costs. Despite dying at a younger age, people from more deprived neighbourhoods tend to require more healthcare, and cost the National Health Service (NHS) more over their lifetimes than people from more affluent neighbourhoods.
- Socioeconomic inequality cost the NHS in England £4.8 billion in 2011/2012 as a result of excess hospital admissions.
- There is a financial as well as a moral case for tackling socioeconomic inequality: reducing socioeconomic inequalities in health would reduce the excess morbidity of the poor, resulting in longer lives. Our modelling suggests that the reduction in healthcare costs resulting from reducing morbidity among the poor would outweigh the increase in healthcare costs resulting from their increased longevity.

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Contributors MA assembled the data set and performed the analysis. MA and TD drafted the manuscript. All authors were involved in designing the study and revising the manuscript.

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Competing interests RC reports grants from NIHR, during the conduct of the study.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement The code for the analysis and aggregated data that form the basis of the results are available from: https://github.com/miqdadasaria/cost-of-inequality.

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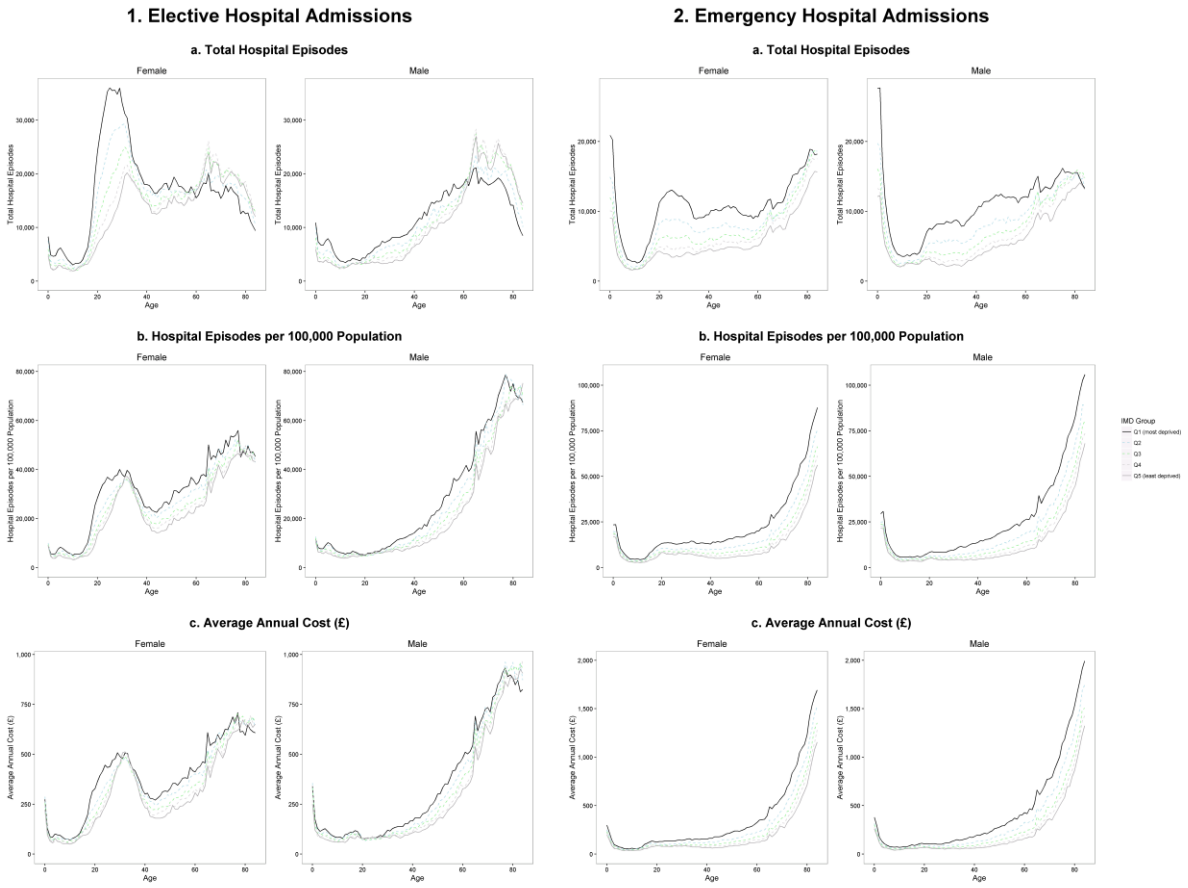
Appendix 1: The costs of inequality: whole-population modelling study of lifetime inpatient hospital costs in the English National Health Service by level of neighbourhood deprivation

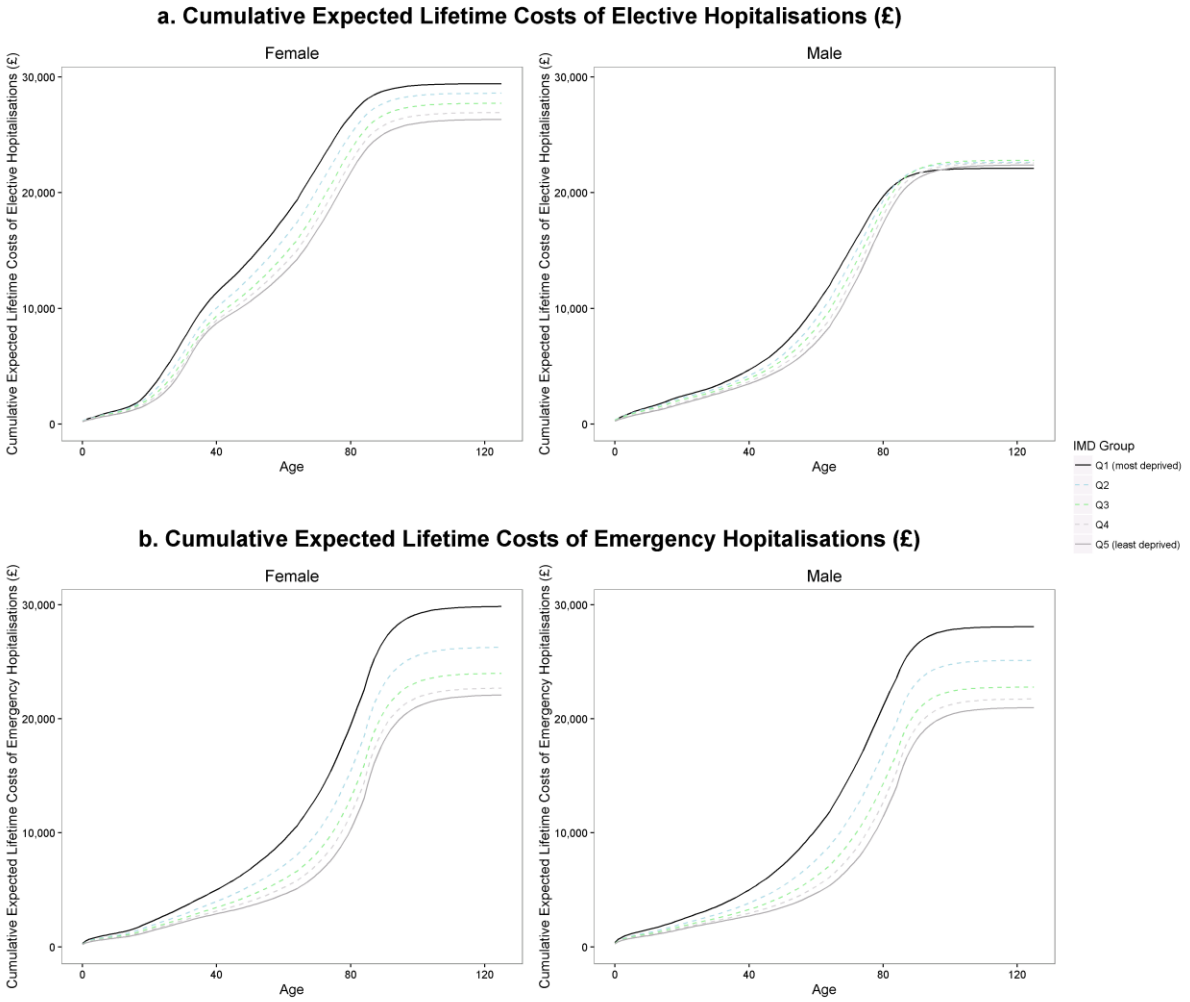
This supplementary appendix provides additional details about the social gradient in hospital utilisation and associated costs in terms of type of inpatient appointments (elective versus emergency) as described in **Figures A1** and **A2** as well as describing the social gradient in use of outpatient care as described in **Figure A3**.

Figure A1: Hospital inpatient admissions split by admission type, age, sex and deprivation



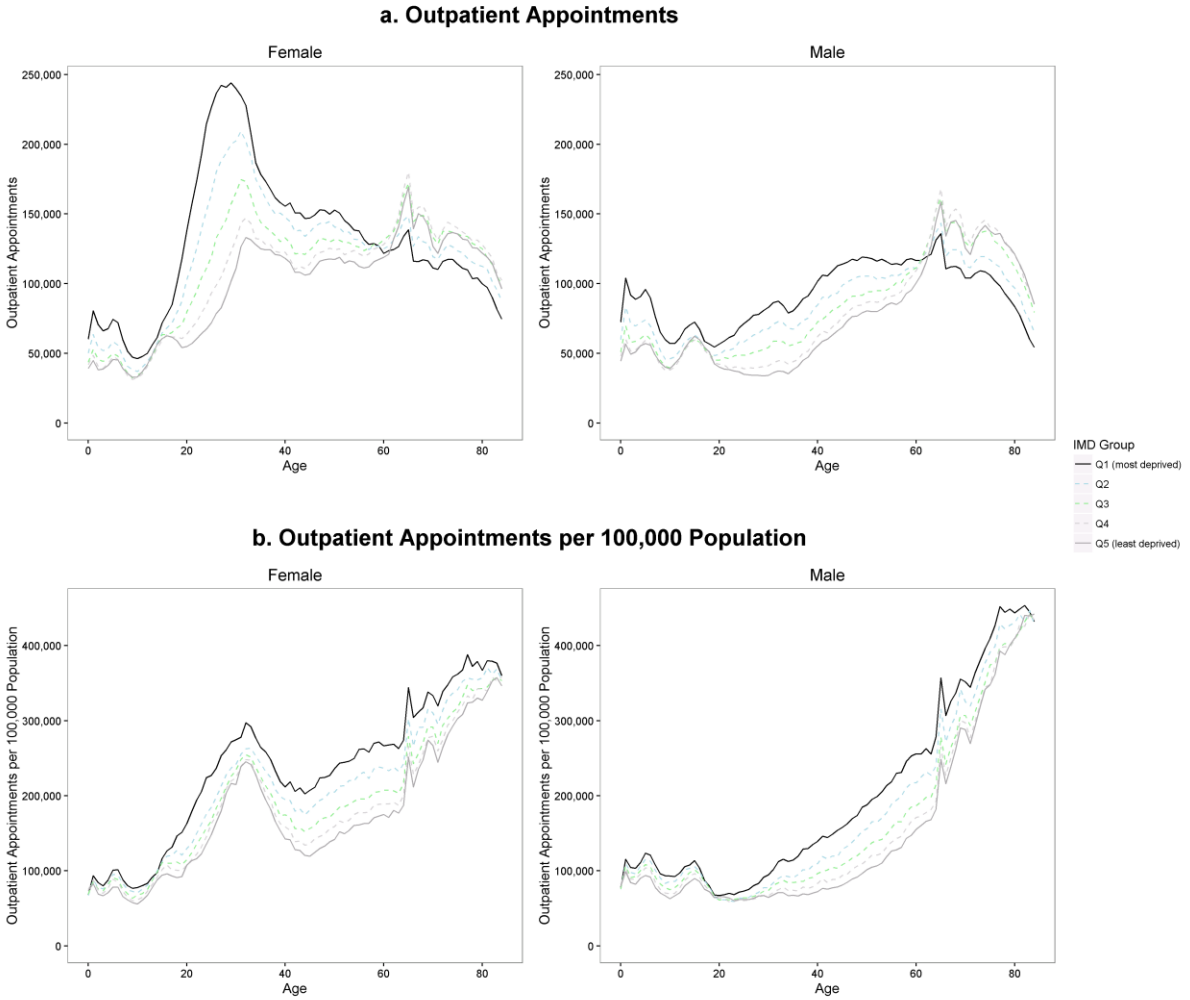
Notes to figure A1: Graphs are based on hospital episode statistics for year 2011/12 and are broken down by admission type (set of graphs on the left show elective admission while those on the right show emergency admissions), sex (female on the left within each admission type and male on the right), deprivation (different line colours) and are plotted against age. **Panel a** shows the total number of hospital episodes. **Panel b** shows the hospitalisation rate i.e. adjusts for the demographic structure of the population. **Panel c** translates from hospital episodes to average annual costs due to these hospitalisation.

Figure A2: Hospital inpatient costs broken down by admission type age, sex and deprivation



Notes to figure A2: Graphs are based on and mortality data and hospital episode statistics for year 2011/12 and are broken down by sex (female on the left male on the right), deprivation (different line colours) and are plotted against age. **Panel a** shows cumulative expected hospital costs due to elective hospital episode and **Panel b** shows the cumulative expected hospital costs due to emergency hospital episodes. These costs are calculated by adjusting hospital costs by survival probabilities and cumulating these adjusted costs over all previous years.

Figure A3: Outpatient appointments split by age, sex and deprivation



Notes to figure A3: Graphs are based on hospital episode statistics for year 2011/12 and are broken down by sex (female on the left male on the right), deprivation (different line colours) and are plotted against age. **Panel a** shows the total number of outpatient appointments. **Panel b** shows the appointment rate i.e. adjusts for the demographic structure of the population.

Appendix 2: Missing data exploration

From the 18 808 903 total episodes in the HES inpatient data set for 2011/12 costs were successfully calculated for 17 147 086 episodes. Of the 165 925 episodes that costs were not calculated for we had deprivation and sex data for just under half of these. For these 775 349 un-costed hospital episodes we compare the deprivation and sex distribution with that of the 17 147 086 costed hospital episodes to determine the plausibility of the assumption we use in our study that the data is missing at random.

Figure A2.1 Summary of missing costed hospital inpatient episodes

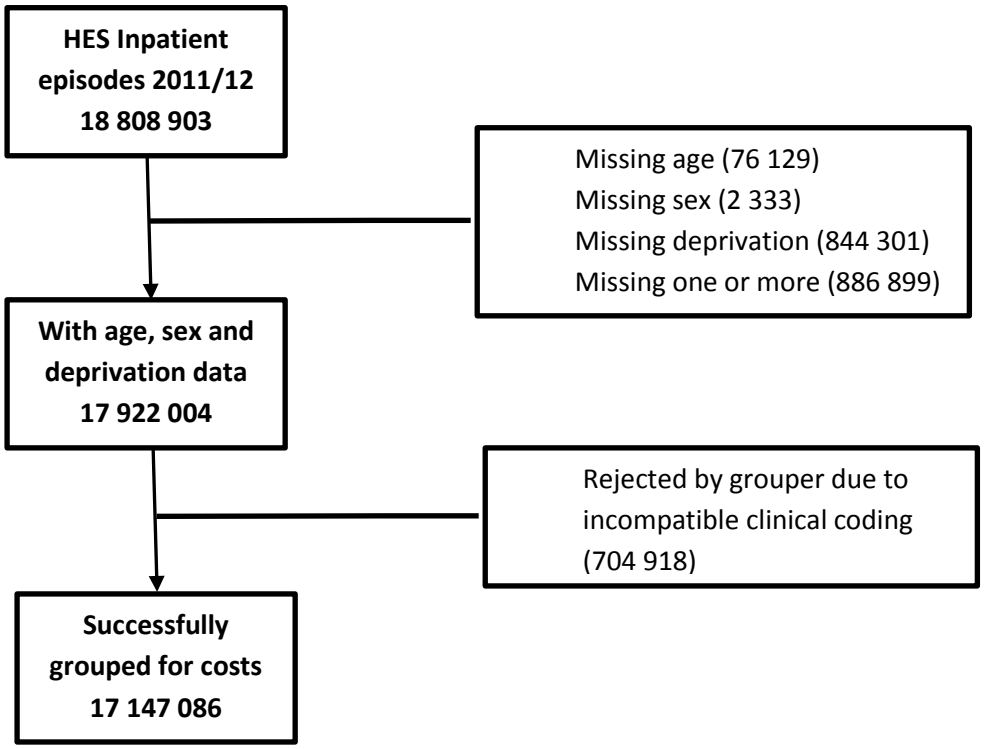


Table A2.1 Missing hospital episodes with sex and deprivation data (N=775 349)

Sex	Index of Multiple Deprivation Quintile					
	Q1 (most deprived)	Q2	Q3	Q4	Q5 (least deprived)	Overall
Female	73 881	85 403	91 695	97 335	90 282	438 596
%	9.5%	11.0%	11.8%	12.6%	11.6%	57.0%
Male	57 586	66 864	69 230	74 501	68 572	336 753
%	7.4%	8.6%	8.9%	9.6%	8.8%	43.0%
Overall	131 467	152 267	160 925	171 836	158 854	775 349
%	16.9%	19.6%	20.7%	22.2%	20.4%	100%

Table A2.2 Non missing hospital episodes (N=17 147 086)

Sex	Index of Multiple Deprivation Quintile					
	Q1 (most deprived)	Q2	Q3	Q4	Q5 (least deprived)	Overall
Female	2 265 302	2 014 667	1 858 579	1 718 387	1 556 750	9 413 685
%	13.2%	11.7%	10.8%	10.0%	9.1%	54.8%
Male	1 795 280	1 591 580	1 544 481	1 458 715	1 343 345	7 733 401
%	10.5%	9.3%	9.0%	8.5%	7.8%	45.1%
Overall	4 060 582	3 606 247	3 403 060	3 177 102	2 900 095	17 147 086
%	23.7%	21.0%	19.8%	18.5%	16.9%	100%

Key points to note from this exploration of the missing data are that for approximately half the missing data for which we have information on sex and deprivation the distribution of missing data is very similar to that of the non-missing data. Looking more closely we see that data is marginally more likely to be missing from less deprived groups than from more deprived groups.

The implication of using the assumption that the data are missing at random and inflating all costs by the proportion of missing data is that should the pattern we observed in the tables above also hold in the other half of the missing data then we will be over inflating costs in the more deprived populations and under inflating costs in the least deprived populations. Should this be the case then our estimate of the cost of inequality will be biased upwards i.e. may be an overestimate.

Appendix B: Paper 2 - Unequal socioeconomic distribution of the primary care workforce: whole-population small area longitudinal study

BMJ Open

Unequal socioeconomic distribution of the primary care workforce: whole-population small area longitudinal study

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ABSTRACT

Objective: To measure changes in socioeconomic inequality in the distribution of family physicians (general practitioners (GPs)) relative to need in England from 2004/2005 to 2013/2014.

Design: Whole-population small area longitudinal data linkage study.

Setting: England from 2004/2005 to 2013/2014.

Participants: 32 482 lower layer super output areas (neighbourhoods of 1500 people on average).

Main outcome measures: Slope index of inequality (SII) between the most and least deprived small areas in annual full-time equivalent GPs (FTE GPs) per 100 000 need adjusted population.

Results: In 2004/2005, inequality in primary care supply as measured by the SII in FTE GPs was 4.2 (95% CI 3.1 to 5.3) GPs per 100 000. By 2013/2014, this SII had fallen to −0.7 (95% CI −2.5 to 1.1) GPs per 100 000. The number of FTE GPs per 100 000 serving the most deprived fifth of small areas increased over this period from 54.0 to 60.5, while increasing from 57.2 to 59.9 in the least deprived fifth, so that by the end of the study period there were more GPs per 100 000 need adjusted population in the most deprived areas than in the least deprived. The increase in GP supply in the most deprived fifth of neighbourhoods was larger in areas that received targeted investment for establishing new practices under the 'Equitable Access to Primary Medical Care'.

Conclusions: There was a substantial reduction in socioeconomic inequality in family physician supply associated with national policy. This policy may not have completely eliminated socioeconomic inequality in family physician supply since existing need adjustment formulae do not fully capture the additional burden of multimorbidity in deprived neighbourhoods. The small area approach introduced in this study can be used routinely to monitor socioeconomic inequality of access to primary care and to indicate workforce shortages in particular neighbourhoods.

Strengths and limitations of this study

- Our study introduces a new small area level method for measuring inequality in general practitioner supply that focuses specifically on socioeconomic inequality and captures inequality within National Health Service (NHS) administrative areas as well as between them.
- The main limitation of this study is the lack of a generally accepted and up-to-date measure of relative need for primary care in deprived small areas.
- Currently, the best available measure is the workload adjustment recommended in the 2007 review of the Carr-Hill formula for allocating primary care funding. However, concerns have been raised that the Carr-Hill formula may not fully reflect the additional needs for primary care in deprived populations.

INTRODUCTION

There is long-standing international policy concern about unequal socioeconomic distribution of the primary care workforce, which can harm population health and contribute to wider socioeconomic inequalities in health.[1–3] As the UK Chair of the Royal College of General Practitioners recently wrote, "The general practice workforce is unevenly spread across the country, with the fewest doctors in the most deprived areas, exacerbating health inequalities".[4] This problem may grow in future, as substantial future primary care workforce shortages are projected over the next two decades in the UK, USA and elsewhere.[4–6] Demand for primary care is increasing due to increasing numbers of people with multiple chronic conditions (multimorbidity), especially in deprived populations,[7–9] and attempts by policymakers to shift care from secondary to primary care settings.[10] Workload is also increasing due to the increasing complexity of care and associated administrative burdens.[11] In England, for example, the Royal College of General Practitioners estimates that 8000 more full-time equivalent (FTE) primary care physicians (general

practitioners (GPs)) will be needed by 2020,[12] while worryingly recent trends indicate a fall in applications for medical training in primary care.[13]

Previous studies have found substantial geographical inequalities in family physician supply between large subnational areas, even in high-income countries with universal health coverage.[14–21] However, because these studies have focused on large areas they have not been able to accurately describe socioeconomic inequality in primary care supply by pinpointing primary care shortages in specific disadvantaged neighbourhoods. Studies in England using data from 1974 to 2006 have found substantial and persistent geographical inequality in GP supply relative to need between National Health Service (NHS) administrative areas—Family Practitioner Committees until 1990, then Family Health Service Authorities until 2000, then Primary Care Trusts (PCTs).[22–26] Historically, these inequalities have been largely impervious to NHS policy initiatives designed to reduce them, such as the deprivation-weighted capitation payments introduced in 1990. There is also evidence that some policies may have increased large area inequality, such as the abolition of entry controls in 'overdoctored' areas in England in 2002.[22]

In the late 2000s following the 2006 White Paper 'Our Health, Our Care, Our Say', a renewed effort was made to increase GP supply in deprived areas as part of wider attempts to meet government targets for reducing health inequality.[24 27–29] Most notably, the 'Equitable Access to Primary Medical Care' (EAPMC) programme that invested £250 million towards establishing new general practices and GP-led heath centres as well as extending opening hours and expanding services in the 38 most 'underdoctored' PCT areas.[28] This programme was announced by a Labour government in the 2006 White Paper, funded from 2008,[28] and wound down from 2011, a year or so after the new Coalition government came to power.[30] Our study aims to measure socioeconomic inequality in GP supply from 2004/2005 to 2013/2014, and to examine whether the EAPMC programme was associated with any beneficial impact on reducing socioeconomic inequality. Our study introduces a new way of measuring inequality in GP supply, based on small area variations, which focuses specifically on socioeconomic inequality. Studies based on large area variations may mask important changing patterns of socioeconomic inequality within administrative areas. Our study examines variation between small area populations of approximately 1500 people, allowing us to capture changing patterns of socioeconomic inequality in much more fine-grained detail than previous studies.

DATA AND METHODS

We constructed whole-population national data sets at both small area level and practice level. Using the NHS Attribution Data Set of GP-registered populations, we linked practice level data on primary care supply for the 10 years, 2004/2005 through 2013/2014, with corresponding small area level data on population and deprivation. We use data from all 9092 general practices in the English NHS that were open for at least 1 year of the study period. Our data on primary care supply were obtained from the annual NHS General and Personal Medical Services workforce census, taken at 30 September each year, midway through the financial year.

In line with previous research studies and official reports, the primary indicator of GP supply reported in this study is the FTE number of GP principals and salaried GPs, who make up the vast majority of the GP workforce.[4 22 23 27 31] We also conducted robustness checks using other GP supply variables, including (1) headcount of GP principals and salaried GPs; (2) GP registrars (trainee doctors on short-term placements having 'supernumerary' contracts, designed primarily for training rather than delivering patient care);[32] and (3) GP retainers (sessional GPs who only work a maximum of four sessions of approximately half a day each week, and only make up a small fraction of the workforce).[33 34] We also conducted robustness checks using the limited available data on practice nurse supply, available at practice level for 2013/2014 but only at PCT level before that. Our data do not include locum GPs or supply of emergency primary care services outside normal office hours.

The small area unit of analysis was the 2001 lower super output area (LSOA)—a geographical unit defined by the 2001 census. There are 32 482 of these small areas in England each with a mean population of approximately 1500 people. Data on the LSOA of residence of each practice-registered patient for each year were used to attribute GP supply from practice level to LSOA level, using population-weighted averages. LSOAs were ranked by deprivation according to their Index of Multiple Deprivation (IMD) 2010 ranks, and split into deprivation quintile and decile groups with equal numbers of LSOAs in each group. Office for National Statistics (ONS) mid-year population estimates at LSOA level were used to derive the population of each deprivation group. We used ONS population estimates because GP practice list data are less thoroughly cleaned and validated and tends to overestimate population size, for example, due to people leaving the area without notifying their GP. LSOA populations were adjusted for their relative needs for primary care using the workload adjustment aspect of the most recently updated version of the Carr-Hill formula for primary care resource allocation.[35] This version of the formula was recommended in 2007 by the Formula Review Group established by NHS employers and the British Medical Association (BMA), and though never implemented in practice it remains the most authoritative and up-to-date analysis of the determinants of primary care workload in England. This adjustment takes into consideration the age and sex structure and IMD health deprivation score of each LSOA to upscale populations that are expected to require more primary care and downscale populations

expected to require less. We report both adjusted and unadjusted results, and also conduct robustness checks using an alternative need formula: the 2013/2014 Nuffield index of general and acute hospital need.[36] As a further robustness check, the analysis was repeated at practice level by reverse attributing LSOA population and deprivation variables to GP practices and aggregating GP supply numbers by population-weighted practices into five approximately equally sized deprivation-based groups. To provide insight into the components of change in GP supply, we also produced descriptive statistics by deprivation group and year on the numbers of practices opening and closing, the average size of GP practices, and the average number of small areas served by each practice as an indication of whether increases in GP supply can be attributed to patients travelling further.

The primary measures of inequality were the slope index of inequality (SII) and relative index of inequality (RII), both based on linear regression analysis at the level of IMD decile group. This involves modelling GP supply as a linear function of deprivation decile, entered as a continuous variable scaled from 0 to 1. The SII is the coefficient in this regression; the RII is that coefficient divided by the mean GP supply. The SII can be interpreted as the modelled difference in the number of FTE GPs per 100 000 population between the most and least deprived small areas (the absolute gap); while the RII can be interpreted as this difference as a proportion of the national average (the proportionate gap). Regression models using pooled data for multiple years were used to test whether observed changes in inequality between years were statistically significant, based on interaction terms between year and deprivation.

To examine associations between change in GP supply inequality and the EAPMC programme, we identified the 38 PCTs that were considered to be 'underdoctored' and hence eligible to receive funding from this programme from a Department of Health press release on the policy.[37] We then compared changes in GP supply by deprivation group of LSOAs within these 'underdoctored' PCTs (which cover a population of approximately 10 million people) with changes in GP supply in deprivation groups of LSOAs within the remaining PCTs (which cover a population of approximately 43 million people), focusing on change between the year the policy was announced, in 2006, and the year the policy was wound down, in 2011.

RESULTS

Total numbers of GPs in England by year are reported in table 1, in terms of both headcount and FTE, along with total population figures. Although the total headcount of GPs continued to increase throughout the period, FTE numbers have been approximately flat since 2009/2010 while the patient population has continued to grow. In England as a whole, GP supply increased from 55.1 to 60.2 FTE GPs per 100 000 population from 2004/2005 to 2006/2007, but remained approximately stable thereafter, rising to 60.7 in 2009/2010 then falling to 59.4 by 2013/2014. Crude trends in total numbers of FTE GPs split by small area level deprivation are shown in figure 1 (these are not adjusted for population change). Total numbers of FTE GPs have grown much faster in the most deprived fifth of English small areas than elsewhere, with GP supply in the most affluent fifth growing at the slowest pace over the past 10 years. This pattern is also reflected in the raw headcount of GPs (see online supplementary appendix figure A4.3).

Figure 2 shows these trends adjusted for population size and need. In England as a whole, GP supply increased relative to population need from 2004/2005 to 2006/2007 but remained approximately stable thereafter. The geographical distribution of this GP supply in relation to the deprivation of the areas served by GPs, however, changed substantially over the study period. In 2004/2005, there was 'prorich' inequality in GP supply relative to need, with 54.0 FTE GPs per 100 000 of need adjusted population in the most deprived fifth of small areas and 57.2 FTE GPs per 100 000 of need

Table 1 Total GP workforce in England from 2004/2015 to 2013/2014*

		GP headcount		GP full-time equivalent	
Year	Total population	Total	Per 100 000 population	Total	Per 100 000 population
2004/2005	50 109 707	30 751	61.37	27 621	55.12
2005/2006	50 466 162	31 924	63.26	28 540	56.55
2006/2007	50 763 893	32 646	64.31	30 557	60.19
2007/2008	51 106 181	32 995	64.56	30 609	59.89
2008/2009	51 464 646	33 911	65.89	30 603	59.46
2009/2010	51 807 127	35 072	67.70	31 422	60.65
2010/2011	52 234 045	36 073	69.06	31 173	59.68
2011/2012	52 690 703	36 628	69.52	31 197	59.21
2012/2013	53 488 001	36 771	68.75	31 418	58.74
2013/2014	53 859 917	36 849	68.42	31 993	59.40

*Excluding GP registrars, retainers and locums.
GP, general practitioner.

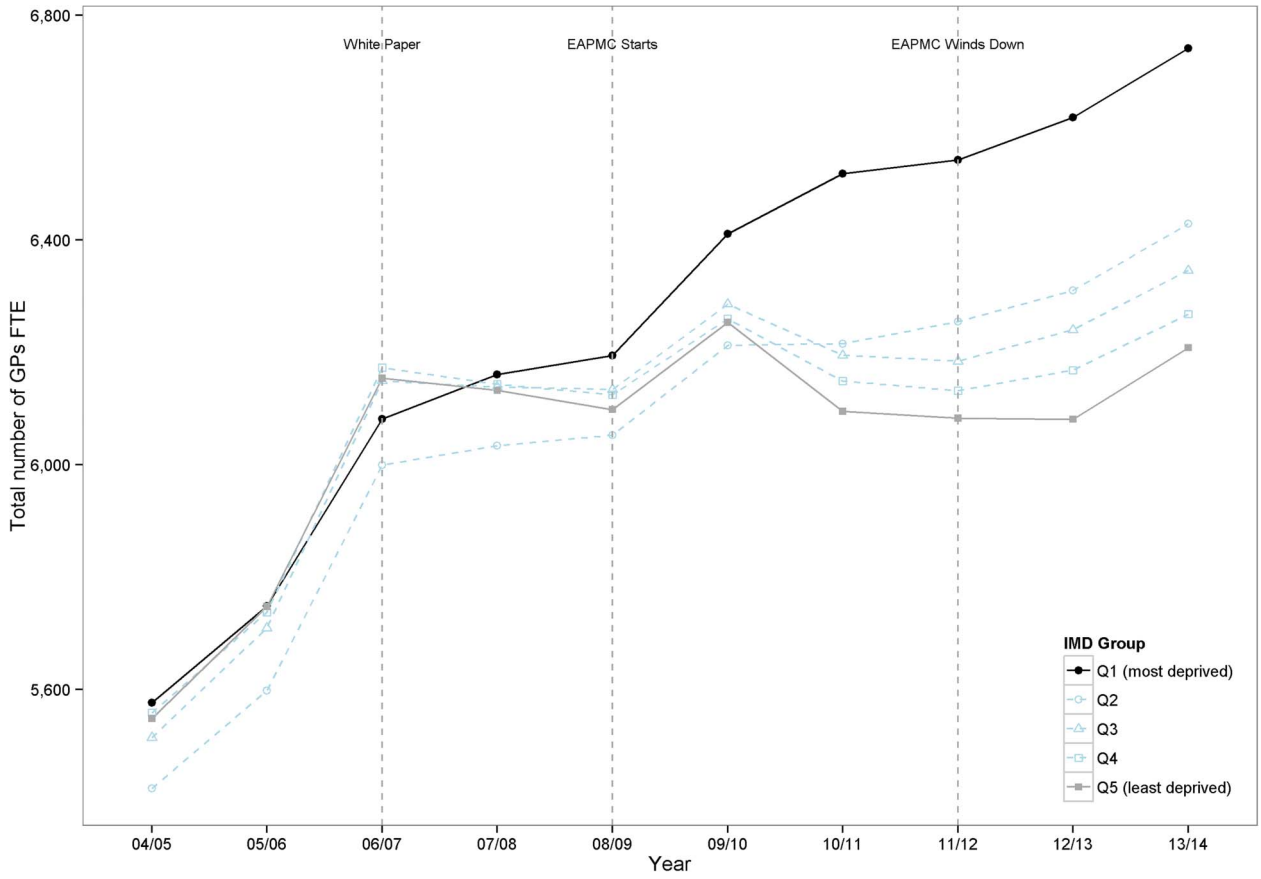

Figure 1 Total GP workforce1 by Deprivation Quintile Group, from 2004/2005 to 2013/2014. Note: Number of FTE GPs, excluding registrars and retainers. FTE, full time equivalent; GP, general practitioner; IMD, Index of Multiple Deprivation.

adjusted population in the least deprived fifth of areas resulting in an SII of 4.2 (95% CI 3.1 to 5.3). By the end of the study period, this inequality had reversed with 60.5 and 59.9 FTE GPs per 100 000 need adjusted population in the most deprived and least deprived fifths of small areas, respectively, and an SII of −0.7 (95% CI −2.5 to 1.1).

This decrease in socioeconomic inequality in GP supply relative to need occurred between 2006/2007 and 2011/2012, a period over which the SII fell from 5.2 (95% CI 4.7 to 5.8) to −2.1 (95% CI −4.4 to 0.2). During this 5-year period, people living in the most deprived fifth of English small areas experienced a steady increase in GP supply relative to need, which was particularly rapid from 2008/2009 to 2010/2011, while people living in the least deprived three-fifths experienced a decline. By 2010/2011, the 'prorich' inequality in GP supply relative to need appeared to have disappeared. Nationally, the increase in GP supply relative to need in deprived small areas from 2006/2007 to 2011/2012 was offset by a corresponding reduction in other areas—resulting in a slight overall decline in national GP supply relative to need from 60.2 to 59.2 FTE GPs per 100 000. These inequality trends were driven largely by change in the most and least deprived quintile groups: GP supply in the middle three quintile groups changed little, and remained lower than in the most affluent quintile group.

By 2013/2014, the trend in GP supply per need weighted population appeared to have reversed with GP supply in the most affluent areas growing faster than in the most deprived areas.

Cross-sectional results for 2006/2007 and 2011/2012, before and after the EAPMC programme, are presented in figure 3. This highlights the reversal of the gradient in GP supply from favouring the least deprived areas in 2006/2007 to favouring the most deprived areas in 2011/2012.

Figure 4 shows changes in GP supply between these years, comparing LSOAs in 'underdoctored' PCTs that received funding under the EAMPC programme with those in the other PCTs that did not receive this funding. PCTs classified as 'underdoctored' experienced larger increases in GP supply than PCTs not classified as 'underdoctored'. Furthermore, these larger increases were concentrated in the poorest fifth of LSOAs in England.

The reduction in the SII between 2006/2007 and 2011/2012 when measured at LSOA level (average population 1500) was 7.3 (95% CI 4.9 to 9.7). The same reduction in SII when measured at the much larger CCG level (average population 250 000) was 6.9 (95% CI 1.7 to 12.1). The greater value of the change in SII found when

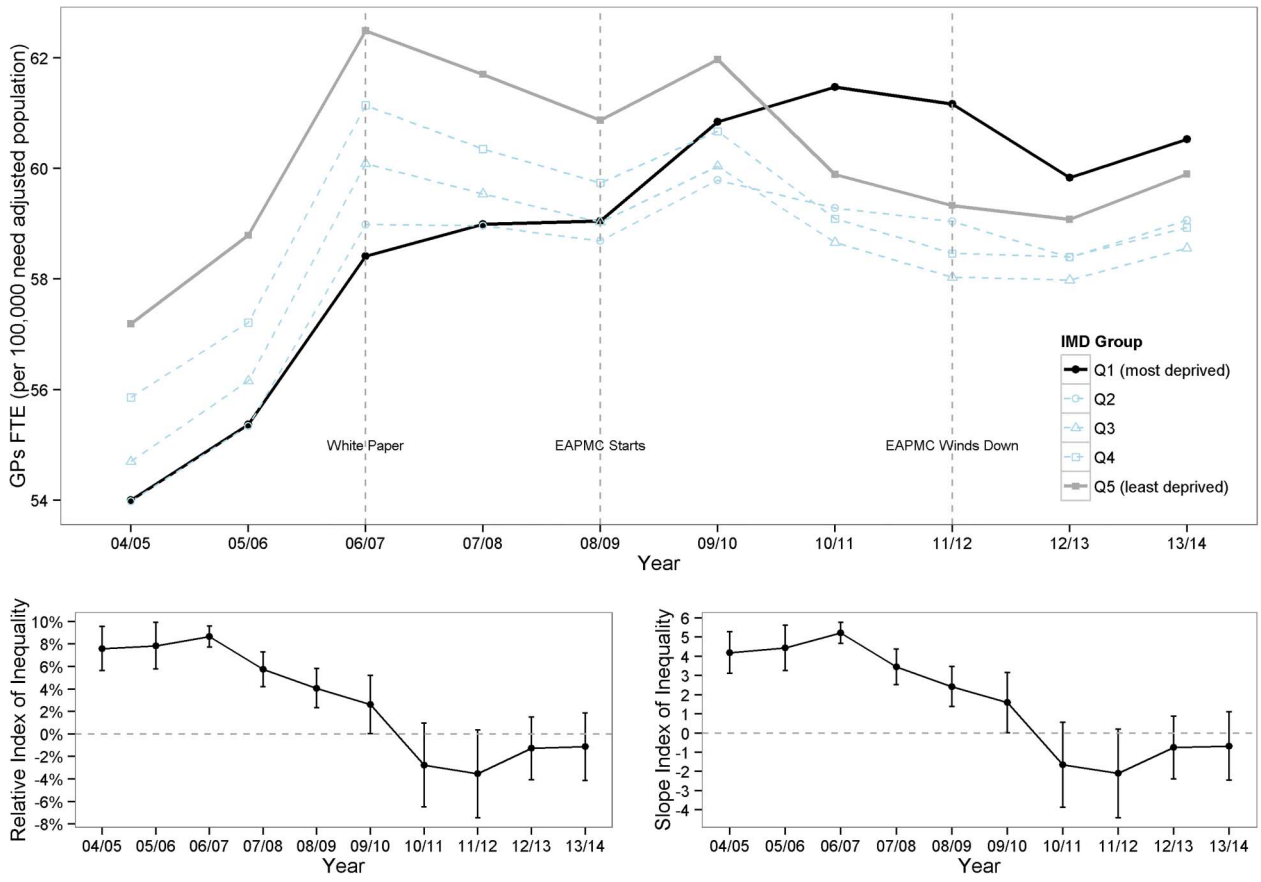

Figure 2 Socioeconomic inequality in GP supply in England 2003/2004 to 2013/2014. Note: (1). The upper panel shows FTE GPs per 100 000 need adjusted population by deprivation quintile group of small areas by year; the two lower panels show inequality indices by year, with 95% CIs. (2). The slope index of inequality can be interpreted as the absolute gap in FTE GPs per 100 000 need adjusted population between the most and least deprived small area, and the relative index of inequality as the percentage gap relative to the average area. In each case, a positive index indicates 'prorich' inequality favouring less deprived areas. EAPMC, Equitable Access to Primary Medical Care; FTE, full time equivalent; GP, general practitioner; IMD, Index of Multiple Deprivation.

using the finer grained geography demonstrates that by conducting our analysis at the small area level, we are able to identify both changes in within CCG inequality as well as changes in between CCG inequality, the first of which would have been overlooked had the analysis been conducted at the larger unit of analysis.

Our main finding of a reduction in socioeconomic inequality in GP supply from 2006/2007 to 2011/2012 was robust to extensive sensitivity analyses using different definitions of primary care supply (headcount and FTE, with and without adjustment for population size (see online supplementary appendix figure A4.3) and need (see online supplementary appendix figure A4.4), with and without GP registrars and retainers (see online supplementary appendix figures A4.1 and A5.1), with and without practice nurses at PCT level (see online supplementary appendix figures A14.1 and A14.3), different units of analysis small area (see online supplementary appendix figure A4.1), practice (see online supplementary appendix figure A8.1), PCT (see online supplementary appendix figure A14.1) and CCG (see online supplementary appendix figure A15.1) and different measures of inequality (absolute and relative)). This finding was also robust to using a different need adjustment formula: the Nuffield general and acute hospital need index for 2013/2014 (see online supplementary appendix figure A17.3).[36]

The greater increase in GP supply in deprived small areas appears primarily to have been driven by the opening of new practices, rather than recruitment into existing practices. In 2009/2010, 2010/2011 and 2011/2012, there were substantial net increases in GP supply in deprived areas of around 28, 167 and 26 FTE GPs, respectively, resulting from the opening and closing of practices (see online supplementary appendix table 1.7). However, this was followed by substantial net falls in both subsequent years of around 55 and 65 FTE GPs, respectively, as more practices closed than opened. Meanwhile, average practice size grew at similar rates in all deprivation groups (see online supplementary appendix figure 8.6). There does not appear to be any evidence of patients living in deprived areas travelling further to increase their access to GPs, on the contrary average numbers of LSOAs per practice remained stable

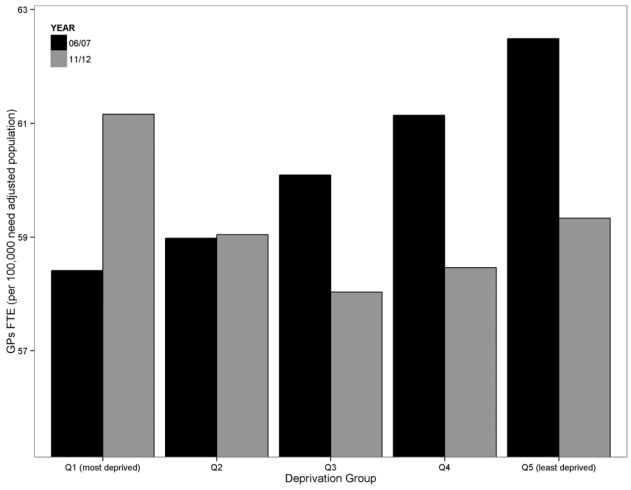

Figure 3 Socioeconomic gradient in GP supply in 2006/2007 and 2011/2012, before and after the Equitable Access to Primary Medical Care programme. FTE, full time equivalent; GP, general practitioner.

throughout the 10-year period of the study (see online supplementary appendix figure 8.5). Full details of these results as well as further breakdowns of the results presented in the paper can be found in the accompanying online supplementary appendix.

DISCUSSION

Statement of principal findings

We found a substantial reduction in socioeconomic inequality in GP supply in England from 2006/2007 to 2011/2012. This can partly be attributed to national policy in the form of the EAPMC programme, which provided additional funding for new GP practices in 'underdoctored' areas of the country. The greater increase in GP supply in deprived small areas appears primarily to have been driven by the opening of new practices, rather than recruitment into existing practices. Socioeconomic inequality in GP supply subsequently increased slightly in 2012/2013 and 2013/2014, as the NHS funding situation tightened and practices started closing more rapidly in deprived areas.

Strengths and weaknesses of the study

Our study introduces a new small area level method for measuring inequality in GP supply that focuses specifically on socioeconomic inequality and captures inequality within NHS administrative areas as well as between them. Previous large area level methods can only tell policymakers which Clinical Commissioning Groups (CCGs) are the most 'underdoctored'. As well as this, our new method also allows policymakers to take a close-up look at the situation within CCGs and identify which individual neighbourhoods and GP practices are the most deprived and underdoctored. This ability could potentially be used to redirect funding for new practices and new GPs more accurately towards the neighbourhoods that need them most.

The main limitation of this study is the lack of a generally accepted and up-to-date measure of relative need for primary care in deprived small areas. Currently, the best available measure is the workload adjustment recommended in the 2007 review of the Carr-Hill formula for allocating primary care funding.[35] This adjustment is based on regression analysis of the determinants of consultation rates in a sample of 454 practices serving 3.8 million patients from April 2003 to April 2004.[38] However, concerns have been raised that the Carr-Hill formula may not fully reflect the additional needs for primary care in deprived populations.[39] In our implementation of this formula, the average individual living in the most deprived fifth of English small areas was estimated to have 3.8% more need than the average individual living in the least deprived fifth in 2013/2014 (see online supplementary appendix table A2.7). This implied additional needs weight for deprived areas may be an underestimate, for three reasons. First, due to data constraints, we were unable to implement one element of the recommended adjustment: temporary resident status in each age-sex category. Second, the health deprivation domain of the IMD 2010 does not fully capture the burden of multimorbidity, which tends to be greater in deprived populations.[9] Third, the adjustment is based on workload patterns in the early 2000s. If there were substantial unmet needs for primary care in deprived populations in the early 2000s, the adjustment may underestimate the appropriate level of workload in those populations. This limitation means that we cannot draw firm conclusions about levels of need, and in particular we cannot conclude that socioeconomic inequality in GP supply has now been eliminated. However, we can still conclude that there was a reduction in socioeconomic inequality in GP supply relative to need from 2006/2007 to 2011/2012. To challenge that conclusion, one would have to hypothesise an offsetting increase in relative need for primary care in the most deprived fifth of small areas relative to other areas. This is implausible, for two reasons. First, according to the Carr-Hill formula, relative need for primary care in the most deprived fifth of small areas actually decreased relative to need in the most affluent fifth over the 10-year period of the study, due to gradual changes in age-sex composition between deprivation groups (see online supplementary appendix figure 17.1). Furthermore, it is not plausible that there was a sudden and substantial increase in relative needs in the most deprived fifth of areas between 2006/2007 and 2011/2012 relative to the second most deprived fifth of areas. A second limitation is that the official statistics on GP supply do not include data on the supply of locums.[40 41] However, growth in the use of GP locums in areas struggling to recruit is unlikely to explain our findings since historically recruitment appears to be more difficult in deprived areas.[42 43]

Comparison with previous studies

Two previous studies have examined changing patterns of inequality in GP supply relative to need in England using national data. Gravelle and Sutton[22] examined

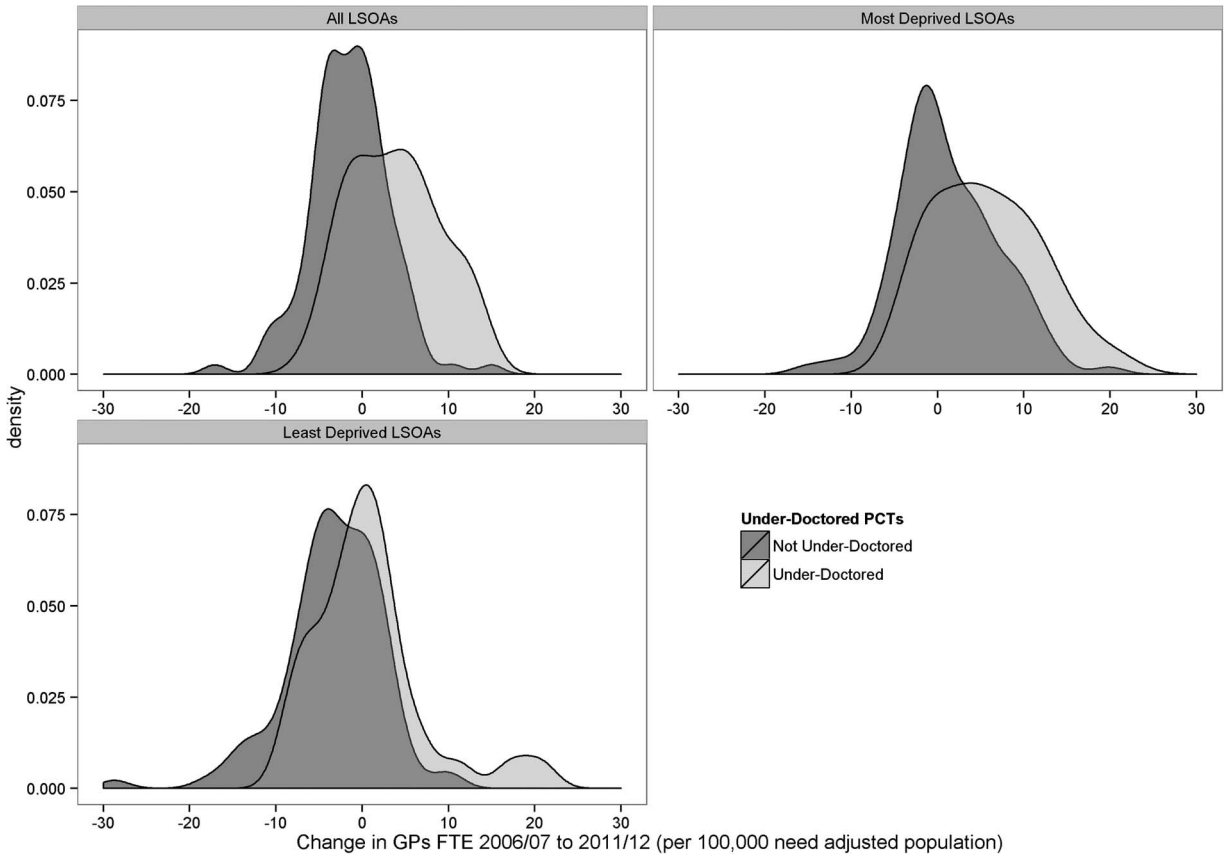

Figure 4 Change in GP supply between 2006/2007 and 2011/2012 by Deprivation Quintile Group, comparing 'underdoctored' PCTs and other PCTs (Kernel density plots). FTE, full time equivalent; GP, general practitioner; LSOA, lower super output area; PCT, Primary Care Trust.

overall inequality in GP supply between Family Practitioner Committee areas from 1974 to 1990 and between Family Health Service Authority areas from 1990 to 1995. They found substantial and persistent overall inequality, with strong within-area correlation between 1975 and 1995—most of the administrative areas that were 'underdoctored' in 1974 were still 'underdoctored' in 1995. Goddard *et al* extended this time series by adding the years 1996 to 2006, during which period PCT areas were introduced.[23] They found that overall variation between administrative areas increased between 1995 and 2006. Both studies concluded that NHS policy had little impact on overall inequality in GP supply, though the second concluded that the abolition of entry controls on 'overdoctored' administrative areas in 2002 may have increased overall inequality. Our finding of a reduction in GP supply inequality associated with NHS policy in the late 2000s may seem surprising in the light of these previous findings that inequality in GP supply has not changed much since the 1970s. However, these previous studies are not directly comparable to ours since they examined overall inequality in GP supply between large administrative areas, rather than socioeconomic inequality between small areas. Furthermore, they examined earlier time periods subject to different policy initiatives. For example, the deprivation-weighted capitation payment system introduced in 1990 resulted in complex marginal incentive structures that may have merely shifted GPs from one deprived area to another.[22] By contrast, the EAPMC programme was specifically targeted at opening new GP practices in deprived areas, involved substantial financial expenditure, and was implemented at a time of vigorous centralised NHS target setting and performance monitoring. Viewed in that light, it is less surprising that this programme succeeded in helping to increase GP supply in deprived areas. Equally, it is perhaps not surprising that socioeconomic inequality started to rise again after the programme was wound down in 2011/2012, as money ran out and practices started to close.

Meaning of the study: possible explanations and implications for clinicians and policymakers

The reduction in socioeconomic inequality in GP supply was associated with national policy to recruit more GPs in deprived areas of England, as announced in the 2006 White Paper and followed by the EAPMC programme from 2008 to 2011. GP supply relative to need increased from 2006/2007 to 2011/2012 in the group of 38 PCTs that received funding from the EAPMC programme, especially in the most deprived fifth of small areas

within those PCTs, while decreasing in other PCTs. The increase in GP supply in deprived small areas appears primarily to have been driven by the opening of new practices, rather than recruitment into existing practices. While inequality has increased again since the end of the EAPMC funding it has not yet reached the levels observed in the early 2000s. However, the ongoing NHS funding squeeze and difficulties in GP recruitment and retention particularly in deprived areas suggest that there is a risk of inequality in GP supply continuing to rise in future years. For example, vacancies in GP training posts are especially high in the North of England, where 29% of training posts were unfilled in August 2014.[44] Retention of GPs is also a significant problem, with one study suggesting that nearly a third of GPs intend to leave direct patient care within 5 years.[31]

Unanswered questions and future research

It is not known how much more need for primary care there is in deprived areas relative to affluent areas. Our estimates of this are based on the best available measure of need for primary care: the workload adjustment from the 2007 revision of the Carr-Hill formula for allocating primary care resources. Our figures show that in 2013/2014, the most recent year available, the most deprived fifth of areas received slightly more GP supply relative to need than other areas. However, we cannot conclude from this that 'prorich' inequality in GP supply has disappeared since, as explained above, there are good reasons for thinking that the Carr-Hill formula may underestimate need in deprived areas.[39]

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Contributors MA accessed, extracted and assembled the data, conducted the main data analysis, contributed to study design, and drafted and revised the paper. RC initiated the collaborative project, had the original idea for the study, supervised the data assembly and analysis, and drafted and revised the paper. MA and RC are joint guarantors. RF helped interpret the data from a primary care perspective, and drafted and revised the paper. SA contributed to study design and conducted some preliminary data analysis. All authors, external and internal, had full access to all of the data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis. MA and RC affirm that the manuscript is an honest, accurate, and transparent account of the study being reported and that any discrepancies from the study as planned have been explained.

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Appendix to paper:

Unequal socioeconomic distribution of the primary care workforce: whole-population small area longitudinal study

This appendix consists of seventeen sections providing further details on and breakdowns of the results in the paper as well as results of various sensitivity analyses.

Section 1 GP supply by IMD quintile

This section presents data tables showing numbers of GPs both in terms of head count and in terms of full time equivalents broken down by IMD deprivation quintiles for years 2004/05 to 2013/14. These results are presented for total numbers of GPs as well as broken down into the three subgroups GPs excluding registrars and retainers, GP registrars only and GP retainers only. For these results GP numbers are attributed to LSOAs and then LSOAs are aggregated according to IMD scores calculated at LSOA level. This worksheet also contains results where IMD deprivation scores are attributed to GP practices and these are then used to aggregate GP numbers into population weighted fifths by deprivation. Several additional sets of data underpinning the plots in various sensitivity analyses are also given in these tables.

Section 2 Inequality Indices

This section presents the numbers of GP FTE in the richest and poorest fifths of LSOAs as well as the absolute gap, relative gap, slope index of inequality and relative index of inequality for years 2004/05 to 2013/14. Results are broken down into the same subgroups and sensitivities as in section 1.

Section 3 GP supply by PCT in 2006 and 2011

This section looks at GP supply by PCT in 2006/07 and 2011/12 the two years that we compare to evaluate whether the investment in underdoctored areas had any effect. PCTs are marked by underdoctored status as identified in the policy documents that defined where this investment would be targeted. Numbers are presented for all LSOAs as well as for only the most deprived fifth of LSOAs and least deprived fifth of LSOAs in each PCT. PCTs that do not include any LSOAs in the most or least deprived fifths have NAs in place of numbers in the relevant fields. There is also a second table in this worksheet showing similar results for GPs excluding registrars and retainers.

Section 4 Basecase results - LSOA level deprivation - excluding GP registrars and GP retainers

This section presents a full set of results expanding on those presented in the paper. The results are for GPs excluding registrars and retainers, these are attributed to LSOAs and then aggregated by LSOA level IMD scores into deprivation quintiles. The results show:

(1) the trend over time by deprivation quintile in need adjusted full time equivalent GP supply per 100,000 of population

(2) cross- sectional results for 2006/07 and 20011/12 in need adjusted full time equivalent GP supply per 100,000 of population

(3) the trends in total numbers of GP both in terms of head count and in terms of full time equivalent GPs split by deprivation quintile

(4) unadjusted and adjusted time trends in numbers of GPs in terms of head count and full time equivalents split by derpivation quintile

(5) regression results to test whether there has been a siginificant change in the slope index of inequality between 2006/07 and 2011/12

(6) distributions of changes in GP supply between 2006/07 and 2011/12 at PCT level split by under-doctored status looking at all LSOAs, the most deprived fifth of LSOAs and the least deprived fifth of LSOAs

(7) distributions of FTE practice nurses in 2013/14

(8) scatter plot of GP FTE in each LSOA plotted against deprivation in 2006/07 and 2011/12

(9) scatter plot of changes in GP FTE in each LSOA against deprivation between 2006/07 and 2011/12

(10) the trend over time in GP FTE by deprivation decile

Section 5 Sensitivity analysis including GP registrars and GP retainers

This section shows the first six sets of results as those in section 4 but looking at GP supply including GP registrars and retainers

Section 6 Sensitivity analysis looking only at GP registrars

This section shows the first five sets of results as those in section 4 but looking only at the supply of GP registrars

Section 7 Sensitivity analysis looking only at GP retainers

This section shows the first five sets of results as those in section 4 but looking only at the supply of GP registrars

Section 8 Sensitivity analysis looking at practice level deprivation quintiles rather than LSOA level deprivation quintiles excluding GP registrars and GP retainers

This section shows the first five sets of results as those in section 4 but with attibution of IMD score to GP practice and aggregation into deprivation quintiles at practice level rather than attribution of the GP supply to LSOA level and aggregation at LSOA level as done in the base case. Inaddition to this there are also plots of:
(6) trends in numbers of LSOA that practices draw their patients from over time by deprivation quintile
(7) trends in mean numbers of GPs per practice over time by deprivation quintile

Section 9 Sensitivity analysis looking at practice level deprivation quintiles including registrars and retainers

This section is the same as section 8 except it shows results for GP numbers including registrars and retainers rather than all GPs as shown in section 8.

Section 10 Sensitivity analysis London NHS CR excluding registrars and retainers

This section shows the first five sets of results as those in section 4 but looking only at LSOAs in the London NHS CR

Section 11 Sensitivity analysis North of England NHS CR excluding registrars and retainers

This section shows the first five sets of results as those in section 4 but looking only at LSOAs in the North of England NHS CR

Section 12 Sensitivity analysis Midlands and East of England NHS CR excluding registrars and retainers

This section shows the first five sets of results as those in section 4 but looking only at LSOAs in the Midland and East of England NHS CR

Section 13 Sensitivity analysis South of England NHS CR excluding registrars and retainers

This section shows the first five sets of results as those in section 4 but looking only at LSOAs in the South of England NHS CR

Section 14 Sensitivity analysis PCT level looking at trends in Nurse and GP FTE excluding registrars and retainers

This section shows trends in Nurse FTE and GP FTE with deprivation quintiles derived from population weighted PCTs. Historical data for nurse FTE was only available to us at PCT level.

Section 15 Sensitivity analysis looking at CCG level deprivation quintiles excluding registrars and retainers

This section is the same as section 4 except it shows results aggregated into deprivation quintiles based on population weighted CCGs.

Section 16 Trends in GP practices opening and closing and their impact on GP FTE

This section shows the numbers of GP practices opening and closing over time by deprivation group and the impact this has had in terms of gains and losses of GP FTE excluding registrars and retainers in these groups

Section 17 Need adjustment details and sensitivity analysis

This section explains the Carr-Hill Workload need adjustment formula used, explores its impacts on the results over time and explores the sensitivity of the results to using an alternative Nuffield person based resource allocation formula on the results.

Appendix Section 1

This section presents data tables showing numbers of GPs both in terms of head count and in terms of full time equivalents broken down by IMD deprivation quintiles for years 2004/05 to 2013/14.

These results are presented for total numbers of GPs as well as broken down into the three subgroups GPs excluding registrars and retainers, GP registrars only and GP retainers only.

For these results GP numbers are attributed to LSOAs and then LSOAs are aggregated according to IMD scores calculated at LSOA level.

This worksheet also contains results where IMD deprivation scores are attributed to GP practices and these are then used to aggregate GP numbers into population weighted fifths by deprivation.

Several additional sets of data underpinning the plots in various sensitivity analyses explored in further sections of this appendix are also given in the tables in this section. These include details of the trends in the numbers of opening and closing of GP practices over time and their impact in terms of GP FTE, trends in practice size over time and trends in practice nurse populations over time.

Table A1.1: GP Supply by IMD Quintile Including Registrars and Retainers

				All GPs (Including Registrars and Retainers)					
				GP Headcount			GP Full Time Equivalent		
Year	IMD Quintile	Population	Need adjusted population	Total	Unadjusted per 100k	Need adjusted per 100k	Total	Unadjusted per 100k	Need adjusted per 100k
2004	1 (most deprived)	9,951,665	10,327,060	6656	66.89	64.46	6045	60.74	58.54
2004	2	9,922,657	10,048,907	6562	66.14	65.31	5895	59.41	58.66
2004	3	10,032,274	10,082,658	6811	67.89	67.55	6040	60.21	59.91
2004	4	10,062,460	9,949,765	6962	69.19	69.97	6139	61.00	61.69
2004	5 (least deprived)	10,140,651	9,701,318	7067	69.69	72.84	6194	61.08	63.85
2005	1 (most deprived)	10,017,043	10,380,909	6826	68.14	65.75	6190	61.79	59.63
2005	2	9,998,176	10,114,567	6774	67.75	66.97	6062	60.63	59.94
2005	3	10,115,862	10,165,383	7047	69.66	69.32	6232	61.61	61.31
2005	4	10,133,726	10,028,822	7179	70.85	71.59	6320	62.37	63.02
2005	5 (least deprived)	10,201,355	9,776,480	7265	71.21	74.31	6360	62.35	65.06
2006	1 (most deprived)	10,061,435	10,411,858	6969	69.27	66.93	6505	64.65	62.47
2006	2	10,062,639	10,172,317	6869	68.26	67.52	6429	63.89	63.20
2006	3	10,182,896	10,234,380	7133	70.05	69.70	6631	65.12	64.80
2006	4	10,194,108	10,096,472	7251	71.13	71.82	6707	65.79	66.43
2006	5 (least deprived)	10,262,815	9,848,867	7319	71.31	74.31	6718	65.46	68.21
2007	1 (most deprived)	10,107,634	10,443,538	7036	69.61	67.37	6513	64.43	62.36
2007	2	10,132,298	10,233,624	6862	67.72	67.05	6394	63.11	62.48
2007	3	10,257,247	10,310,359	7009	68.33	67.98	6508	63.45	63.12
2007	4	10,268,083	10,180,175	7091	69.06	69.65	6556	63.85	64.40
2007	5 (least deprived)	10,340,919	9,938,486	7147	69.11	71.91	6546	63.30	65.86
2008	1 (most deprived)	10,172,305	10,490,011	7499	73.72	71.49	6757	66.43	64.41
2008	2	10,222,041	10,313,147	7301	71.42	70.79	6633	64.89	64.32
2008	3	10,336,944	10,392,001	7479	72.35	71.97	6767	65.47	65.12
2008	4	10,326,760	10,251,648	7553	73.14	73.68	6820	66.05	66.53
2008	5 (least deprived)	10,406,596	10,017,839	7603	73.06	75.90	6809	65.43	67.97
2009	1 (most deprived)	10,242,974	10,537,912	7907	77.19	75.03	7056	68.89	66.96
2009	2	10,312,215	10,390,335	7651	74.19	73.64	6896	66.87	66.37
2009	3	10,412,543	10,470,074	7805	74.96	74.55	7026	67.48	67.11
2009	4	10,376,595	10,317,632	7854	75.69	76.13	7064	68.08	68.46
2009	5 (least deprived)	10,461,735	10,091,174	7974	76.22	79.02	7127	68.12	70.62
2010	1 (most deprived)	10,336,179	10,604,558	8353	80.81	78.77	7190	69.56	67.80
2010	2	10,418,358	10,484,925	7946	76.27	75.78	6918	66.40	65.98
2010	3	10,500,292	10,561,037	8019	76.37	75.93	6961	66.29	65.91
2010	4	10,452,346	10,406,831	8040	76.92	77.25	6971	66.70	66.99
2010	5 (least deprived)	10,526,870	10,176,694	8087	76.82	79.47	6978	66.29	68.57
2011	1 (most deprived)	10,456,433	10,697,690	8485	81.14	79.31	7186	68.72	67.17
2011	2	10,543,934	10,594,848	8102	76.84	76.47	6955	65.96	65.64
2011	3	10,591,723	10,656,814	8156	77.00	76.53	6977	65.87	65.47
2011	4	10,519,160	10,489,422	8147	77.45	77.67	6975	66.31	66.50
2011	5 (least deprived)	10,579,453	10,251,929	8193	77.45	79.92	7006	66.23	68.34
2012	1 (most deprived)	10,893,479	11,062,381	8605	78.99	77.78	7342	67.40	66.37
2012	2	10,782,713	10,807,827	8227	76.29	76.12	7102	65.87	65.71
2012	3	10,694,991	10,762,883	8235	77.00	76.51	7089	66.29	65.87
2012	4	10,552,487	10,562,156	8207	77.77	77.70	7052	66.83	66.77
2012	5 (least deprived)	10,564,331	10,292,754	8165	77.29	79.33	6981	66.08	67.83
2013	1 (most deprived)	10,994,820	11,137,074	8460	76.94	75.96	7334	66.70	65.85
2013	2	10,873,567	10,885,678	8103	74.52	74.43	7077	65.08	65.01
2013	3	10,765,378	10,837,339	8062	74.89	74.39	7011	65.13	64.70
2013	4	10,610,984	10,635,953	7995	75.34	75.17	6942	65.42	65.27
2013	5 (least deprived)	10,615,169	10,363,872	7967	75.05	76.87	6888	64.88	66.46

Table A1.2: GP Supply by IMD Quintile Excluding Registrars and Retainers

				Excluding Registrars and Retainers					
				GP Headcount			GP Full Time Equivalent		
Year	IMD Quintile	Population	Need adjusted population	Total	Unadjusted per 100k	Need adjusted per 100k	Total	Unadjusted per 100k	Need adjusted per 100k
2004	1 (most deprived)	9,951,665	10,327,060	6118	61.48	59.24	5576	56.03	54.00
2004	2	9,922,657	10,048,907	6002	60.49	59.73	5424	54.66	53.98
2004	3	10,032,274	10,082,658	6164	61.44	61.14	5515	54.97	54.70
2004	4	10,062,460	9,949,765	6233	61.95	62.65	5558	55.24	55.86
2004	5 (least deprived)	10,140,651	9,701,318	6233	61.47	64.25	5548	54.71	57.19
2005	1 (most deprived)	10,017,043	10,380,909	6318	63.07	60.86	5748	57.38	55.37
2005	2	9,998,176	10,114,567	6221	62.22	61.51	5598	55.99	55.34
2005	3	10,115,862	10,165,383	6418	63.45	63.14	5709	56.44	56.16
2005	4	10,133,726	10,028,822	6470	63.84	64.51	5738	56.62	57.21
2005	5 (least deprived)	10,201,355	9,776,480	6497	63.69	66.46	5747	56.34	58.79
2006	1 (most deprived)	10,061,435	10,411,858	6484	64.44	62.28	6082	60.45	58.41
2006	2	10,062,639	10,172,317	6371	63.31	62.63	5999	59.62	58.98
2006	3	10,182,896	10,234,380	6563	64.45	64.13	6149	60.39	60.09
2006	4	10,194,108	10,096,472	6607	64.81	65.44	6173	60.55	61.14
2006	5 (least deprived)	10,262,815	9,848,867	6621	64.52	67.23	6154	59.96	62.49
2007	1 (most deprived)	10,107,634	10,443,538	6642	65.71	63.59	6161	60.95	58.99
2007	2	10,132,298	10,233,624	6460	63.76	63.13	6034	59.55	58.96
2007	3	10,257,247	10,310,359	6597	64.31	63.98	6139	59.85	59.54
2007	4	10,268,083	10,180,175	6627	64.54	65.10	6143	59.83	60.35
2007	5 (least deprived)	10,340,919	9,938,486	6670	64.50	67.11	6132	59.30	61.70
2008	1 (most deprived)	10,172,305	10,490,011	6883	67.67	65.62	6194	60.89	59.05
2008	2	10,222,041	10,313,147	6663	65.18	64.61	6053	59.21	58.69
2008	3	10,336,944	10,392,001	6785	65.64	65.29	6134	59.34	59.03
2008	4	10,326,760	10,251,648	6783	65.69	66.17	6124	59.31	59.74
2008	5 (least deprived)	10,406,596	10,017,839	6796	65.31	67.84	6098	58.60	60.87
2009	1 (most deprived)	10,242,974	10,537,912	7202	70.32	68.35	6411	62.59	60.84
2009	2	10,312,215	10,390,335	6907	66.98	66.47	6212	60.24	59.79
2009	3	10,412,543	10,470,074	6994	67.17	66.80	6286	60.37	60.04
2009	4	10,376,595	10,317,632	6967	67.14	67.52	6260	60.32	60.67
2009	5 (least deprived)	10,461,735	10,091,174	7002	66.93	69.39	6253	59.77	61.97
2010	1 (most deprived)	10,336,179	10,604,558	7609	73.61	71.75	6518	63.06	61.47
2010	2	10,418,358	10,484,925	7157	68.69	68.26	6216	59.66	59.28
2010	3	10,500,292	10,561,037	7152	68.11	67.72	6195	59.00	58.66
2010	4	10,452,346	10,406,831	7096	67.89	68.19	6149	58.83	59.09
2010	5 (least deprived)	10,526,870	10,176,694	7060	67.07	69.37	6095	57.90	59.89
2011	1 (most deprived)	10,456,433	10,697,690	7754	74.15	72.48	6543	62.57	61.16
2011	2	10,543,934	10,594,848	7309	69.32	68.99	6255	59.32	59.04
2011	3	10,591,723	10,656,814	7257	68.51	68.09	6185	58.39	58.03
2011	4	10,519,160	10,489,422	7181	68.26	68.46	6132	58.29	58.46
2011	5 (least deprived)	10,579,453	10,251,929	7128	67.37	69.53	6083	57.50	59.33
2012	1 (most deprived)	10,893,479	11,062,381	7802	71.62	70.52	6618	60.75	59.83
2012	2	10,782,713	10,807,827	7346	68.13	67.97	6310	58.52	58.39
2012	3	10,694,991	10,762,883	7283	68.09	67.67	6240	58.35	57.98
2012	4	10,552,487	10,562,156	7206	68.29	68.22	6168	58.45	58.40
2012	5 (least deprived)	10,564,331	10,292,754	7135	67.54	69.32	6081	57.56	59.08
2013	1 (most deprived)	10,994,820	11,137,074	7796	70.91	70.00	6741	61.31	60.53
2013	2	10,873,567	10,885,678	7371	67.79	67.72	6429	59.12	59.06
2013	3	10,765,378	10,837,339	7301	67.82	67.37	6346	58.95	58.56
2013	4	10,610,984	10,635,953	7213	67.97	67.81	6268	59.07	58.93
2013	5 (least deprived)	10,615,169	10,363,872	7168	67.53	69.16	6208	58.49	59.90

Table A1.3: GP Supply by IMD Quintile Registrars Only

				Registrars Only					
				GP Headcount			GP Full Time Equivalent		
Year	IMD Quintile	Population	Need adjusted population	Total	Unadjusted per 100k	Need adjusted per 100k	Total	Unadjusted per 100k	Need adjusted per 100k
2004	1 (most deprived)	9,951,665	10,327,060	456	4.58	4.41	440	4.43	4.26
2004	2	9,922,657	10,048,907	447	4.51	4.45	433	4.36	4.30
2004	3	10,032,274	10,082,658	496	4.94	4.92	474	4.73	4.71
2004	4	10,062,460	9,949,765	543	5.39	5.45	519	5.16	5.21
2004	5 (least deprived)	10,140,651	9,701,318	598	5.90	6.17	567	5.60	5.85
2005	1 (most deprived)	10,017,043	10,380,909	437	4.36	4.21	419	4.18	4.04
2005	2	9,998,176	10,114,567	452	4.52	4.47	432	4.32	4.27
2005	3	10,115,862	10,165,383	506	5.00	4.98	481	4.75	4.73
2005	4	10,133,726	10,028,822	562	5.55	5.60	533	5.26	5.31
2005	5 (least deprived)	10,201,355	9,776,480	585	5.73	5.98	550	5.39	5.62
2006	1 (most deprived)	10,061,435	10,411,858	411	4.09	3.95	395	3.93	3.80
2006	2	10,062,639	10,172,317	409	4.07	4.02	394	3.91	3.87
2006	3	10,182,896	10,234,380	450	4.42	4.40	432	4.24	4.22
2006	4	10,194,108	10,096,472	490	4.80	4.85	469	4.61	4.65
2006	5 (least deprived)	10,262,815	9,848,867	498	4.86	5.06	480	4.68	4.88
2007	1 (most deprived)	10,107,634	10,443,538	324	3.20	3.10	308	3.05	2.95
2007	2	10,132,298	10,233,624	317	3.13	3.10	304	3.00	2.97
2007	3	10,257,247	10,310,359	309	3.02	3.00	298	2.91	2.89
2007	4	10,268,083	10,180,175	333	3.25	3.27	321	3.13	3.15
2007	5 (least deprived)	10,340,919	9,938,486	303	2.93	3.05	294	2.84	2.95
2008	1 (most deprived)	10,172,305	10,490,011	558	5.49	5.32	528	5.19	5.03
2008	2	10,222,041	10,313,147	567	5.54	5.49	536	5.24	5.19
2008	3	10,336,944	10,392,001	604	5.84	5.81	577	5.58	5.55
2008	4	10,326,760	10,251,648	651	6.30	6.35	622	6.02	6.07
2008	5 (least deprived)	10,406,596	10,017,839	638	6.13	6.37	608	5.84	6.07
2009	1 (most deprived)	10,242,974	10,537,912	651	6.35	6.18	612	5.97	5.81
2009	2	10,312,215	10,390,335	679	6.59	6.54	640	6.21	6.16
2009	3	10,412,543	10,470,074	726	6.97	6.93	682	6.55	6.51
2009	4	10,376,595	10,317,632	778	7.49	7.54	730	7.04	7.08
2009	5 (least deprived)	10,461,735	10,091,174	819	7.83	8.11	769	7.35	7.62
2010	1 (most deprived)	10,336,179	10,604,558	698	6.76	6.59	654	6.33	6.17
2010	2	10,418,358	10,484,925	728	6.99	6.94	678	6.51	6.46
2010	3	10,500,292	10,561,037	786	7.48	7.44	733	6.98	6.94
2010	4	10,452,346	10,406,831	842	8.05	8.09	782	7.48	7.51
2010	5 (least deprived)	10,526,870	10,176,694	896	8.51	8.80	829	7.88	8.15
2011	1 (most deprived)	10,456,433	10,697,690	687	6.57	6.42	626	5.99	5.85
2011	2	10,543,934	10,594,848	738	7.00	6.96	679	6.44	6.40
2011	3	10,591,723	10,656,814	828	7.82	7.77	764	7.22	7.17
2011	4	10,519,160	10,489,422	879	8.35	8.38	809	7.69	7.72
2011	5 (least deprived)	10,579,453	10,251,929	955	9.03	9.32	881	8.33	8.59
2012	1 (most deprived)	10,893,479	11,062,381	765	7.03	6.92	706	6.48	6.38
2012	2	10,782,713	10,807,827	832	7.72	7.70	769	7.13	7.11
2012	3	10,694,991	10,762,883	890	8.32	8.27	820	7.66	7.62
2012	4	10,552,487	10,562,156	922	8.74	8.73	846	8.02	8.01
2012	5 (least deprived)	10,564,331	10,292,754	934	8.84	9.07	854	8.09	8.30
2013	1 (most deprived)	10,994,820	11,137,074	626	5.70	5.62	576	5.24	5.17
2013	2	10,873,567	10,885,678	685	6.30	6.29	628	5.77	5.77
2013	3	10,765,378	10,837,339	708	6.58	6.54	642	5.96	5.92
2013	4	10,610,984	10,635,953	716	6.74	6.73	645	6.08	6.06
2013	5 (least deprived)	10,615,169	10,363,872	717	6.76	6.92	643	6.06	6.21

Table A1.4: GP Supply by IMD Quintile Retainers Only

				Retainers Only					
				GP Headcount			GP Full Time Equivalent		
Year	IMD Quintile	Population	Need adjusted population	Total	Unadjusted per 100k	Need adjusted per 100k	Total	Unadjusted per 100k	Need adjusted per 100k
2004	1 (most deprived)	9,951,665	10,327,060	83	0.83	0.80	28	0.29	0.28
2004	2	9,922,657	10,048,907	113	1.14	1.12	38	0.39	0.38
2004	3	10,032,274	10,082,658	151	1.51	1.50	51	0.51	0.51
2004	4	10,062,460	9,949,765	186	1.85	1.87	61	0.61	0.62
2004	5 (least deprived)	10,140,651	9,701,318	235	2.32	2.42	78	0.77	0.81
2005	1 (most deprived)	10,017,043	10,380,909	71	0.71	0.68	23	0.23	0.22
2005	2	9,998,176	10,114,567	101	1.01	1.00	33	0.33	0.33
2005	3	10,115,862	10,165,383	123	1.21	1.21	42	0.41	0.41
2005	4	10,133,726	10,028,822	148	1.46	1.47	50	0.49	0.49
2005	5 (least deprived)	10,201,355	9,776,480	183	1.79	1.87	63	0.62	0.65
2006	1 (most deprived)	10,061,435	10,411,858	74	0.74	0.71	28	0.27	0.26
2006	2	10,062,639	10,172,317	89	0.88	0.87	36	0.36	0.35
2006	3	10,182,896	10,234,380	121	1.18	1.18	50	0.49	0.49
2006	4	10,194,108	10,096,472	154	1.51	1.53	65	0.63	0.64
2006	5 (least deprived)	10,262,815	9,848,867	199	1.94	2.02	84	0.82	0.85
2007	1 (most deprived)	10,107,634	10,443,538	70	0.70	0.67	44	0.43	0.42
2007	2	10,132,298	10,233,624	84	0.83	0.82	56	0.55	0.55
2007	3	10,257,247	10,310,359	103	1.00	1.00	72	0.70	0.69
2007	4	10,268,083	10,180,175	131	1.27	1.28	91	0.89	0.90
2007	5 (least deprived)	10,340,919	9,938,486	174	1.68	1.75	120	1.16	1.21
2008	1 (most deprived)	10,172,305	10,490,011	57	0.56	0.55	35	0.34	0.33
2008	2	10,222,041	10,313,147	71	0.70	0.69	45	0.44	0.44
2008	3	10,336,944	10,392,001	90	0.87	0.87	56	0.55	0.54
2008	4	10,326,760	10,251,648	119	1.15	1.16	74	0.72	0.72
2008	5 (least deprived)	10,406,596	10,017,839	169	1.63	1.69	102	0.98	1.02
2009	1 (most deprived)	10,242,974	10,537,912	54	0.52	0.51	33	0.33	0.32
2009	2	10,312,215	10,390,335	65	0.63	0.63	43	0.42	0.42
2009	3	10,412,543	10,470,074	86	0.83	0.82	58	0.56	0.56
2009	4	10,376,595	10,317,632	110	1.06	1.07	74	0.71	0.72
2009	5 (least deprived)	10,461,735	10,091,174	153	1.47	1.52	104	1.00	1.03
2010	1 (most deprived)	10,336,179	10,604,558	46	0.45	0.43	18	0.17	0.17
2010	2	10,418,358	10,484,925	62	0.59	0.59	24	0.23	0.23
2010	3	10,500,292	10,561,037	82	0.78	0.78	33	0.31	0.31
2010	4	10,452,346	10,406,831	102	0.98	0.98	41	0.39	0.39
2010	5 (least deprived)	10,526,870	10,176,694	131	1.25	1.29	53	0.51	0.52
2011	1 (most deprived)	10,456,433	10,697,690	44	0.43	0.42	17	0.16	0.16
2011	2	10,543,934	10,594,848	55	0.52	0.52	21	0.20	0.20
2011	3	10,591,723	10,656,814	71	0.67	0.67	28	0.26	0.26
2011	4	10,519,160	10,489,422	88	0.84	0.84	34	0.32	0.32
2011	5 (least deprived)	10,579,453	10,251,929	110	1.04	1.08	43	0.40	0.42
2012	1 (most deprived)	10,893,479	11,062,381	38	0.35	0.34	19	0.17	0.17
2012	2	10,782,713	10,807,827	49	0.45	0.45	23	0.21	0.21
2012	3	10,694,991	10,762,883	62	0.58	0.58	30	0.28	0.27
2012	4	10,552,487	10,562,156	79	0.75	0.75	38	0.36	0.36
2012	5 (least deprived)	10,564,331	10,292,754	97	0.91	0.94	46	0.43	0.45
2013	1 (most deprived)	10,994,820	11,137,074	37	0.34	0.34	17	0.15	0.15
2013	2	10,873,567	10,885,678	46	0.42	0.42	20	0.19	0.19
2013	3	10,765,378	10,837,339	53	0.49	0.49	23	0.22	0.22
2013	4	10,610,984	10,635,953	66	0.63	0.62	29	0.28	0.28
2013	5 (least deprived)	10,615,169	10,363,872	82	0.77	0.79	36	0.34	0.35

Table A1.5: GP Supply by IMD Quintile Including Registrars and Retainers Practice Level Aggregation

				ALL GPs (Practice Level Aggregation)					
				GP Headcount			GP Full Time Equivalent		
Year	IMD Quintile	Population	Need adjusted population	Total	Unadjusted per 100k	Need adjusted per 100k	Total	Unadjusted per 100k	Need adjusted per 100k
2004	1 (most deprived)	9,951,665	10,327,060	6509	64.93	63.53	5943	59.29	58.01
2004	2	9,922,657	10,048,907	6574	65.57	64.70	5931	59.16	58.37
2004	3	10,032,274	10,082,658	6662	66.50	66.13	5950	59.39	59.06
2004	4	10,062,460	9,949,765	7117	71.01	71.52	6209	61.95	62.39
2004	5 (least deprived)	10,140,651	9,701,318	7197	71.84	74.35	6280	62.69	64.88
2005	1 (most deprived)	10,017,043	10,380,909	6681	66.15	64.78	6085	60.25	59.00
2005	2	9,998,176	10,114,567	6782	67.21	66.34	6107	60.52	59.74
2005	3	10,115,862	10,165,383	6868	68.07	67.66	6112	60.57	60.21
2005	4	10,133,726	10,028,822	7362	72.93	73.45	6414	63.54	63.99
2005	5 (least deprived)	10,201,355	9,776,480	7398	73.31	75.83	6447	63.89	66.08
2006	1 (most deprived)	10,061,435	10,411,858	6813	67.08	65.76	6371	62.73	61.49
2006	2	10,062,639	10,172,317	6863	67.57	66.70	6411	63.12	62.30
2006	3	10,182,896	10,234,380	7029	69.25	68.85	6574	64.76	64.39
2006	4	10,194,108	10,096,472	7412	72.99	73.44	6883	67.77	68.19
2006	5 (least deprived)	10,262,815	9,848,867	7424	73.17	75.67	6752	66.55	68.82
2007	1 (most deprived)	10,107,634	10,443,538	6956	68.04	66.77	6437	62.97	61.79
2007	2	10,132,298	10,233,624	6912	67.61	66.77	6427	62.87	62.08
2007	3	10,257,247	10,310,359	6894	67.47	67.07	6436	62.99	62.61
2007	4	10,268,083	10,180,175	7159	69.99	70.36	6665	65.16	65.51
2007	5 (least deprived)	10,340,919	9,938,486	7223	70.72	73.09	6551	64.14	66.29
2008	1 (most deprived)	10,172,305	10,490,011	7375	71.64	70.40	6636	64.46	63.35
2008	2	10,222,041	10,313,147	7411	71.95	71.06	6742	65.46	64.65
2008	3	10,336,944	10,392,001	7330	71.23	70.81	6667	64.80	64.41
2008	4	10,326,760	10,251,648	7613	73.97	74.32	6894	66.99	67.30
2008	5 (least deprived)	10,406,596	10,017,839	7707	74.92	77.34	6846	66.55	68.70
2009	1 (most deprived)	10,242,974	10,537,912	7856	75.75	74.56	6985	67.35	66.29
2009	2	10,312,215	10,390,335	7627	73.64	72.79	6902	66.64	65.87
2009	3	10,412,543	10,470,074	7650	73.83	73.40	6907	66.66	66.28
2009	4	10,376,595	10,317,632	7952	76.77	77.05	7179	69.31	69.55
2009	5 (least deprived)	10,461,735	10,091,174	8107	78.26	80.67	7196	69.47	71.61
2010	1 (most deprived)	10,336,179	10,604,558	8327	79.69	78.60	7134	68.28	67.34
2010	2	10,418,358	10,484,925	7947	76.07	75.22	6959	66.61	65.86
2010	3	10,500,292	10,561,037	7780	74.48	74.06	6789	64.99	64.63
2010	4	10,452,346	10,406,831	8200	78.48	78.69	7106	68.01	68.19
2010	5 (least deprived)	10,526,870	10,176,694	8191	78.43	80.70	7030	67.31	69.26
2011	1 (most deprived)	10,456,433	10,697,690	8469	80.33	79.42	7121	67.55	66.78
2011	2	10,543,934	10,594,848	8037	76.21	75.43	6970	66.09	65.41
2011	3	10,591,723	10,656,814	7918	75.19	74.74	6792	64.49	64.11
2011	4	10,519,160	10,489,422	8277	78.57	78.69	7068	67.10	67.20
2011	5 (least deprived)	10,579,453	10,251,929	8382	79.55	81.69	7148	67.84	69.66
2012	1 (most deprived)	10,893,479	11,062,381	8414	78.61	78.14	7132	66.63	66.23
2012	2	10,782,713	10,807,827	8119	75.85	75.18	7062	65.98	65.39
2012	3	10,694,991	10,762,883	8087	75.66	75.18	7001	65.50	65.08
2012	4	10,552,487	10,562,156	8413	78.61	78.55	7223	67.49	67.43
2012	5 (least deprived)	10,564,331	10,292,754	8405	78.64	80.40	7150	66.89	68.39
2013	1 (most deprived)	10,994,820	11,137,074	8281	76.83	76.49	7144	66.29	66.00
2013	2	10,873,567	10,885,678	7964	73.93	73.33	7016	65.13	64.60
2013	3	10,765,378	10,837,339	7910	73.41	72.98	6907	64.10	63.73
2013	4	10,610,984	10,635,953	8184	76.02	75.87	7095	65.91	65.78
2013	5 (least deprived)	10,615,169	10,363,872	8247	76.58	78.18	7089	65.83	67.21

Table A1.6: GP Supply by IMD Quintile Excluding Registrars and Retainers Practice Level Aggregation

				Excluding Registrars and Retainers (Practice Level Aggregation)					
				GP Headcount			GP Full Time Equivalent		
Year	IMD Quintile	Population	Need adjusted population	Total	Unadjusted per 100k	Need adjusted per 100k	Total	Unadjusted per 100k	Need adjusted per 100k
2004	1 (most deprived)	9,951,665	10,327,060	6040	60.25	58.95	5526	55.13	53.94
2004	2	9,922,657	10,048,907	5990	59.75	58.96	5433	54.20	53.48
2004	3	10,032,274	10,082,658	6095	60.84	60.50	5473	54.63	54.32
2004	4	10,062,460	9,949,765	6350	63.36	63.82	5607	55.94	56.35
2004	5 (least deprived)	10,140,651	9,701,318	6276	62.64	64.84	5582	55.72	57.67
2005	1 (most deprived)	10,017,043	10,380,909	6240	61.78	60.50	5698	56.42	55.25
2005	2	9,998,176	10,114,567	6195	61.39	60.60	5606	55.56	54.84
2005	3	10,115,862	10,165,383	6313	62.57	62.19	5639	55.88	55.55
2005	4	10,133,726	10,028,822	6618	65.56	66.03	5809	57.54	57.96
2005	5 (least deprived)	10,201,355	9,776,480	6558	64.99	67.22	5788	57.36	59.33
2006	1 (most deprived)	10,061,435	10,411,858	6379	62.81	61.57	5989	58.97	57.81
2006	2	10,062,639	10,172,317	6369	62.71	61.89	5982	58.90	58.14
2006	3	10,182,896	10,234,380	6493	63.97	63.60	6110	60.19	59.85
2006	4	10,194,108	10,096,472	6723	66.20	66.61	6311	62.15	62.53
2006	5 (least deprived)	10,262,815	9,848,867	6682	65.86	68.10	6164	60.76	62.83
2007	1 (most deprived)	10,107,634	10,443,538	6608	64.64	63.43	6130	59.96	58.84
2007	2	10,132,298	10,233,624	6474	63.33	62.54	6035	59.03	58.29
2007	3	10,257,247	10,310,359	6497	63.58	63.21	6069	59.39	59.04
2007	4	10,268,083	10,180,175	6700	65.50	65.85	6259	61.18	61.51
2007	5 (least deprived)	10,340,919	9,938,486	6716	65.76	67.96	6117	59.90	61.90
2008	1 (most deprived)	10,172,305	10,490,011	6847	66.51	65.36	6152	59.76	58.72
2008	2	10,222,041	10,313,147	6706	65.10	64.30	6103	59.25	58.52
2008	3	10,336,944	10,392,001	6679	64.91	64.52	6065	58.94	58.59
2008	4	10,326,760	10,251,648	6850	66.55	66.87	6201	60.24	60.53
2008	5 (least deprived)	10,406,596	10,017,839	6829	66.38	68.53	6083	59.13	61.04
2009	1 (most deprived)	10,242,974	10,537,912	7234	69.76	68.65	6412	61.83	60.85
2009	2	10,312,215	10,390,335	6849	66.12	65.37	6189	59.75	59.06
2009	3	10,412,543	10,470,074	6890	66.50	66.11	6208	59.91	59.56
2009	4	10,376,595	10,317,632	7048	68.04	68.29	6362	61.42	61.64
2009	5 (least deprived)	10,461,735	10,091,174	7051	68.07	70.16	6253	60.36	62.22
2010	1 (most deprived)	10,336,179	10,604,558	7695	73.65	72.64	6556	62.74	61.89
2010	2	10,418,358	10,484,925	7093	67.89	67.14	6203	59.38	58.72
2010	3	10,500,292	10,561,037	6974	66.76	66.39	6065	58.06	57.73
2010	4	10,452,346	10,406,831	7235	69.24	69.43	6266	59.97	60.13
2010	5 (least deprived)	10,526,870	10,176,694	7076	67.75	69.71	6083	58.24	59.93
2011	1 (most deprived)	10,456,433	10,697,690	7867	74.62	73.78	6589	62.50	61.79
2011	2	10,543,934	10,594,848	7196	68.23	67.53	6226	59.03	58.43
2011	3	10,591,723	10,656,814	7064	67.08	66.68	6042	57.37	57.03
2011	4	10,519,160	10,489,422	7286	69.17	69.27	6201	58.87	58.96
2011	5 (least deprived)	10,579,453	10,251,929	7215	68.47	70.32	6139	58.26	59.84
2012	1 (most deprived)	10,893,479	11,062,381	7714	72.07	71.64	6498	60.71	60.35
2012	2	10,782,713	10,807,827	7246	67.69	67.10	6278	58.65	58.13
2012	3	10,694,991	10,762,883	7151	66.90	66.48	6153	57.57	57.20
2012	4	10,552,487	10,562,156	7361	68.78	68.72	6295	58.82	58.77
2012	5 (least deprived)	10,564,331	10,292,754	7299	68.29	69.82	6193	57.95	59.25
2013	1 (most deprived)	10,994,820	11,137,074	7678	71.24	70.92	6603	61.26	60.99
2013	2	10,873,567	10,885,678	7254	67.34	66.79	6381	59.24	58.75
2013	3	10,765,378	10,837,339	7185	66.68	66.29	6270	58.19	57.85
2013	4	10,610,984	10,635,953	7357	68.34	68.21	6379	59.25	59.14
2013	5 (least deprived)	10,615,169	10,363,872	7375	68.48	69.92	6359	59.05	60.28

Table A1.7: GP Supply by IMD Quintile Related to Opening and Closing of Practices

				Opening and Closing of GP Practices					
				GP Practices Opening		GP Practices Closing		Net Change in GP Practices	
Year	IMD Quintile	Population	Need adjusted population	Number of Practices	Number of GP FTE	Number of Practices	Number of GP FTE	Number of Practices	Number of GP FTE
2004	1 (most deprived)	9,951,665	10,327,060	-	-	-	-	-	-
2004	2	9,922,657	10,048,907	-	-	-	-	-	-
2004	3	10,032,274	10,082,658	-	-	-	-	-	-
2004	4	10,062,460	9,949,765	-	-	-	-	-	-
2004	5 (least deprived)	10,140,651	9,701,318	-	-	-	-	-	-
2005	1 (most deprived)	10,017,043	10,380,909	38	25.00	59	20.00	-21	5.00
2005	2	9,998,176	10,114,567	21	19.60	36	11.60	-15	8.00
2005	3	10,115,862	10,165,383	12	25.60	31	15.20	-19	10.40
2005	4	10,133,726	10,028,822	8	9.20	31	6.60	-23	2.60
2005	5 (least deprived)	10,201,355	9,776,480	10	9.40	32	15.60	-22	-6.20
2006	1 (most deprived)	10,061,435	10,411,858	16	25.30	56	13.80	-40	11.50
2006	2	10,062,639	10,172,317	9	26.60	35	9.80	-26	16.80
2006	3	10,182,896	10,234,380	8	15.39	17	5.00	-9	10.39
2006	4	10,194,108	10,096,472	6	6.00	14	12.20	-8	-6.20
2006	5 (least deprived)	10,262,815	9,848,867	4	6.00	15	2.00	-11	4.00
2007	1 (most deprived)	10,107,634	10,443,538	18	10.04	48	13.00	-30	-2.96
2007	2	10,132,298	10,233,624	4	9.17	36	8.92	-32	0.25
2007	3	10,257,247	10,310,359	6	19.67	34	27.08	-28	-7.41
2007	4	10,268,083	10,180,175	5	8.19	24	9.91	-19	-1.72
2007	5 (least deprived)	10,340,919	9,938,486	6	3.00	26	9.06	-20	-6.06
2008	1 (most deprived)	10,172,305	10,490,011	11	8.20	42	16.00	-31	-7.80
2008	2	10,222,041	10,313,147	4	5.05	18	8.25	-14	-3.20
2008	3	10,336,944	10,392,001	3	1.00	18	7.00	-15	-6.00
2008	4	10,326,760	10,251,648	2	4.66	6	5.00	-4	-0.34
2008	5 (least deprived)	10,406,596	10,017,839	1	6.86	6	7.68	-5	-0.82
2009	1 (most deprived)	10,242,974	10,537,912	80	51.59	39	24.01	41	27.58
2009	2	10,312,215	10,390,335	56	28.87	22	27.31	34	1.56
2009	3	10,412,543	10,470,074	49	11.44	22	11.02	27	0.42
2009	4	10,376,595	10,317,632	18	1.60	13	7.75	5	-6.15
2009	5 (least deprived)	10,461,735	10,091,174	17	4.11	5	6.00	12	-1.89
2010	1 (most deprived)	10,336,179	10,604,558	99	191.98	30	24.49	69	167.49
2010	2	10,418,358	10,484,925	38	89.25	19	7.96	19	81.29
2010	3	10,500,292	10,561,037	17	32.11	10	5.88	7	26.23
2010	4	10,452,346	10,406,831	14	35.53	17	13.22	-3	22.31
2010	5 (least deprived)	10,526,870	10,176,694	7	16.95	14	7.71	-7	9.24
2011	1 (most deprived)	10,456,433	10,697,690	18	46.11	37	20.59	-19	25.52
2011	2	10,543,934	10,594,848	7	22.26	27	20.52	-20	1.74
2011	3	10,591,723	10,656,814	2	2.59	23	10.82	-21	-8.23
2011	4	10,519,160	10,489,422	4	4.28	19	12.88	-15	-8.60
2011	5 (least deprived)	10,579,453	10,251,929	1	3.00	13	9.18	-12	-6.18
2012	1 (most deprived)	10,893,479	11,062,381	10	19.26	61	74.45	-51	-55.19
2012	2	10,782,713	10,807,827	1	4.00	31	30.77	-30	-26.77
2012	3	10,694,991	10,762,883	0	0.00	23	28.52	-23	-28.52
2012	4	10,552,487	10,562,156	1	3.96	21	25.40	-20	-21.45
2012	5 (least deprived)	10,564,331	10,292,754	0	0.00	11	10.32	-11	-10.32
2013	1 (most deprived)	10,994,820	11,137,074	5	3.89	130	69.20	-125	-65.31
2013	2	10,873,567	10,885,678	3	6.97	76	23.75	-73	-16.78
2013	3	10,765,378	10,837,339	5	9.56	93	39.10	-88	-29.54
2013	4	10,610,984	10,635,953	4	13.81	61	40.30	-57	-26.50
2013	5 (least deprived)	10,615,169	10,363,872	2	5.84	46	32.35	-44	-26.51

Table A1.8: GP Supply by IMD Quintile Other Sensitivity Analyses

				Other Sensitivity Analyses			
Year	IMD Quintile	Population	Need adjusted population	Mean GP FTE per Practice	Mean LSOAs per Practice	Nurse FTE (PCT level Data)	Nurse FTE per 100k need adjusted (PCT level Data)
2004	1 (most deprived)	9,951,665	10,327,060	2.47	116	2,750.12	27.05
2004	2	9,922,657	10,048,907	3.10	97	2,877.33	26.73
2004	3	10,032,274	10,082,658	3.46	77	2,698.58	25.95
2004	4	10,062,460	9,949,765	3.79	63	2,801.97	26.87
2004	5 (least deprived)	10,140,651	9,701,318	4.03	53	619.36	5.90
2005	1 (most deprived)	10,017,043	10,380,909	2.56	114	2,827.48	25.30
2005	2	9,998,176	10,114,567	3.24	96	3,084.49	28.97
2005	3	10,115,862	10,165,383	3.58	77	2,444.92	25.17
2005	4	10,133,726	10,028,822	3.92	63	2,766.40	25.65
2005	5 (least deprived)	10,201,355	9,776,480	4.22	53	2,870.08	26.48
2006	1 (most deprived)	10,061,435	10,411,858	2.75	112	2,379.12	24.72
2006	2	10,062,639	10,172,317	3.50	95	627.92	6.02
2006	3	10,182,896	10,234,380	3.90	76	1,784.83	16.89
2006	4	10,194,108	10,096,472	4.29	63	2,970.37	26.93
2006	5 (least deprived)	10,262,815	9,848,867	4.54	53	2,709.54	25.80
2007	1 (most deprived)	10,107,634	10,443,538	2.81	113	2,743.65	26.81
2007	2	10,132,298	10,233,624	3.61	95	3,069.98	27.66
2007	3	10,257,247	10,310,359	3.89	76	2,998.94	27.82
2007	4	10,268,083	10,180,175	4.27	63	1,853.89	17.63
2007	5 (least deprived)	10,340,919	9,938,486	4.52	53	1,290.83	13.01
2008	1 (most deprived)	10,172,305	10,490,011	2.87	112	1,305.49	13.06
2008	2	10,222,041	10,313,147	3.65	94	3,304.54	31.27
2008	3	10,336,944	10,392,001	3.89	77	2,913.88	27.46
2008	4	10,326,760	10,251,648	4.24	63	2,837.45	28.24
2008	5 (least deprived)	10,406,596	10,017,839	4.51	53	2,795.96	27.67
2009	1 (most deprived)	10,242,974	10,537,912	2.97	111	3,102.89	29.14
2009	2	10,312,215	10,390,335	3.74	97	2,953.78	27.61
2009	3	10,412,543	10,470,074	3.98	77	2,579.57	25.49
2009	4	10,376,595	10,317,632	4.37	63	2,278.37	23.01
2009	5 (least deprived)	10,461,735	10,091,174	4.66	53	559.31	5.73
2010	1 (most deprived)	10,336,179	10,604,558	2.91	110	570.55	5.80
2010	2	10,418,358	10,484,925	3.67	97	2,767.23	27.92
2010	3	10,500,292	10,561,037	3.90	77	2,249.80	22.48
2010	4	10,452,346	10,406,831	4.28	63	2,990.75	27.35
2010	5 (least deprived)	10,526,870	10,176,694	4.53	53	2,393.42	23.66
2011	1 (most deprived)	10,456,433	10,697,690	2.93	112	3,151.84	28.72
2011	2	10,543,934	10,594,848	3.71	98	2,672.13	26.18
2011	3	10,591,723	10,656,814	3.91	78	2,942.80	27.44
2011	4	10,519,160	10,489,422	4.28	64	2,274.21	23.18
2011	5 (least deprived)	10,579,453	10,251,929	4.56	54	2,843.30	25.95
2012	1 (most deprived)	10,893,479	11,062,381	3.06	114	2,575.48	25.02
2012	2	10,782,713	10,807,827	3.85	100	189.61	1.99
2012	3	10,694,991	10,762,883	4.01	80	2,646.99	25.74
2012	4	10,552,487	10,562,156	4.35	65	2,787.59	27.90
2012	5 (least deprived)	10,564,331	10,292,754	4.62	55	2,716.02	26.99
2013	1 (most deprived)	10,994,820	11,137,074	3.18	119	2,558.39	25.07
2013	2	10,873,567	10,885,678	3.99	102	2,751.39	26.68
2013	3	10,765,378	10,837,339	4.11	83	2,691.70	24.76
2013	4	10,610,984	10,635,953	4.48	67	183.18	1.93
2013	5 (least deprived)	10,615,169	10,363,872	4.80	57	2,610.09	24.05

Appendix Section 2

This section presents the numbers of GP FTE in the richest and poorest fifths of areas as well as the absolute gap, relative gap, slope index of inequality and relative index of inequality for years 2004/05 to 2013/14.

In the tables that follow Q1 refers to the most deprived fifth of areas and Q5 refers to the least deprived fifth of areas. ABS_GAP referes to the absolute gap between these two groups of areas i.e. Q5 - Q1 this is similar to the slope index of inequality (SII) which models this gap but also takes into account the levels observed in the other three fifths of the distribution. REL_GAP refers to the relative gap between the most and least deprived groups calculated as ABS_GAP/Q5 and is somewhat similar to the relative index of inequality (RII) which expresses the SII as a proportion of the national average.

Table A2.1: Inequality Indices GPs FTE Including Registrars and Retainers

	All GPs (Including Registrars and Retainers)					
Year	**Q1**	**Q5**	**ABS_GAP**	**REL_GAP**	**SII**	**RII**
2004	58.54	63.85	5.31	8%	6.90	11.39%
2005	59.63	65.06	5.43	8%	7.08	11.46%
2006	62.47	68.21	5.74	8%	7.40	11.38%
2007	62.36	65.86	3.50	5%	4.50	7.06%
2008	64.41	67.97	3.56	5%	4.72	7.19%
2009	66.96	70.62	3.66	5%	4.75	7.00%
2010	67.80	68.57	0.77	1%	1.32	1.98%
2011	67.17	68.34	1.17	2%	1.66	2.49%
2012	66.37	67.83	1.46	2%	1.99	3.00%
2013	65.85	66.46	0.61	1%	0.77	1.18%

Table A2.2: Inequality Indices GPs FTE Excluding Registrars and Retainers

	Excluding Registrars and Retainers					
Year	**Q1**	**Q5**	**ABS_GAP**	**REL_GAP**	**SII (95% CI)**	**RII (95% CI)**
2004	54.00	57.19	3.19	6%	4.19 (3.10 to 5.28)	7.60% (5.63 to 9.57)
2005	55.37	58.79	3.42	6%	4.44 (3.26 to 5.62)	7.85% (5.77 to 9.94)
2006	58.41	62.49	4.08	7%	5.22 (4.66 to 5.77)	8.66% (7.74 to 9.58)
2007	58.99	61.70	2.71	4%	3.45 (2.53 to 4.36)	5.75% (4.22 to 7.28)
2008	59.05	60.87	1.82	3%	2.42 (1.38 to 3.46)	4.07% (2.32 to 5.82)
2009	60.84	61.97	1.13	2%	1.59 (0.02 to 3.16)	2.62% (0.03 to 5.21)
2010	61.47	59.89	-1.58	-3%	-1.65 (-3.87 to 0.57)	-2.77% (-6.49 to 0.95)
2011	61.16	59.33	-1.83	-3%	-2.10 (-4.41 to 0.21)	-3.55% (-7.45 to 0.35)
2012	59.83	59.08	-0.75	-1%	-0.75 (-2.38 to 0.88)	-1.28% (-4.06 to 1.50)
2013	60.53	59.90	-0.63	-1%	-0.68 (-2.46 to 1.11)	-1.14% (-4.15 to 1.87)

Table A2.3: Inequality Indices GPs FTE Registrars Only

	Registrars Only					
Year	Q1	Q5	ABS_GAP	REL_GAP	SII	RII
2004	4.26	5.85	1.59	27%	2.05	42.08%
2005	4.04	5.62	1.58	28%	2.12	44.10%
2006	3.80	4.88	1.08	22%	1.46	34.14%
2007	2.95	2.95	0.00	0%	0.09	2.94%
2008	5.03	6.07	1.04	17%	1.46	26.20%
2009	5.81	7.62	1.81	24%	2.30	34.60%
2010	6.17	8.15	1.98	24%	2.54	36.03%
2011	5.85	8.59	2.74	32%	3.43	47.97%
2012	6.38	8.30	1.92	23%	2.40	32.04%
2013	5.17	6.21	1.04	17%	1.21	20.73%

Table A2.4: Inequality Indices GPs FTE Retainers Only

	Retainers Only					
Year	Q1	Q5	ABS_GAP	REL_GAP	SII	RII
2004	0.28	0.81	0.53	65%	0.66	127.43%
2005	0.22	0.65	0.43	66%	0.51	122.80%
2006	0.26	0.85	0.59	69%	0.73	140.95%
2007	0.42	1.21	0.79	65%	0.96	127.32%
2008	0.33	1.02	0.69	68%	0.83	136.07%
2009	0.32	1.03	0.71	69%	0.87	142.08%
2010	0.17	0.52	0.35	67%	0.44	134.83%
2011	0.16	0.42	0.26	62%	0.32	117.20%
2012	0.17	0.45	0.28	62%	0.35	120.38%
2013	0.15	0.35	0.20	57%	0.24	102.56%

Table A2.5: Inequality Indices GPs FTE Including Registrars and Retainers Practice Level Aggregation

	ALL GPs (Practice Level Aggregation)					
Year	Q1	Q5	ABS_GAP	REL_GAP	SII	RII
2004	58.01	64.88	6.87	11%	8.63	14.26%
2005	59.00	66.08	7.08	11%	9.15	14.81%
2006	61.49	68.82	7.33	11%	10.06	15.46%
2007	61.79	66.29	4.50	7%	6.00	9.42%
2008	63.35	68.70	5.35	8%	6.48	9.86%
2009	66.29	71.61	5.32	7%	7.06	10.39%
2010	67.34	69.26	1.92	3%	2.69	4.02%
2011	66.78	69.66	2.88	4%	3.48	5.23%
2012	66.23	68.39	2.16	3%	2.82	4.24%
2013	66.00	67.21	1.21	2%	1.51	2.31%

Table A2.6: Inequality Indices GPs FTE Excluding Registrars and Retainers Practice Level Aggregation

	Excluding Registrars and Retainers (Practice Level Aggregation)					
Year	Q1	Q5	ABS_GAP	REL_GAP	SII	RII
2004	53.94	57.67	3.73	6%	4.97	9.02%
2005	55.25	59.33	4.08	7%	5.58	9.86%
2006	57.81	62.83	5.02	8%	7.05	11.71%
2007	58.84	61.90	3.06	5%	4.53	7.56%
2008	58.72	61.04	2.32	4%	3.25	5.46%
2009	60.85	62.22	1.37	2%	2.56	4.21%
2010	61.89	59.93	-1.96	-3%	-1.57	-2.62%
2011	61.79	59.84	-1.95	-3%	-1.96	-3.30%
2012	60.35	59.25	-1.10	-2%	-1.09	-1.86%
2013	60.99	60.28	-0.71	-1%	-0.73	-1.23%

Table A2.7: Inequality Indices GPs FTE Excluding Registrars and Retainers CCG Level Aggregation

	Excluding Registrars and Retainers					
Year	Q1	Q5	ABS_GAP	REL_GAP	SII (95% CI)	RII (95% CI)
2004	54.17	57.34	3.17	6%	4.63 (2.07 to 7.19)	0.08 (0.04 to 0.13)
2005	55.97	58.81	2.84	5%	4.82 (1.66 to 7.98)	0.08 (0.03 to 0.14)
2006	58.16	62.72	4.56	7%	6.49 (3.79 to 9.18)	0.11 (0.06 to 0.15)
2007	59.00	61.88	2.88	5%	4.37 (2.17 to 6.58)	0.07 (0.04 to 0.11)
2008	58.88	61.12	2.24	4%	3.11 (0.53 to 5.70)	0.05 (0.01 to 0.10)
2009	60.49	62.87	2.38	4%	3.06 (-0.62 to 6.75)	0.05 (-0.01 to 0.11)
2010	61.22	60.69	-0.53	-1%	-0.35 (-4.55 to 3.86)	-0.01 (-0.08 to 0.06)
2011	60.80	60.53	-0.27	0%	-0.40 (-4.81 to 4.01)	-0.01 (-0.08 to 0.07)
2012	59.29	59.37	0.08	0%	-0.18 (-4.40 to 4.04)	0.00 (-0.07 to 0.07)
2013	60.21	59.98	-0.23	0%	-0.32 (-5.61 to 4.98)	-0.01 (-0.09 to 0.08)

Table A2.8: Carr-Hill Adjustment Relative Need Gap Compared to Most Affluent Fifth

	Relative Need Gap Compared to Q5			
YEAR	Q1	Q2	Q3	Q4
2004	8.47%	5.86%	5.05%	3.36%
2005	8.14%	5.56%	4.86%	3.27%
2006	7.83%	5.34%	4.73%	3.20%
2007	7.51%	5.09%	4.59%	3.16%
2008	7.13%	4.81%	4.43%	3.13%
2009	6.66%	4.46%	4.24%	3.07%
2010	6.13%	4.10%	4.04%	2.99%
2011	5.58%	3.69%	3.83%	2.90%
2012	4.23%	2.88%	3.29%	2.73%
2013	3.75%	2.54%	3.11%	2.67%

Appendix Section 3

This section looks at GP supply by PCT in 2006/07 and 2011/12 the two years that we compare to evaluate whether the investment in underdoctored areas had any effect. PCTs are marked by underdoctored status as identified in the policy documents that defined where this investment would be targeted. Numbers are presented for all LSOAs as well as for only the most deprived fifth of LSOAs and least deprived fifth of LSOAs in each PCT. PCTs that do not include any LSOAs in the most or least deprived fifths have NAs in place of numbers in the relevant fields. There is also a second table in this worksheet showing similar results for GPs excluding registrars and retainers.

Table A3.1: GP supply by PCT 2006 and 2011 excluding registrars and retainers

		Full Time Equivalent GPs Excluding Registrars and Retainers (per 100,000 need adjusted population)								
		All LSOAs			Most Deprived Fifth of LSOAs			Least Deprived Fifth of LSOAs		
PCT	Under-Doctored PCT	2006	2011	Change 2011-2006	2006	2011	Change 2011-2006	2006	2011	Change 2011-2006
Ashton, Leigh and Wigan	1	54.52	54.04	-0.48	53.01	55.05	2.04	62.08	55.76	-6.32
Barking and Dagenham	1	41.72	47.99	6.27	40.58	48.78	8.20	NA	NA	NA
Barnet	0	66.07	55.37	-10.70	63.80	51.39	-12.41	68.14	55.31	-12.83
Barnsley	1	54.57	65.97	11.40	52.12	69.98	17.86	74.95	76.78	1.83
Bassetlaw	0	53.19	54.69	1.50	51.21	58.25	7.04	60.31	61.43	1.12
Bath and North East Somerset	0	61.45	59.86	-1.59	60.95	56.33	-4.62	60.35	58.82	-1.53
Bedfordshire	0	62.89	60.38	-2.51	58.52	67.38	8.86	64.71	59.20	-5.51
Berkshire East	0	56.59	57.73	1.14	53.92	60.99	7.07	60.08	59.75	-0.33
Berkshire West	0	61.35	58.24	-3.11	54.97	53.93	-1.04	62.86	58.81	-4.05
Bexley	0	44.50	48.86	4.36	44.88	50.15	5.27	45.39	50.00	4.61
Birmingham East and North	1	54.98	55.30	0.32	55.53	56.99	1.46	54.45	54.05	-0.40
Blackburn with Darwen Teaching	1	47.14	59.48	12.34	46.47	58.52	12.05	48.69	65.93	17.24
Blackpool	1	51.62	60.01	8.39	53.82	65.90	12.08	NA	NA	NA
Bolton Teaching	1	54.00	58.88	4.88	54.16	60.23	6.07	58.18	61.66	3.48
Bournemouth and Poole Teaching	0	65.05	58.21	-6.84	68.33	63.73	-4.60	65.04	57.31	-7.73
Bradford and Airedale Teaching	0	64.45	64.29	-0.16	64.11	64.87	0.76	62.53	62.43	-0.10
Brent Teaching	0	69.34	70.45	1.11	73.02	70.83	-2.19	NA	NA	NA
Brighton and Hove City	0	62.60	56.20	-6.40	60.56	58.90	-1.66	68.46	56.71	-11.75
Bristol	0	62.75	59.64	-3.11	64.96	63.77	-1.19	66.35	57.20	-9.15
Bromley	0	55.83	54.52	-1.31	50.54	53.38	2.84	58.41	55.75	-2.66
Buckinghamshire	0	66.22	62.92	-3.30	NA	NA	NA	67.47	63.39	-4.08
Bury	0	60.91	57.50	-3.41	55.61	59.66	4.05	67.98	59.07	-8.91
Calderdale	1	51.24	49.28	-1.96	50.30	46.14	-4.16	51.55	53.32	1.77
Cambridgeshire	0	69.26	61.34	-7.92	59.14	57.94	-1.20	70.01	61.38	-8.63
Camden	0	72.35	76.71	4.36	68.98	79.29	10.31	79.27	81.99	2.72
Central and Eastern Cheshire	0	59.42	54.14	-5.28	58.07	53.56	-4.51	60.23	53.91	-6.32
Central Lancashire	0	54.39	50.69	-3.70	53.04	51.02	-2.02	56.89	52.79	-4.10
City and Hackney Teaching	0	72.61	71.61	-1.00	74.43	72.63	-1.80	38.94	37.84	-1.10
Cornwall and Isles of Scilly	0	70.47	59.92	-10.55	70.65	63.96	-6.69	79.89	51.14	-28.75
County Durham	0	62.62	62.12	-0.50	59.30	62.99	3.69	72.35	64.64	-7.71
Coventry Teaching	0	58.81	60.95	2.14	62.35	65.95	3.60	50.87	57.05	6.18
Croydon	0	66.99	66.70	-0.29	68.77	66.31	-2.46	69.20	64.72	-4.48
Cumbria Teaching	0	63.22	64.60	1.38	59.44	62.00	2.56	63.48	64.23	0.75
Darlington	0	67.44	69.31	1.87	66.26	69.88	3.62	67.24	67.29	0.05
Derby City	0	56.09	52.19	-3.90	56.85	56.71	-0.14	57.79	52.39	-5.40
Derbyshire County	0	60.21	55.51	-4.70	56.90	56.08	-0.82	62.15	56.40	-5.75
Devon	0	80.32	79.07	-1.25	83.49	84.89	1.40	76.50	75.07	-1.43
Doncaster	0	55.31	60.27	4.96	55.25	64.11	8.86	63.13	63.78	0.65
Dorset	0	68.43	57.28	-11.15	70.55	67.62	-2.93	65.63	54.86	-10.77
Dudley	1	55.76	57.39	1.63	57.96	62.94	4.98	55.34	55.46	0.12
Ealing	0	56.10	61.98	5.88	53.10	62.48	9.38	59.66	64.07	4.41
East Lancashire Teaching	0	50.93	55.67	4.74	48.94	57.44	8.50	51.12	54.46	3.34
East Riding of Yorkshire	0	61.55	52.53	-9.02	55.21	54.40	-0.81	65.75	51.83	-13.92
East Sussex Downs and Weald	0	59.38	60.48	1.10	56.76	68.12	11.36	61.58	61.39	-0.19
Eastern and Coastal Kent	0	55.35	54.37	-0.98	54.32	53.18	-1.14	59.46	57.18	-2.28
Enfield	0	58.18	59.16	0.98	54.60	59.21	4.61	57.13	53.07	-4.06
Gateshead	0	58.88	63.80	4.92	62.30	64.89	2.59	53.85	64.24	10.39
Gloucestershire	0	62.86	59.13	-3.73	60.89	64.65	3.76	65.16	59.24	-5.92
Great Yarmouth and Waveney	0	55.05	58.30	3.25	52.27	61.58	9.31	55.14	57.43	2.29
Greenwich Teaching	1	48.44	61.68	13.24	49.85	64.73	14.88	NA	NA	NA
Halton and St Helens	1	51.90	54.45	2.55	52.39	53.08	0.69	52.63	55.77	3.14
Hammersmith and Fulham	1	60.47	72.94	12.47	59.66	72.70	13.04	NA	NA	NA
Hampshire	0	58.50	57.62	-0.88	61.21	57.23	-3.98	58.94	58.28	-0.66
Haringey Teaching	0	61.40	71.93	10.53	59.47	71.60	12.13	NA	NA	NA

Harrow	0	63.86	64.33	0.47	61.57	57.58	-3.99	62.01	65.12	3.11
Hartlepool	1	50.56	58.29	7.73	50.57	57.24	6.67	53.39	60.37	6.98
Hastings and Rother	0	55.17	59.11	3.94	55.11	64.38	9.27	59.20	58.79	-0.41
Havering	1	49.75	47.10	-2.65	50.06	47.70	-2.36	51.99	45.84	-6.15
Heart of Birmingham Teaching	1	60.39	63.59	3.20	62.87	67.78	4.91	NA	NA	NA
Herefordshire	0	64.95	59.60	-5.35	60.03	57.64	-2.39	65.82	58.39	-7.43
Hertfordshire	0	63.07	58.05	-5.02	56.54	54.75	-1.79	65.72	59.78	-5.94
Heywood, Middleton and Rochdale	1	56.55	53.68	-2.87	57.16	55.77	-1.39	53.84	45.51	-8.33
Hillingdon	0	58.55	58.29	-0.26	59.65	60.11	0.46	57.69	59.07	1.38
Hounslow	1	50.83	59.94	9.11	48.83	69.99	21.16	51.56	62.67	11.11
Hull Teaching	1	54.05	52.88	-1.17	54.59	53.08	-1.51	55.12	56.52	1.40
Isle of Wight National Health Service	0	52.33	52.81	0.48	57.66	52.89	-4.77	48.88	49.23	0.35
Islington	0	75.96	79.83	3.87	76.58	82.33	5.75	NA	NA	NA
Kensington and Chelsea	0	61.81	56.55	-5.26	56.57	60.73	4.16	85.05	66.99	-18.06
Kingston	0	70.41	71.81	1.40	68.80	75.22	6.42	74.26	71.85	-2.41
Kirklees	0	56.67	55.14	-1.53	57.05	54.23	-2.82	61.51	58.04	-3.47
Knowsley	1	47.63	60.33	12.70	48.40	63.87	15.47	NA	NA	NA
Lambeth	0	77.15	75.82	-1.33	76.17	76.64	0.47	NA	NA	NA
Leeds	0	57.60	54.92	-2.68	58.88	57.12	-1.76	60.27	56.11	-4.16
Leicester City	1	49.23	60.00	10.77	50.58	60.76	10.18	47.47	68.17	20.70
Leicestershire County and Rutland	0	58.79	61.58	2.79	62.00	76.25	14.25	60.61	61.79	1.18
Lewisham	0	68.23	65.68	-2.55	69.23	66.98	-2.25	NA	NA	NA
Lincolnshire Teaching	0	50.27	51.58	1.31	48.40	53.74	5.34	53.07	53.27	0.20
Liverpool	1	61.49	62.82	1.33	60.80	63.59	2.79	70.89	67.12	-3.77
Luton	1	55.39	58.15	2.76	59.62	64.56	4.94	52.20	51.58	-0.62
Manchester Teaching	1	56.60	55.70	-0.90	56.49	55.75	-0.74	64.20	55.88	-8.32
Medway	1	49.84	54.67	4.83	46.91	56.67	9.76	49.22	50.93	1.71
Mid Essex	0	59.08	58.55	-0.53	53.06	59.09	6.03	59.49	60.38	0.89
Middlesbrough	0	56.57	61.90	5.33	57.84	66.51	8.67	57.12	58.26	1.14
Milton Keynes	0	66.86	62.28	-4.58	65.13	65.12	-0.01	68.12	61.80	-6.32
Newcastle	1	56.46	56.90	0.44	56.16	59.51	3.35	58.36	56.86	-1.50
Newham	0	72.22	72.89	0.67	71.97	72.89	0.92	NA	NA	NA
Norfolk	0	66.77	63.02	-3.75	67.27	66.26	-1.01	72.48	65.40	-7.08
North East Essex	0	53.84	50.83	-3.01	38.84	39.80	0.96	63.36	59.32	-4.04
North East Lincolnshire	0	57.26	59.43	2.17	57.58	61.87	4.29	60.09	59.09	-1.00
North Lancashire Teaching	1	56.09	52.87	-3.22	54.68	52.51	-2.17	54.72	51.49	-3.23
North Lincolnshire	0	58.80	54.34	-4.46	61.60	59.09	-2.51	59.42	55.75	-3.67
North Somerset	0	52.76	56.18	3.42	51.72	60.08	8.36	59.37	58.38	-0.99
North Staffordshire	0	54.49	56.90	2.41	52.59	58.50	5.91	56.66	59.97	3.31
North Tyneside	0	56.00	61.81	5.81	56.45	63.18	6.73	56.17	59.08	2.91
North Yorkshire and York	0	65.09	61.15	-3.94	65.64	66.15	0.51	65.18	60.60	-4.58
Northamptonshire Teaching	0	56.28	52.24	-4.04	55.73	53.22	-2.51	59.46	54.18	-5.28
Northumberland	0	83.05	65.97	-17.08	79.31	63.96	-15.35	84.62	69.63	-14.99
Nottingham City	1	51.65	49.09	-2.56	51.76	49.68	-2.08	51.18	51.75	0.57
Nottinghamshire County Teaching	0	54.52	54.23	-0.29	51.94	55.67	3.73	58.78	56.67	-2.11
Oldham	1	46.89	52.47	5.58	44.94	56.31	11.37	53.08	50.15	-2.93
Oxfordshire	0	63.34	63.18	-0.16	58.10	70.88	12.78	63.74	60.55	-3.19
Peterborough	0	60.38	61.92	1.54	59.48	62.55	3.07	56.87	59.24	2.37
Plymouth Teaching	0	71.72	68.30	-3.42	72.52	70.01	-2.51	67.51	63.17	-4.34
Portsmouth City Teaching	0	51.75	50.07	-1.68	52.24	49.93	-2.31	55.46	56.92	1.46
Redbridge	0	51.42	47.27	-4.15	51.27	50.91	-0.36	65.13	49.72	-15.41
Redcar and Cleveland	1	56.85	63.35	6.50	57.85	66.23	8.38	61.93	63.65	1.72
Richmond and Twickenham	0	70.38	62.98	-7.40	NA	NA	NA	72.97	65.45	-7.52
Rotherham	0	56.14	58.69	2.55	55.43	60.31	4.88	58.65	56.99	-1.66
Salford	1	48.72	54.20	5.48	46.76	53.19	6.43	53.06	56.49	3.43
Sandwell	1	52.23	49.78	-2.45	52.35	51.04	-1.31	NA	NA	NA
Sefton	1	54.60	48.72	-5.88	53.86	51.54	-2.32	54.88	48.91	-5.97
Sheffield	0	68.64	68.76	0.12	69.46	74.14	4.68	72.72	68.71	-4.01
Shropshire County	0	60.87	55.96	-4.91	60.66	60.93	0.27	59.70	52.87	-6.83
Solihull	0	62.64	56.85	-5.79	63.05	55.01	-8.04	67.08	60.88	-6.20
Somerset	0	70.67	60.05	-10.62	69.99	63.53	-6.46	73.55	60.49	-13.06
South Birmingham	0	60.36	58.85	-1.51	58.80	58.72	-0.08	71.35	63.84	-7.51
South East Essex	0	54.20	53.49	-0.71	52.01	45.99	-6.02	55.10	56.77	1.67
South Gloucestershire	0	64.57	61.71	-2.86	45.55	55.51	9.96	64.34	60.06	-4.28
South Staffordshire	0	57.15	57.66	0.51	58.88	56.10	-2.78	59.08	60.22	1.14
South Tyneside	1	58.94	61.39	2.45	56.87	61.01	4.14	65.20	62.24	-2.96

South West Essex	0	50.10	49.50	-0.60	49.31	43.98	-5.33	52.29	53.85	1.56
Southampton City	0	58.95	54.83	-4.12	59.22	57.86	-1.36	64.89	58.85	-6.04
Southwark	0	72.20	70.87	-1.33	70.72	72.51	1.79	51.03	38.59	-12.44
Stockport	0	54.15	50.59	-3.56	54.79	55.46	0.67	54.89	49.27	-5.62
Stockton-on-Tees Teaching	0	59.59	54.98	-4.61	64.07	59.23	-4.84	59.41	54.64	-4.77
Stoke on Trent	1	46.99	54.56	7.57	44.37	55.87	11.50	52.42	50.85	-1.57
Suffolk	0	60.84	56.81	-4.03	59.81	49.20	-10.61	61.03	57.85	-3.18
Sunderland Teaching	1	56.90	60.35	3.45	57.10	59.02	1.92	57.43	63.14	5.71
Surrey	0	63.26	64.31	1.05	65.76	64.42	-1.34	64.47	65.26	0.79
Sutton and Merton	0	66.45	67.50	1.05	60.60	63.97	3.37	71.72	71.72	0.00
Swindon	0	65.56	63.55	-2.01	62.68	66.10	3.42	67.69	58.87	-8.82
Tameside and Glossop	1	53.20	51.57	-1.63	51.59	54.65	3.06	56.80	49.83	-6.97
Telford and Wrekin	0	56.30	53.68	-2.62	56.52	55.03	-1.49	56.86	52.38	-4.48
Torbay	0	67.19	61.49	-5.70	68.30	67.15	-1.15	65.26	61.35	-3.91
Tower Hamlets	0	66.79	81.77	14.98	66.58	86.46	19.88	61.91	64.14	2.23
Trafford	0	54.28	57.39	3.11	56.84	57.47	0.63	54.74	57.29	2.55
Wakefield District	0	57.30	55.04	-2.26	55.57	55.42	-0.15	59.72	56.77	-2.95
Walsall Teaching	1	50.50	56.98	6.48	50.04	59.27	9.23	53.25	52.07	-1.18
Waltham Forest	0	64.28	60.14	-4.14	62.79	58.91	-3.88	NA	NA	NA
Wandsworth	0	74.48	81.43	6.95	81.55	92.06	10.51	73.22	82.76	9.54
Warrington	0	59.86	55.90	-3.96	63.19	57.34	-5.85	58.44	57.57	-0.87
Warwickshire	0	60.84	60.13	-0.71	51.03	62.70	11.67	63.43	60.99	-2.44
West Essex	0	59.39	59.62	0.23	52.50	58.94	6.44	64.90	63.25	-1.65
West Kent	0	55.95	55.20	-0.75	49.21	51.07	1.86	57.47	55.59	-1.88
West Sussex	0	63.52	55.74	-7.78	56.09	56.69	0.60	65.80	55.89	-9.91
Western Cheshire	0	65.25	61.10	-4.15	67.40	63.42	-3.98	63.48	60.76	-2.72
Westminster	0	63.06	54.21	-8.85	67.87	65.58	-2.29	NA	NA	NA
Wiltshire	0	69.53	64.29	-5.24	71.23	67.58	-3.65	68.96	63.11	-5.85
Wirral	0	64.33	58.40	-5.93	69.03	62.08	-6.95	59.14	54.25	-4.89
Wolverhampton City	1	47.47	52.81	5.34	46.98	55.17	8.19	47.85	48.16	0.31
Worcestershire	0	61.92	63.55	1.63	64.13	63.11	-1.02	62.44	64.99	2.55

Table A3.2: GP supply by PCT 2006 and 2011 including registrars and retainers

		Full Time Equivalent GPs Including Registrars and Retainers (per 100,000 need adjusted population)								
		All LSOAs			Most Deprived Fifth of LSOAs			Least Deprived Fifth of LSOAs		
PCT	Under-Doctored PCT	2006	2011	Change 2011-2006	2006	2011	Change 2011-2006	2006	2011	Change 2011-2006
Ashton, Leigh and Wigan	1	56.77	54.04	-2.73	55.52	55.05	-0.47	64.58	55.76	-8.82
Barking and Dagenham	1	44.04	53.25	9.21	43.05	54.45	11.40	NA	NA	NA
Barnet	0	70.62	61.66	-8.96	67.15	56.60	-10.55	73.76	63.48	-10.28
Barnsley	1	54.66	71.92	17.26	52.17	74.84	22.67	74.95	87.39	12.44
Bassetlaw	0	59.69	64.75	5.06	56.38	65.29	8.91	70.35	76.55	6.20
Bath and North East Somerset	0	63.64	71.32	7.68	62.85	69.43	6.58	62.73	68.88	6.15
Bedfordshire	0	65.68	68.21	2.53	60.82	74.21	13.39	67.91	68.64	0.73
Berkshire East	0	62.86	65.88	3.02	60.94	69.36	8.42	66.65	67.48	0.83
Berkshire West	0	64.68	63.59	-1.09	56.93	56.72	-0.21	66.23	64.30	-1.93
Bexley	0	46.75	55.02	8.27	46.43	51.64	5.21	48.04	58.51	10.47
Birmingham East and North	1	58.86	64.95	6.09	58.68	65.94	7.26	61.89	68.19	6.30
Blackburn with Darwen Teaching	1	47.26	59.48	12.22	46.48	58.52	12.04	49.60	65.93	16.33
Blackpool	1	54.17	60.01	5.84	56.25	65.90	9.65	NA	NA	NA
Bolton Teaching	1	59.88	59.03	-0.85	58.76	60.44	1.68	64.12	61.71	-2.41
Bournemouth and Poole Teaching	0	74.68	70.14	-4.54	78.27	74.34	-3.93	73.95	73.67	-0.28
Bradford and Airedale Teaching	0	71.53	74.14	2.61	68.76	73.60	4.84	72.34	70.88	-1.46
Brent Teaching	0	77.18	79.94	2.76	83.03	81.34	-1.69	NA	NA	NA
Brighton and Hove City	0	65.67	60.90	-4.77	62.59	62.28	-0.31	71.69	60.73	-10.96
Bristol	0	63.85	66.58	2.73	66.29	72.93	6.64	67.52	59.53	-7.99
Bromley	0	59.40	59.84	0.44	52.77	55.77	3.00	62.37	61.59	-0.78
Buckinghamshire	0	73.22	74.16	0.94	NA	NA	NA	75.06	75.90	0.84
Bury	0	66.81	57.51	-9.30	58.55	59.66	1.11	78.45	59.08	-19.37
Calderdale	1	54.85	55.36	0.51	51.12	48.21	-2.91	59.14	66.43	7.29
Cambridgeshire	0	72.60	71.57	-1.03	61.43	60.67	-0.76	72.93	72.50	-0.43
Camden	0	84.42	88.87	4.45	78.66	92.50	13.84	92.73	90.51	-2.22
Central and Eastern Cheshire	0	66.36	62.76	-3.60	61.55	60.20	-1.35	68.38	63.28	-5.10
Central Lancashire	0	57.57	50.72	-6.85	56.39	51.02	-5.37	60.08	52.79	-7.29
City and Hackney Teaching	0	76.14	82.80	6.66	78.12	84.19	6.07	38.99	46.59	7.60
Cornwall and Isles of Scilly	0	74.02	67.19	-6.83	73.18	71.53	-1.65	86.01	62.95	-23.06
County Durham	0	69.09	70.58	1.49	63.94	68.17	4.23	83.44	79.68	-3.76
Coventry Teaching	0	63.23	69.99	6.76	65.24	74.60	9.36	55.60	64.79	9.19
Croydon	0	72.85	76.10	3.25	72.09	71.59	-0.50	76.56	78.88	2.32
Cumbria Teaching	0	66.32	72.05	5.73	62.30	68.16	5.86	66.60	71.57	4.97
Darlington	0	68.57	73.18	4.61	67.31	74.05	6.74	68.14	70.80	2.66
Derby City	0	59.27	58.01	-1.26	61.22	63.08	1.86	59.73	57.30	-2.43
Derbyshire County	0	65.01	65.72	0.71	60.90	65.68	4.78	66.11	65.88	-0.23
Devon	0	86.02	87.85	1.83	91.29	95.00	3.71	82.47	86.16	3.69
Doncaster	0	60.49	68.47	7.98	60.11	71.89	11.78	76.01	81.14	5.13
Dorset	0	73.82	64.12	-9.70	74.18	71.17	-3.01	72.45	63.61	-8.84
Dudley	1	63.70	64.51	0.81	65.34	69.76	4.42	65.59	65.08	-0.51
Ealing	0	59.18	69.16	9.98	55.73	67.99	12.26	62.67	74.45	11.78
East Lancashire Teaching	0	52.74	56.58	3.84	49.57	57.66	8.09	51.92	54.58	2.66
East Riding of Yorkshire	0	65.07	58.83	-6.24	57.41	58.26	0.85	69.72	57.58	-12.14
East Sussex Downs and Weald	0	63.84	67.99	4.15	59.54	76.10	16.56	66.17	67.94	1.77
Eastern and Coastal Kent	0	59.03	60.16	1.13	56.54	58.18	1.64	64.24	64.96	0.72
Enfield	0	60.87	63.11	2.24	55.34	61.26	5.92	62.80	59.29	-3.51
Gateshead	0	66.67	73.29	6.62	70.48	76.40	5.92	59.06	68.56	9.50
Gloucestershire	0	68.54	67.35	-1.19	64.94	69.54	4.60	72.14	68.62	-3.52
Great Yarmouth and Waveney	0	56.55	66.98	10.43	53.53	69.26	15.73	55.35	64.16	8.81
Greenwich Teaching	1	53.21	69.50	16.29	53.80	72.41	18.61	NA	NA	NA
Halton and St Helens	1	56.03	54.48	-1.55	57.17	53.09	-4.08	55.00	55.77	0.77
Hammersmith and Fulham	1	65.55	79.02	13.47	63.83	78.38	14.55	NA	NA	NA
Hampshire	0	64.86	66.32	1.46	65.58	64.69	-0.89	65.93	67.86	1.93
Haringey Teaching	0	67.61	77.80	10.19	63.77	74.87	11.10	NA	NA	NA
Harrow	0	73.31	73.97	0.66	69.31	67.27	-2.04	74.63	75.33	0.70
Hartlepool	1	55.81	60.40	4.59	55.64	59.27	3.63	59.20	62.82	3.62
Hastings and Rother	0	58.78	64.05	5.27	57.16	68.99	11.83	67.26	65.38	-1.88
Havering	1	55.56	53.95	-1.61	56.51	56.49	-0.02	59.88	51.48	-8.40
Heart of Birmingham Teaching	1	65.52	74.77	9.25	68.33	78.72	10.39	NA	NA	NA

Herefordshire	0	71.41	66.68	-4.73	67.88	65.14	-2.74	71.76	66.57	-5.19
Hertfordshire	0	67.81	66.50	-1.31	58.24	58.57	0.33	71.89	70.00	-1.89
Heywood, Middleton and Rochdale	1	58.18	53.68	-4.50	58.56	55.77	-2.79	55.21	45.51	-9.70
Hillingdon	0	64.62	64.26	-0.36	60.77	61.26	0.49	68.81	72.59	3.78
Hounslow	1	51.12	64.01	12.89	48.98	76.88	27.90	51.86	65.16	13.30
Hull Teaching	1	54.05	56.33	2.28	54.59	55.78	1.19	55.15	59.93	4.78
Isle of Wight National Health Service	0	54.68	58.08	3.40	60.10	58.21	-1.89	53.39	53.99	0.60
Islington	0	80.35	86.18	5.83	80.88	88.65	7.77	NA	NA	NA
Kensington and Chelsea	0	70.83	73.70	2.87	58.75	69.29	10.54	108.97	102.92	-6.05
Kingston	0	78.33	79.56	1.23	73.19	84.10	10.91	83.29	81.23	-2.06
Kirklees	0	60.02	62.44	2.42	59.66	59.18	-0.48	65.48	68.12	2.64
Knowsley	1	48.54	61.08	12.54	48.89	64.29	15.40	NA	NA	NA
Lambeth	0	80.65	77.10	-3.55	79.74	77.43	-2.31	NA	NA	NA
Leeds	0	62.92	62.54	-0.38	63.65	64.32	0.67	66.46	64.59	-1.87
Leicester City	1	51.69	66.80	15.11	52.84	67.82	14.98	51.03	74.49	23.46
Leicestershire County and Rutland	0	68.35	73.29	4.94	77.97	87.97	10.00	68.96	73.44	4.48
Lewisham	0	74.24	66.16	-8.08	77.55	67.44	-10.11	NA	NA	NA
Lincolnshire Teaching	0	50.65	57.23	6.58	48.44	58.88	10.44	53.95	60.87	6.92
Liverpool	1	67.46	67.31	-0.15	66.20	67.78	1.58	75.58	71.23	-4.35
Luton	1	59.33	76.73	17.40	64.30	86.93	22.63	55.16	68.26	13.10
Manchester Teaching	1	61.44	55.91	-5.53	61.44	55.91	-5.53	68.03	55.89	-12.14
Medway	1	52.74	62.01	9.27	48.17	60.47	12.30	51.97	57.72	5.75
Mid Essex	0	62.70	66.28	3.58	56.29	70.21	13.92	64.35	69.60	5.25
Middlesbrough	0	59.24	66.71	7.47	60.34	71.64	11.30	60.37	62.89	2.52
Milton Keynes	0	69.56	67.48	-2.08	65.35	66.54	1.19	71.60	68.76	-2.84
Newcastle	1	63.01	67.32	4.31	62.83	68.25	5.42	65.91	71.41	5.50
Newham	0	73.55	82.22	8.67	73.31	81.98	8.67	NA	NA	NA
Norfolk	0	70.02	68.79	-1.23	70.22	72.24	2.02	74.91	70.68	-4.23
North East Essex	0	53.96	57.17	3.21	38.85	41.64	2.79	63.56	65.14	1.58
North East Lincolnshire	0	60.25	64.21	3.96	60.50	66.37	5.87	63.28	63.84	0.56
North Lancashire Teaching	1	63.31	53.47	-9.84	61.58	52.92	-8.66	60.80	52.07	-8.73
North Lincolnshire	0	61.29	61.99	0.70	62.98	65.10	2.12	63.64	68.62	4.98
North Somerset	0	53.50	64.71	11.21	51.72	68.18	16.46	60.59	68.36	7.77
North Staffordshire	0	57.53	67.07	9.54	54.87	63.52	8.65	59.93	72.94	13.01
North Tyneside	0	62.40	71.33	8.93	62.58	73.44	10.86	62.44	68.24	5.80
North Yorkshire and York	0	73.71	68.94	-4.77	73.44	73.60	0.16	73.95	68.40	-5.55
Northamptonshire Teaching	0	60.01	64.91	4.90	59.44	68.98	9.54	62.95	66.23	3.28
Northumberland	0	99.46	76.95	-22.51	91.70	69.52	-22.18	104.30	82.90	-21.40
Nottingham City	1	54.92	53.90	-1.02	55.35	54.79	-0.56	53.42	55.61	2.19
Nottinghamshire County Teaching	0	58.96	71.22	12.26	55.54	74.57	19.03	65.27	77.55	12.28
Oldham	1	48.61	52.47	3.86	47.38	56.31	8.93	53.66	50.15	-3.51
Oxfordshire	0	67.80	72.36	4.56	63.94	80.27	16.33	67.02	69.67	2.65
Peterborough	0	60.54	68.12	7.58	59.48	67.08	7.60	57.87	67.01	9.14
Plymouth Teaching	0	72.88	72.38	-0.50	73.38	72.96	-0.42	69.44	68.50	-0.94
Portsmouth City Teaching	0	57.62	56.99	-0.63	58.09	54.74	-3.35	62.48	63.37	0.89
Redbridge	0	56.36	56.29	-0.07	56.12	60.73	4.61	73.37	58.26	-15.11
Redcar and Cleveland	1	60.06	68.46	8.40	59.51	70.28	10.77	67.39	73.64	6.25
Richmond and Twickenham	0	79.46	76.66	-2.80	NA	NA	NA	81.94	79.99	-1.95
Rotherham	0	61.06	69.35	8.29	60.39	70.72	10.33	63.14	65.92	2.78
Salford	1	52.60	54.20	1.60	50.92	53.19	2.27	59.20	56.49	-2.71
Sandwell	1	58.36	56.15	-2.21	58.52	57.81	-0.71	NA	NA	NA
Sefton	1	59.01	49.76	-9.25	57.91	51.79	-6.12	58.80	49.71	-9.09
Sheffield	0	78.38	80.95	2.57	83.23	89.92	6.69	78.11	74.99	-3.12
Shropshire County	0	66.04	62.38	-3.66	64.45	64.63	0.18	69.37	62.12	-7.25
Solihull	0	69.54	64.48	-5.06	65.40	60.07	-5.33	79.42	71.31	-8.11
Somerset	0	72.98	69.37	-3.61	73.19	75.09	1.90	75.92	70.79	-5.13
South Birmingham	0	71.07	69.67	-1.40	69.10	69.80	0.70	82.56	71.77	-10.79
South East Essex	0	56.91	60.97	4.06	53.56	48.73	-4.83	59.04	69.96	10.92
South Gloucestershire	0	65.56	66.06	0.50	45.55	58.97	13.42	65.45	65.23	-0.22
South Staffordshire	0	61.36	64.94	3.58	62.68	63.54	0.86	64.34	69.50	5.16
South Tyneside	1	64.01	67.83	3.82	62.04	67.52	5.48	71.16	69.57	-1.59
South West Essex	0	52.39	54.40	2.01	51.24	47.14	-4.10	54.23	60.71	6.48
Southampton City	0	62.73	61.49	-1.24	62.77	63.47	0.70	68.31	64.10	-4.21
Southwark	0	74.23	71.00	-3.23	72.44	72.53	0.09	51.09	38.63	-12.46
Stockport	0	59.74	51.76	-7.98	60.24	56.02	-4.22	61.49	50.51	-10.98
Stockton-on-Tees Teaching	0	62.99	61.77	-1.22	67.74	66.32	-1.42	62.68	61.15	-1.53

Stoke on Trent	1	49.26	58.16	8.90	46.36	59.19	12.83	54.34	53.21	-1.13
Suffolk	0	65.31	64.08	-1.23	65.77	58.43	-7.34	64.97	64.68	-0.29
Sunderland Teaching	1	61.61	65.57	3.96	61.05	63.55	2.50	62.36	67.72	5.36
Surrey	0	71.89	74.96	3.07	77.20	72.15	-5.05	72.98	75.54	2.56
Sutton and Merton	0	73.99	75.20	1.21	65.96	70.18	4.22	79.39	79.85	0.46
Swindon	0	66.35	70.13	3.78	64.13	75.88	11.75	67.93	65.41	-2.52
Tameside and Glossop	1	57.17	51.85	-5.32	55.13	54.98	-0.15	63.71	49.86	-13.85
Telford and Wrekin	0	62.47	57.04	-5.43	65.33	58.86	-6.47	61.01	54.89	-6.12
Torbay	0	69.88	66.37	-3.51	70.64	70.77	0.13	70.30	69.80	-0.50
Tower Hamlets	0	73.25	94.10	20.85	73.93	99.25	25.32	65.84	77.06	11.22
Trafford	0	55.85	57.63	1.78	57.77	57.66	-0.11	56.05	57.49	1.44
Wakefield District	0	65.10	67.54	2.44	63.18	66.90	3.72	68.10	69.62	1.52
Walsall Teaching	1	54.82	64.88	10.06	52.94	65.50	12.56	59.31	64.25	4.94
Waltham Forest	0	69.98	69.35	-0.63	66.91	66.36	-0.55	NA	NA	NA
Wandsworth	0	80.97	92.01	11.04	89.84	105.91	16.07	83.39	96.74	13.35
Warrington	0	59.87	61.99	2.12	63.19	62.34	-0.85	58.45	64.93	6.48
Warwickshire	0	67.67	71.19	3.52	54.26	69.08	14.82	71.62	74.49	2.87
West Essex	0	68.60	73.07	4.47	57.79	72.17	14.38	75.90	77.21	1.31
West Kent	0	62.93	63.88	0.95	53.37	58.26	4.89	65.85	65.44	-0.41
West Sussex	0	67.22	67.68	0.46	57.66	62.90	5.24	70.39	69.00	-1.39
Western Cheshire	0	75.75	68.31	-7.44	78.16	72.46	-5.70	72.77	67.79	-4.98
Westminster	0	64.98	60.82	-4.16	68.82	71.47	2.65	NA	NA	NA
Wiltshire	0	70.63	73.22	2.59	72.52	78.04	5.52	69.94	72.26	2.32
Wirral	0	67.01	59.71	-7.30	69.94	62.72	-7.22	65.07	56.55	-8.52
Wolverhampton City	1	52.79	62.02	9.23	52.02	64.88	12.86	51.73	53.48	1.75
Worcestershire	0	68.97	71.68	2.71	71.17	71.57	0.40	69.47	72.62	3.15

Appendix Section 4

Results calculated by attributing GP supply to LSOAs and aggregating based on fifths of LSOAs ranked by IMD score - **GP registrars and retainers excluded from the calculation - these are the basecase results used in the paper**

Figure A4.1: Trend in FTE GP supply over time excluding registrars and retainers

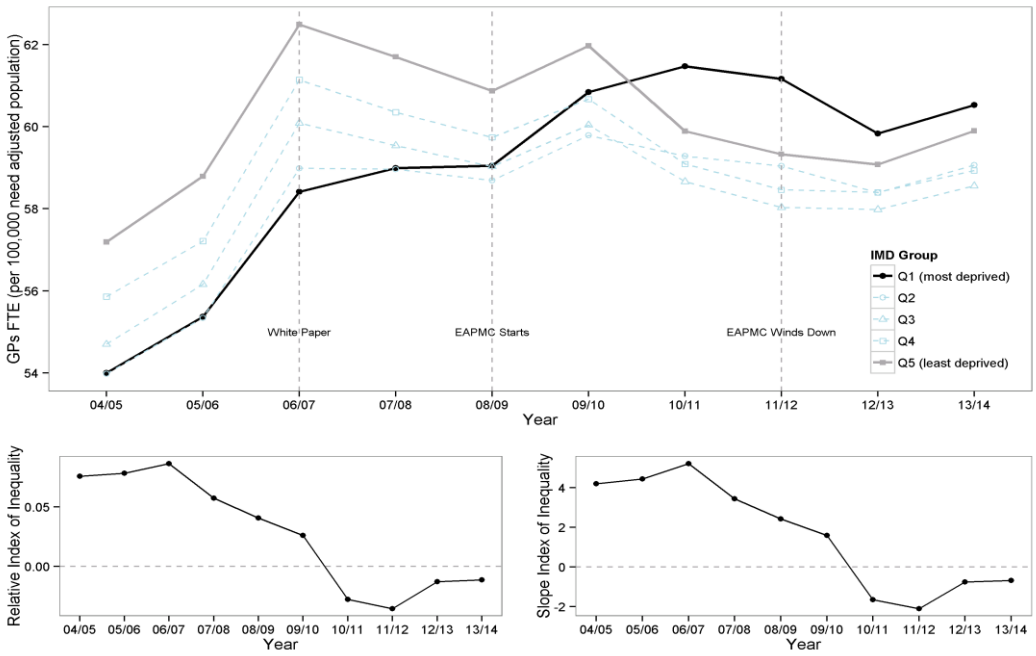


Figure A4.2: FTE GP supply in 2006/07 and 2011/12 excluding registrars and retainers

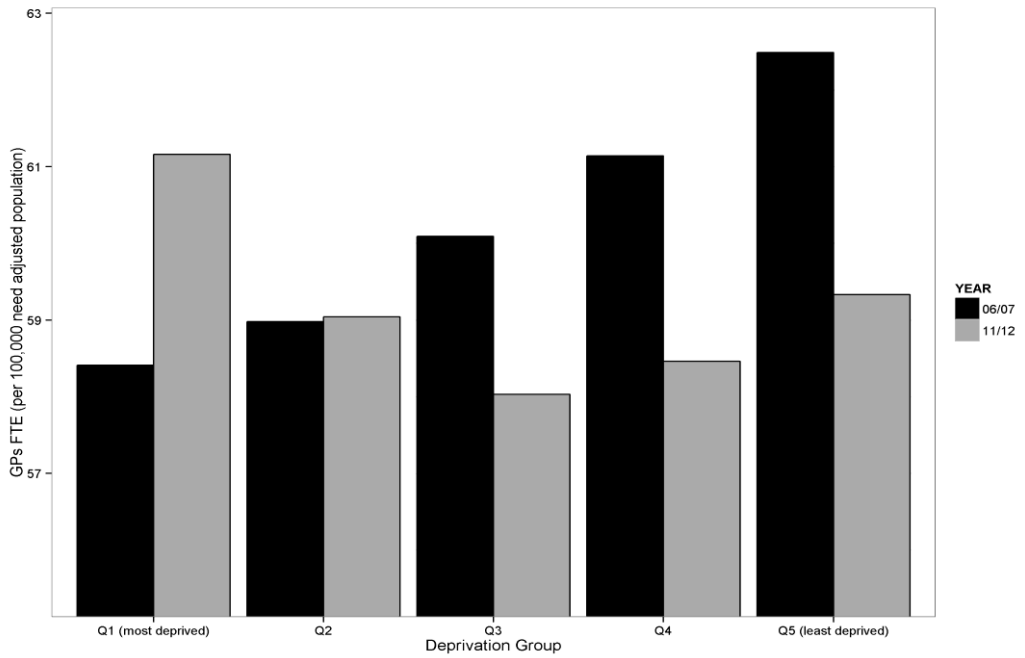


Figure A4.3: Trend in total headcount and FTE GP supply over time excluding registrars and retainers

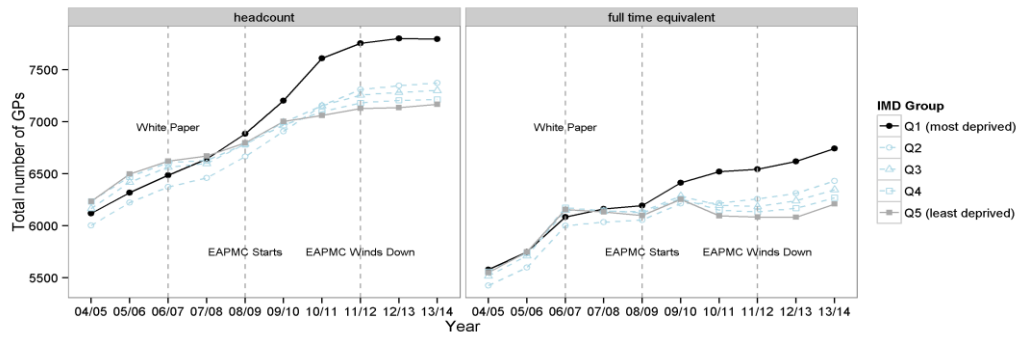
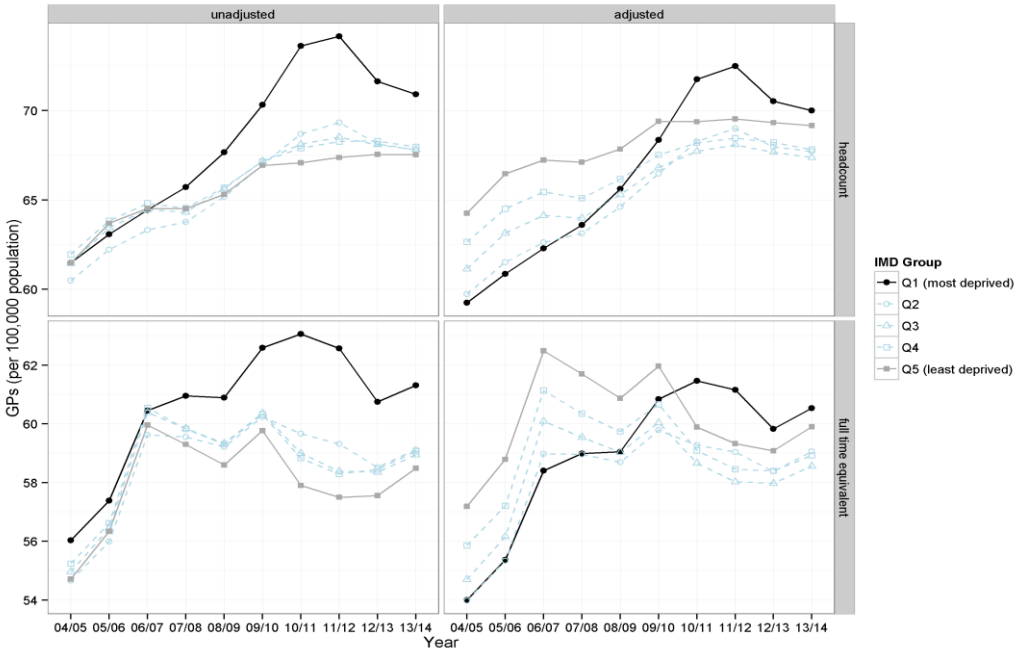


Figure A4.4: Trend in unadjusted and adjusted headcount and FTE GP supply over time excluding registrars and retainers



Regression A4.1: Test for difference in slope index of inequality between 2006/07 and 2011/12

```
Call:
lm(formula = FTE_PER100K_ADJ ~ YEAR * IMD_DECILE, data = subset(deciles,
    YEAR %in% c("2006", "2011")))

Residuals:
     Min       1Q   Median       3Q      Max
-1.27994 -0.31105  0.01673  0.26021  1.44945

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)         57.3527     0.5315 107.910  < 2e-16 ***
YEAR2011             3.0080     0.7516   4.002  0.00103 **
IMD_DECILE           5.2152     0.8566   6.088 1.57e-05 ***
YEAR2011:IMD_DECILE -7.3164     1.2114  -6.040 1.72e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 0.778 on 16 degrees of freedom
Multiple Adjusted R-squared:  0.719
F-statistic:  17.2 on 3 and 16 DF,  p-value: 2.917e-05
```

Figure A4.5: Distribution of change in FTE GP supply in PCTs between 2006/07 and 2011/12 by underdoctored status excluding registrars and retainers

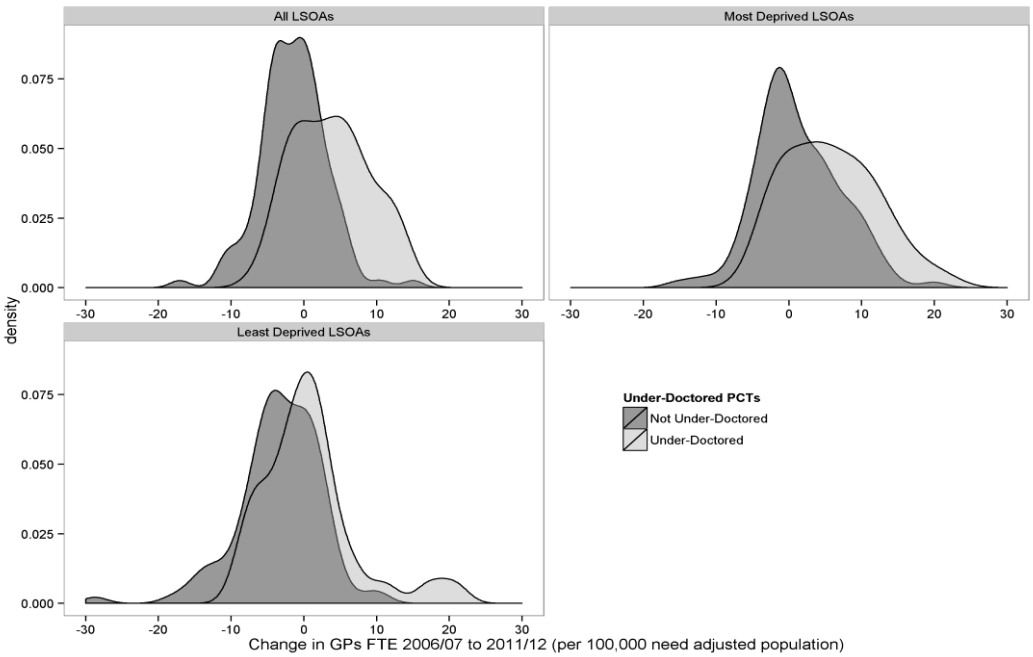


Figure A4.6: Distribution of GP Supply and Practices Nurses in 2013/14

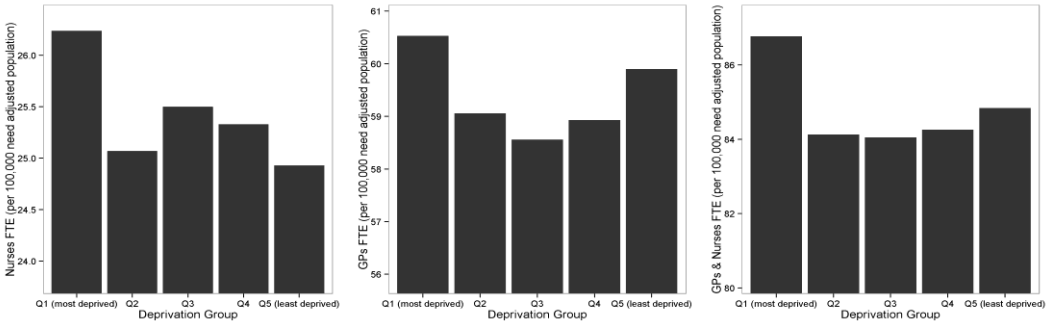


Figure A4.7: Distribution of GP Supply and Practices Nurses in 2013/14 (zeroed scale)

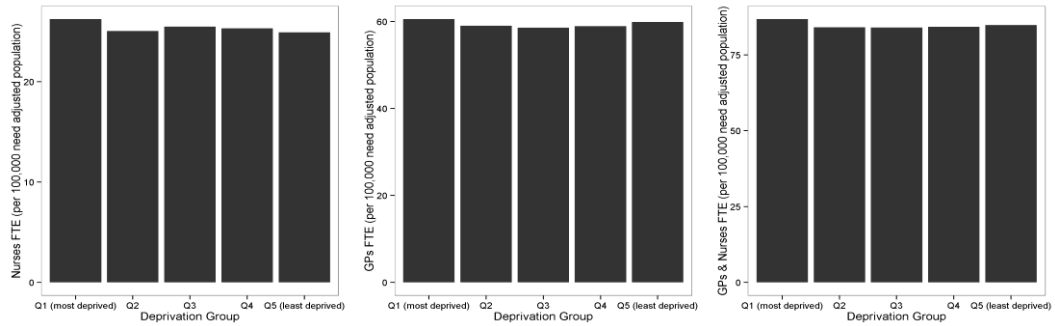


Figure A4.8: GP FTE per 100,000 at LSOA level in 2006/07 and 2011/12

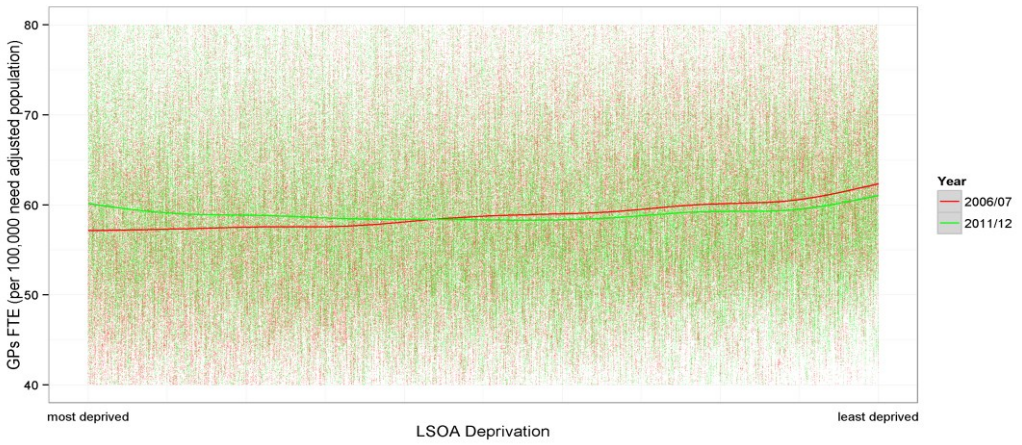


Figure A4.9: Change in GP FTE per 100,000 at LSOA level between 2006/07 and 2011/12

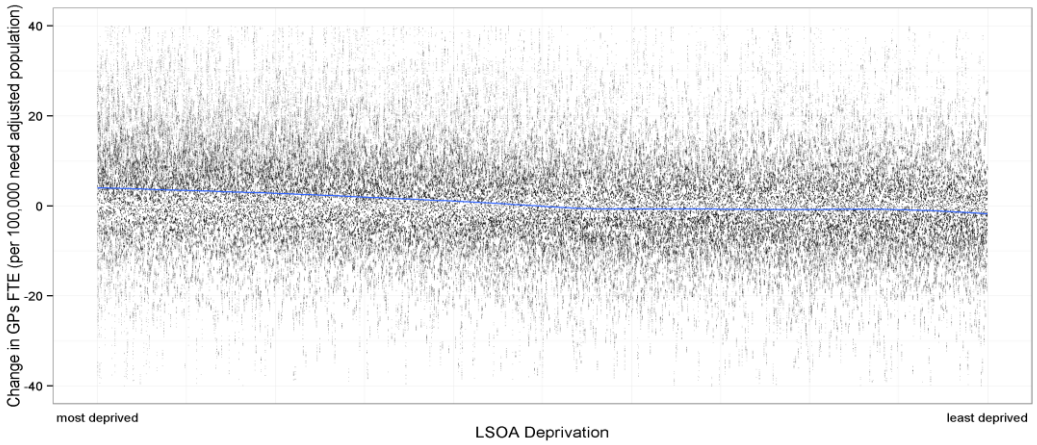
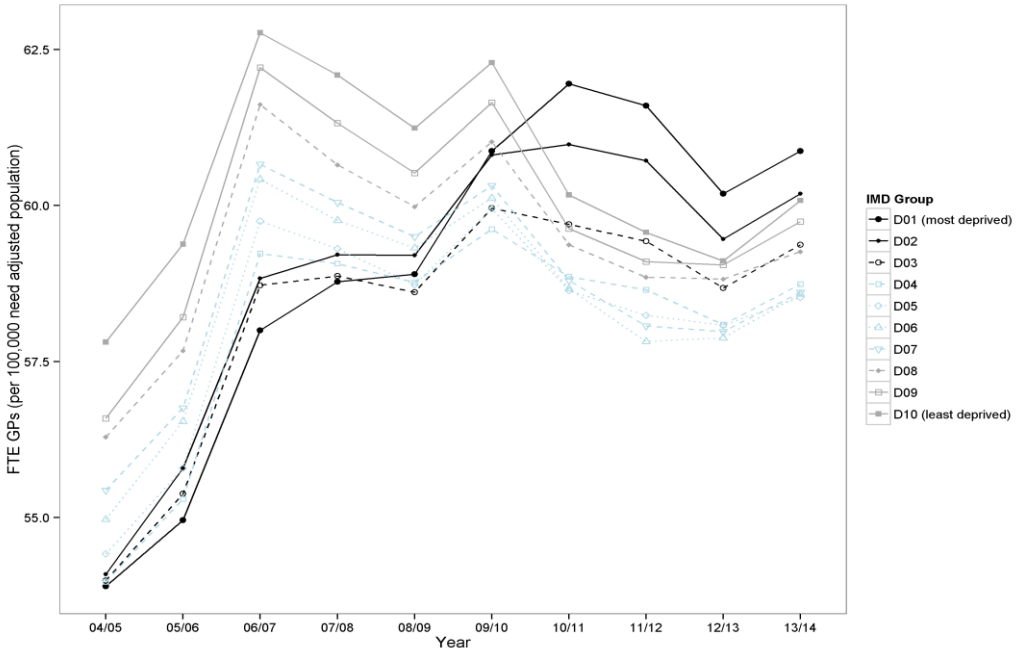


Figure A4.10: GP FTE by IMD Decile



Appendix Section 5

Results calculated by attributing GP supply to LSOAs and aggregating based on fifths of LSOAs ranked by IMD score - **all GPs including registrars and retainers** used in the calculations

Figure A5.1: Trend in FTE GP supply over time including registrars and retainers

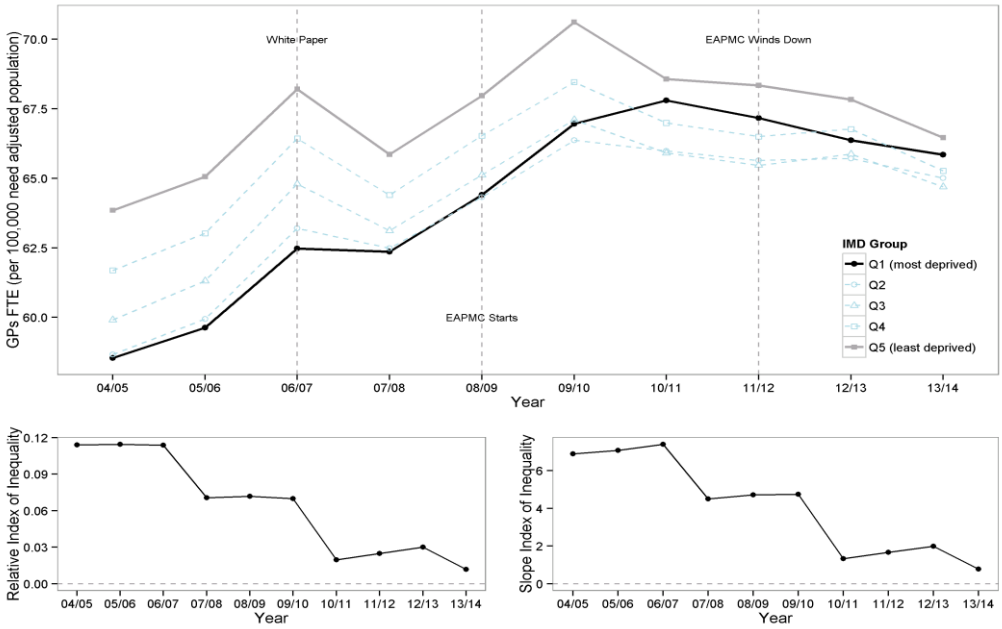


Figure A5.2: FTE GP supply in 2006/07 and 2011/12 including registrars and retainers

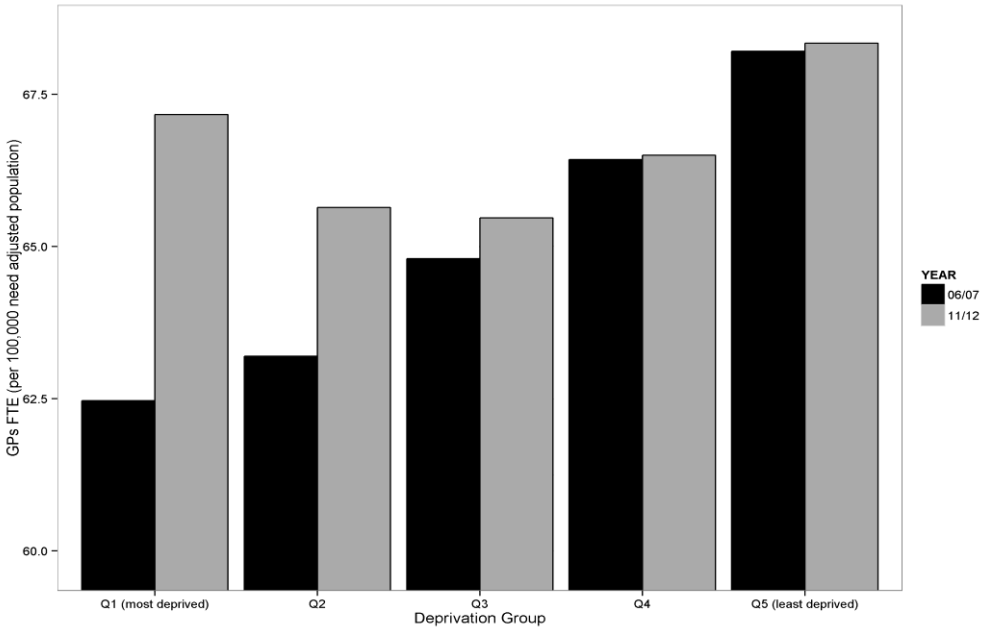


Figure A5.3: Trend in total headcount and FTE GP supply over time including registrars and retainers

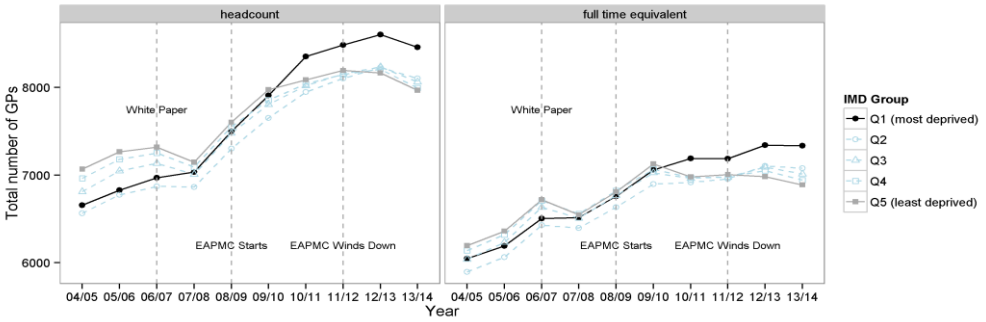
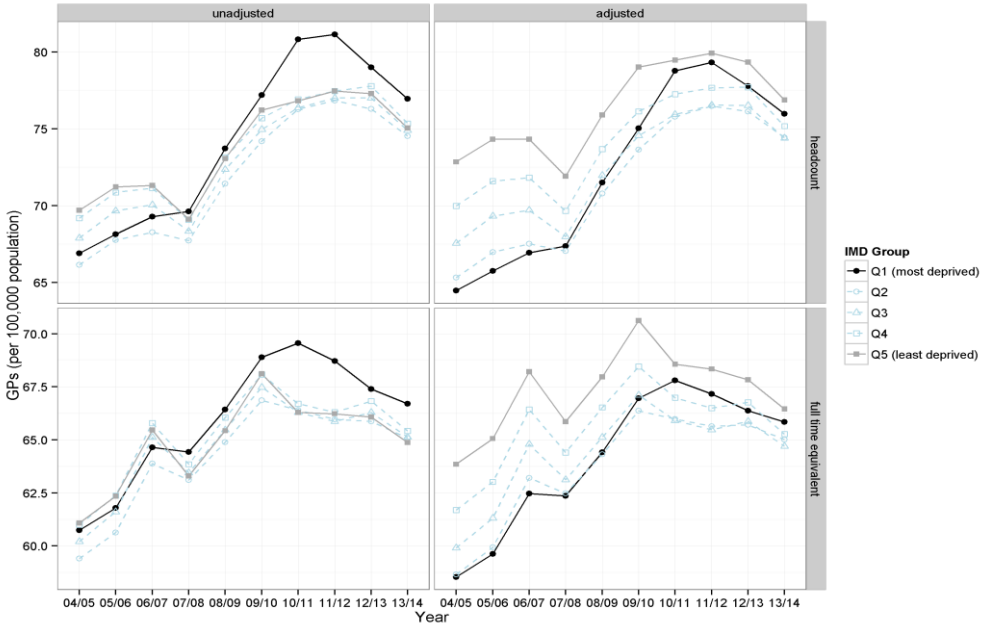


Figure A5.4: Trend in unadjusted and adjusted headcount and FTE GP supply over time including registrars and retainers



Regression A5.1: Test for difference in slope index of inequality between 2006/07 and 2011/12

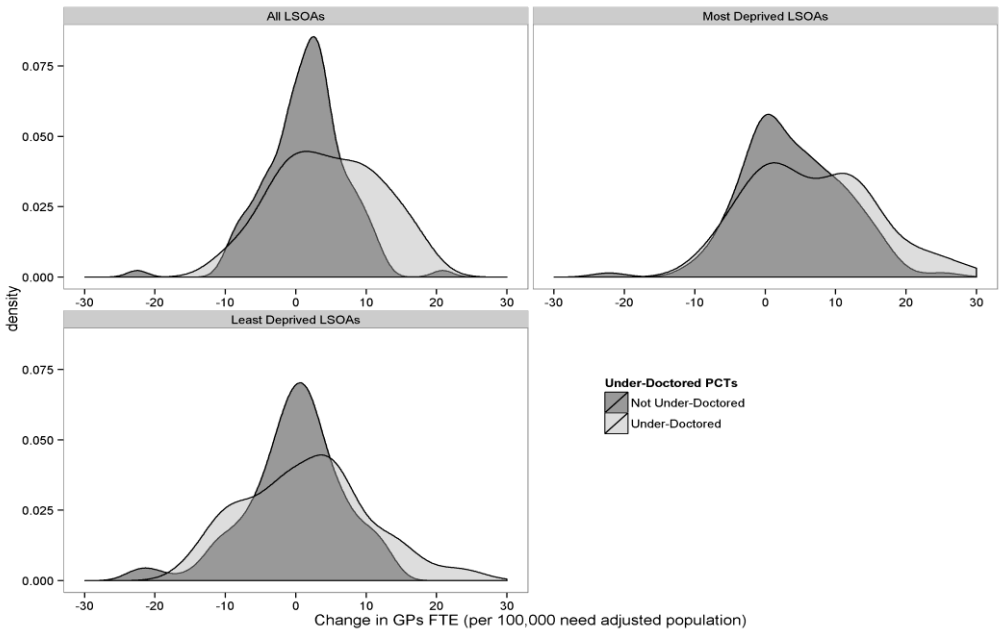
```
Call:
lm(formula = FTE_PER100K_ADJ ~ YEAR * IMD_DECILE, data = subset(deciles,
    YEAR %in% c("2006", "2011")))

Residuals:
     Min       1Q   Median       3Q      Max
-1.16200 -0.40845 -0.07703  0.42570  1.49800

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)        60.9533     0.5718 106.607  < 2e-16 ***
YEAR2011            4.7587     0.8086   5.885 2.30e-05 ***
IMD_DECILE          7.4012     0.9215   8.032 5.27e-07 ***
YEAR2011:IMD_DECILE -5.7412     1.3031  -4.406 0.000442 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.837 on 16 degrees of freedom
Multiple Adjusted R-squared:  0.8138
F-statistic: 28.68 on 3 and 16 DF,  p-value: 1.131e-06
```

Figure A5.5: Distribution of change in FTE GP supply in PCTs between 2006/07 and 2011/12 by underdoctored status including registrars and retainers



Appendix Section 6

Results calculated by attributing GP supply to LSOAs and aggregating based on fifths of LSOAs ranked by IMD score - **only looking at GP registrars**

Figure A6.1: Trend in FTE GP supply over time registrars only

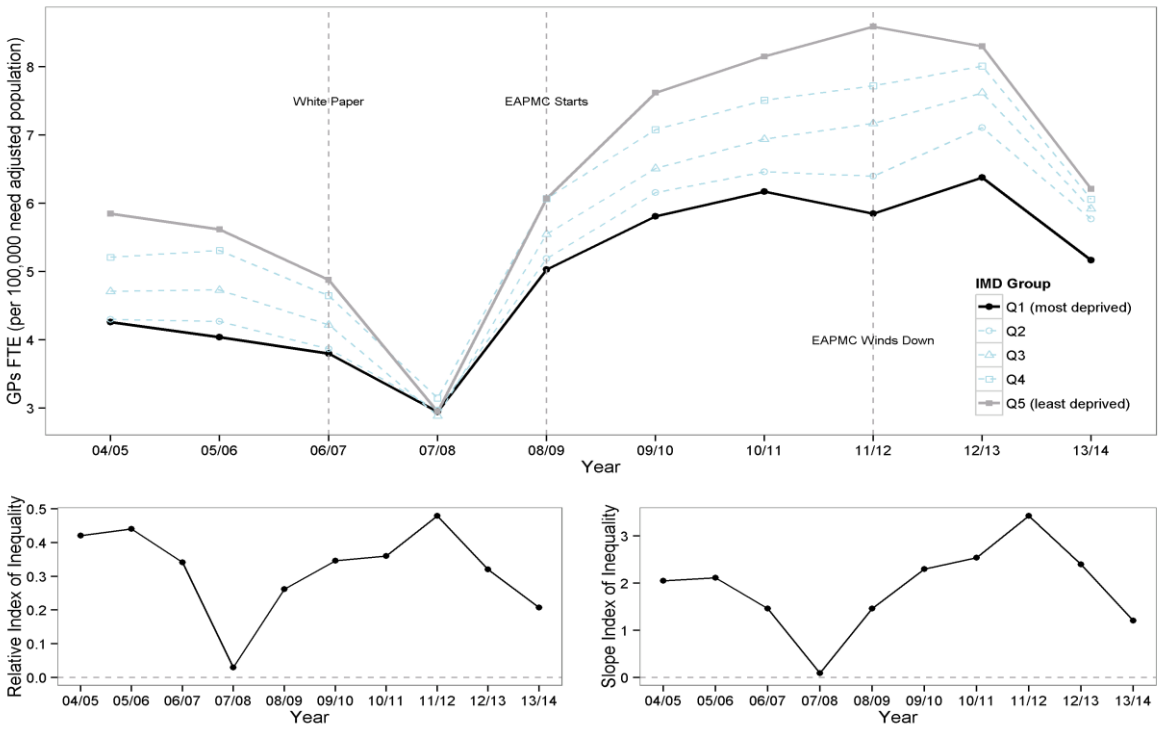


Figure A6.2: FTE GP supply in 2006/07 and 2011/12 registrars only

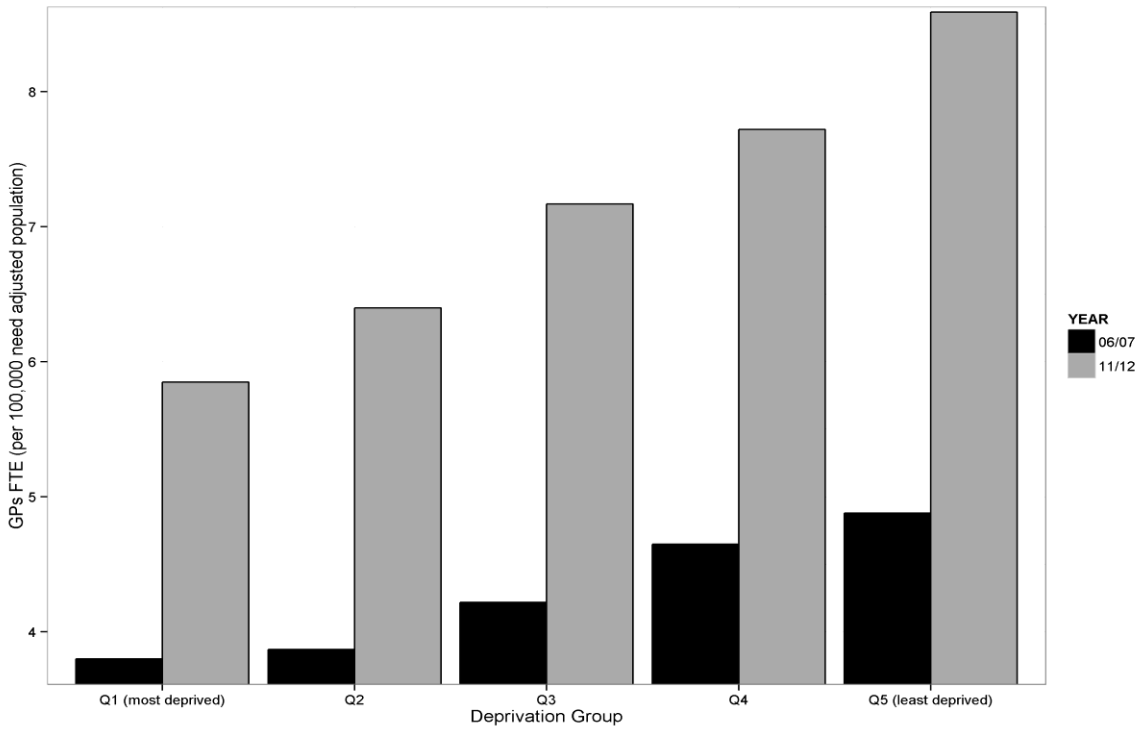


Figure A6.3: Trend in total headcount and FTE GP supply over time registrars only

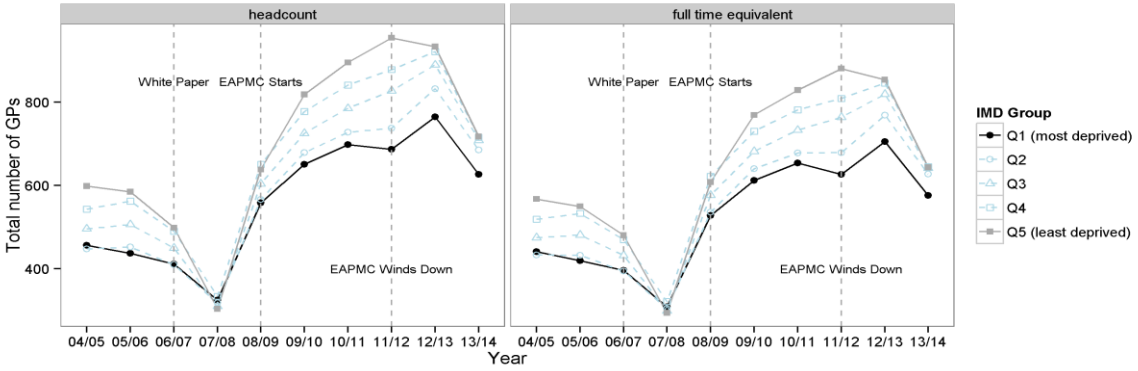
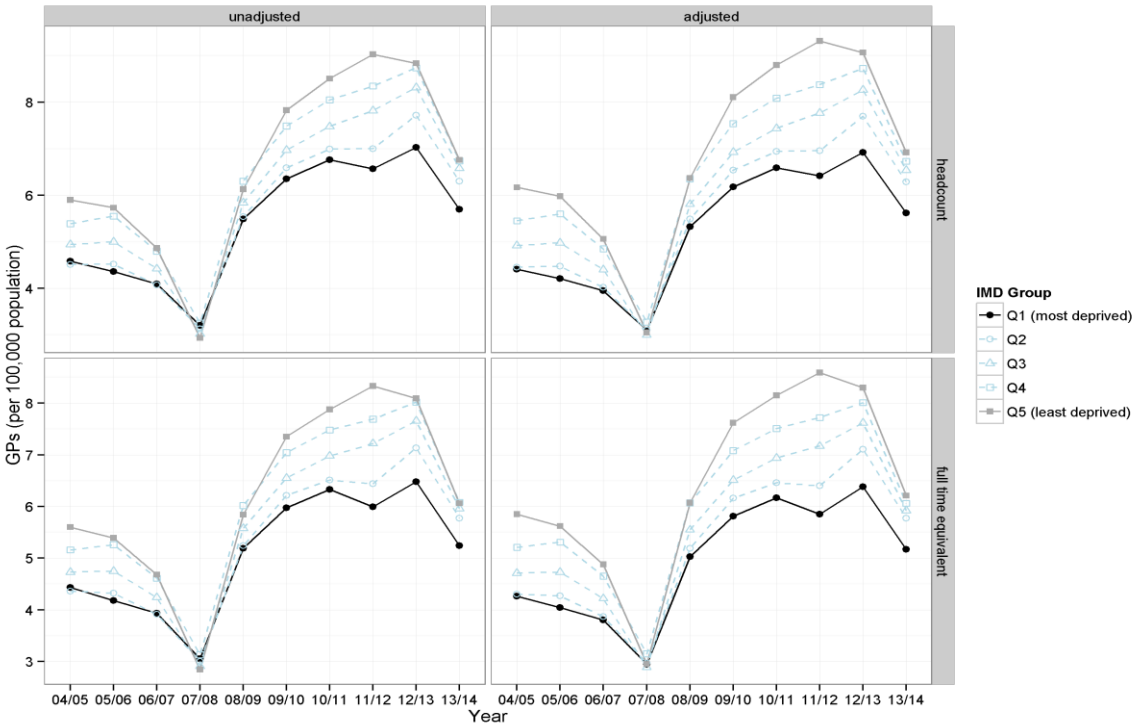


Figure A6.4: Trend in unadjusted and adjusted headcount and FTE GP supply over time registrars only



Regression A6.1: Test for difference in slope index of inequality between 2006/07 and 2011/12

```
Call:
lm(formula = FTE_PER100K_ADJ ~ YEAR * IMD_DECILE, data = subset(deciles,
    YEAR %in% c("2006", "2011")))

Residuals:
     Min       1Q   Median       3Q      Max
-0.21273 -0.06820 -0.01009  0.07977  0.16139

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)         3.47800    0.07755   44.85  < 2e-16 ***
YEAR2011            1.78467    0.10967   16.27 2.24e-11 ***
IMD_DECILE          1.46182    0.12498   11.70 2.98e-09 ***
YEAR2011:IMD_DECILE 1.96788    0.17674   11.13 6.04e-09 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.1135 on 16 degrees of freedom
Multiple Adjusted R-squared:  0.9954
F-statistic:  1360 on 3 and 16 DF,  p-value: < 2.2e-16
```

Appendix Section 7

Results calculated by attributing GP supply to LSOAs and aggregating based on fifths of LSOAs ranked by IMD score - **only looking at GP retainers**

Figure A7.1: Trend in FTE GP supply over time retainers only

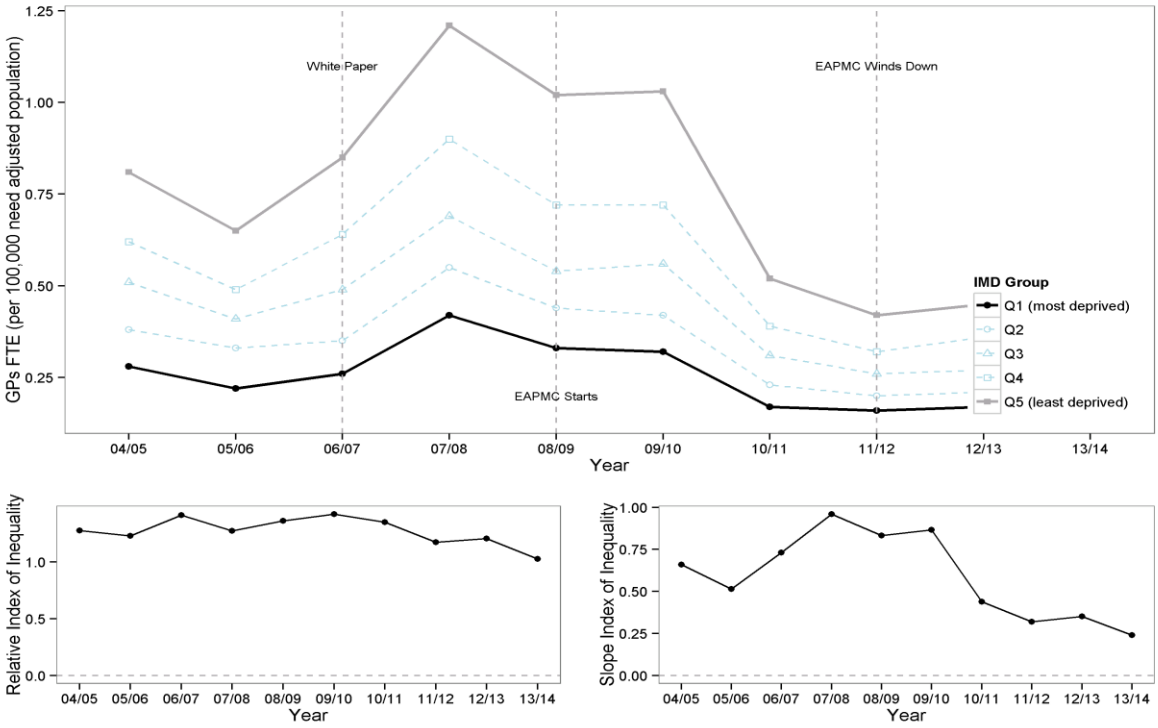


Figure A7.2: FTE GP supply in 2006/07 and 2011/12 retainers only

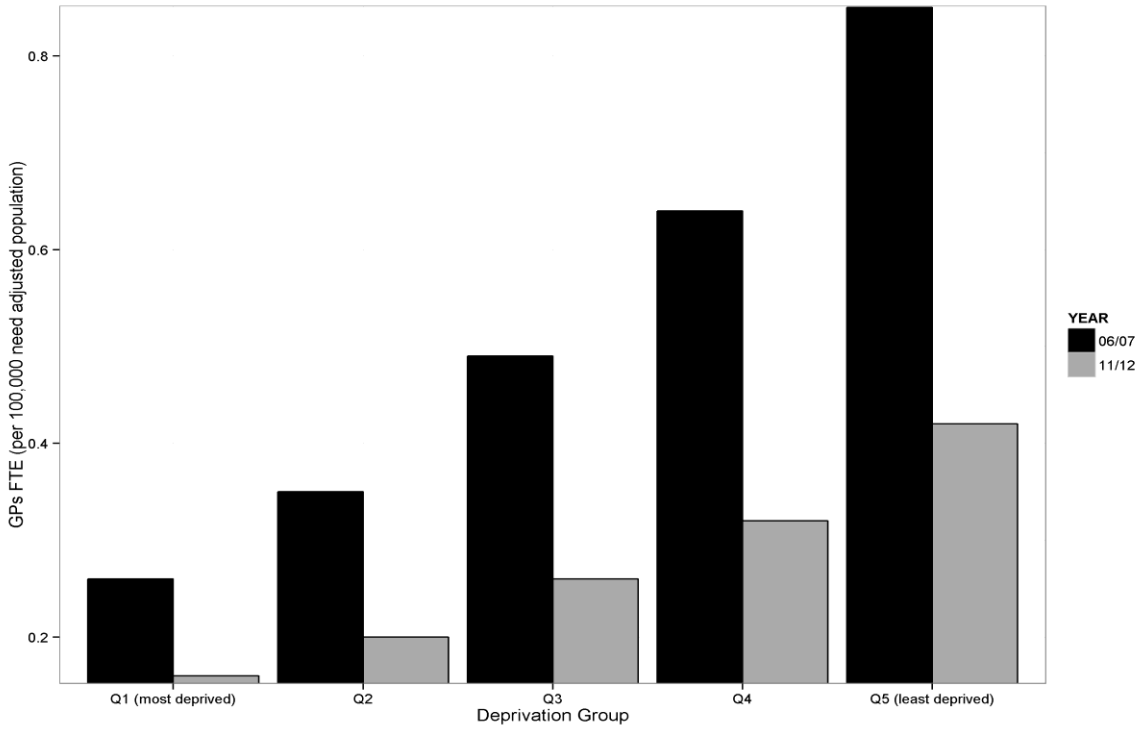


Figure A7.3: Trend in total headcount and FTE GP supply over time retainers only

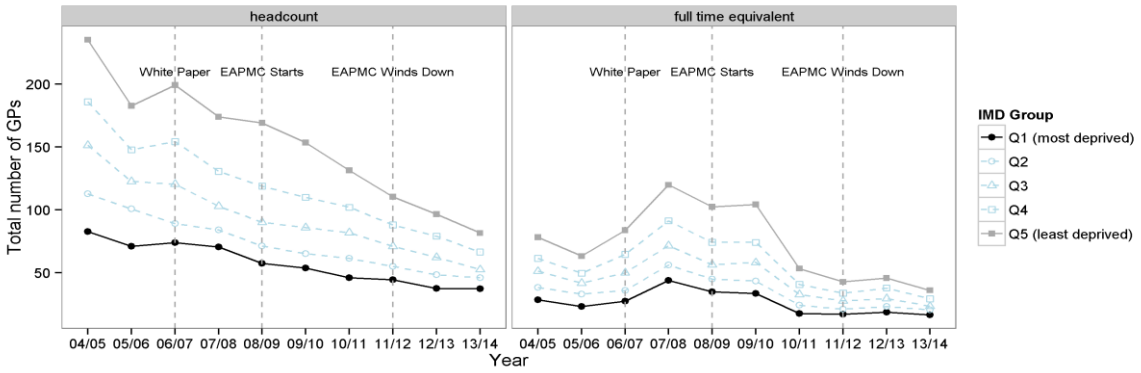
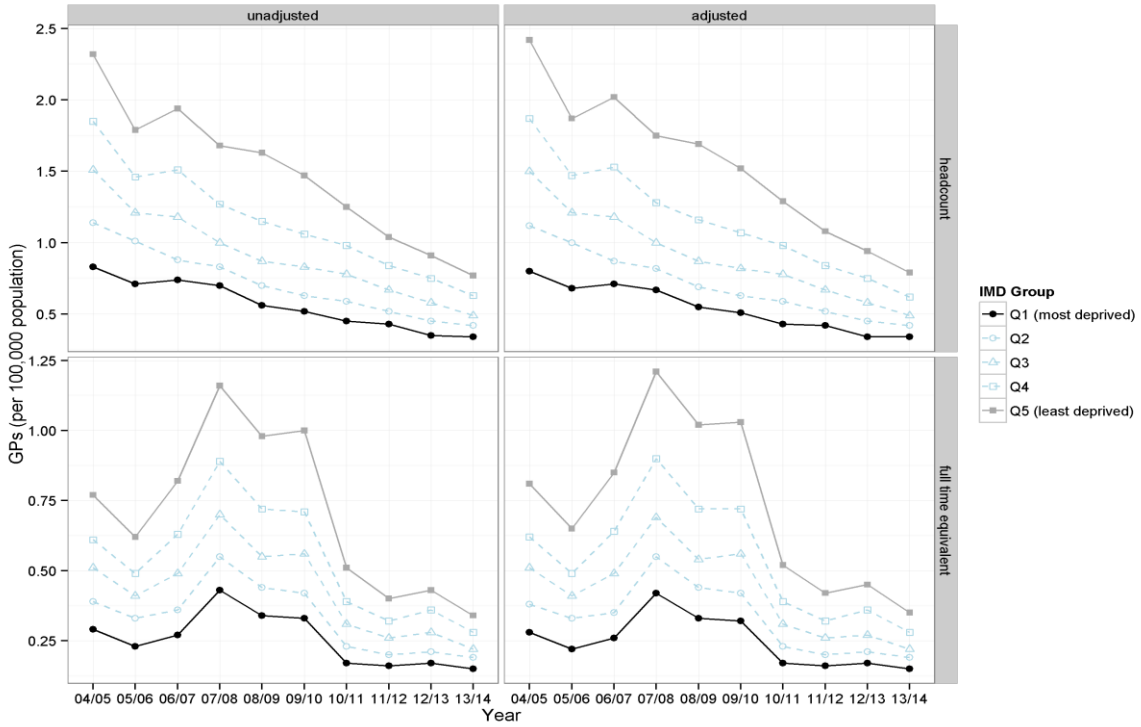


Figure A7.4: Trend in unadjusted and adjusted headcount and FTE GP supply over time retainers only



Regression A7.1: Test for difference in slope index of inequality between 2006/07 and 2011/12

```
Call:
lm(formula = FTE_PER100K_ADJ ~ YEAR * IMD_DECILE, data = subset(deciles,
    YEAR %in% c("2006", "2011")))

Residuals:
      Min        1Q    Median        3Q       Max
-0.049273 -0.022864 -0.010758  0.008636  0.121818

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)          0.11667    0.03033   3.847  0.00143 **
YEAR2011            -0.02000    0.04289  -0.466  0.64730
IMD_DECILE           0.73152    0.04888  14.965 7.91e-11 ***
YEAR2011:IMD_DECILE -0.41273    0.06913  -5.970 1.96e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.0444 on 16 degrees of freedom
Multiple Adjusted R-squared:  0.9565
F-statistic: 140.4 on 3 and 16 DF,  p-value: 1.056e-11
```

Appendix Section 8

Results calculated by **attributing IMD scores to practices excluding registrars and retainers** and aggregating based on fifths of population weighted practices ranked by IMD score

Figure A8.1: Trend in FTE GP supply over time excluding registrars and retainers practice level aggregation

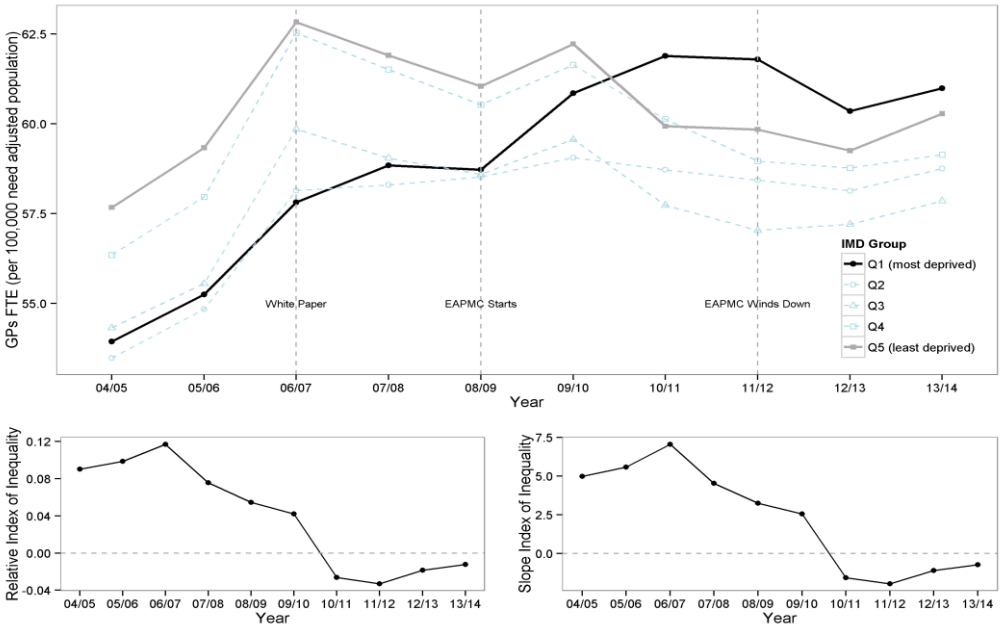


Figure A8.2: FTE GP supply in 2006/07 and 2011/12 excluding registrars and retainers practice level aggregation

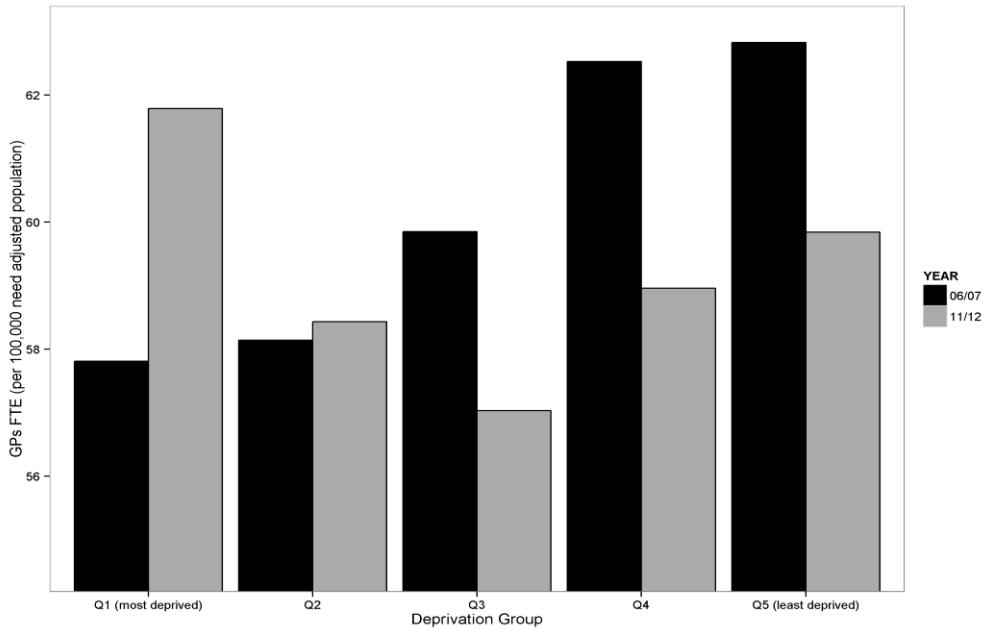


Figure A8.3: Trend in total headcount and FTE GP supply over time excluding registrars and retainers practice level aggregation

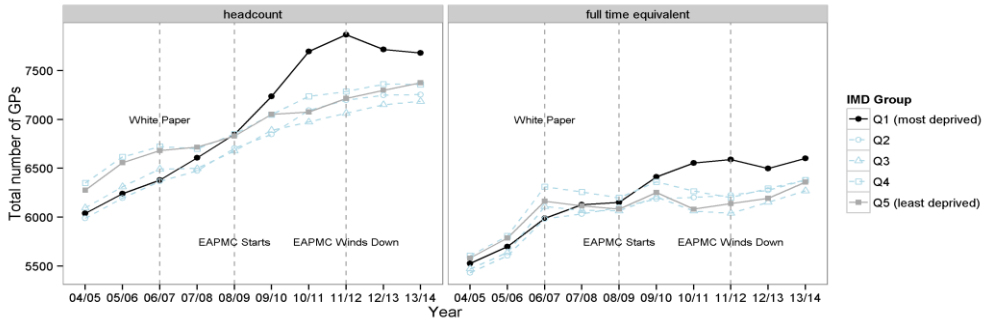
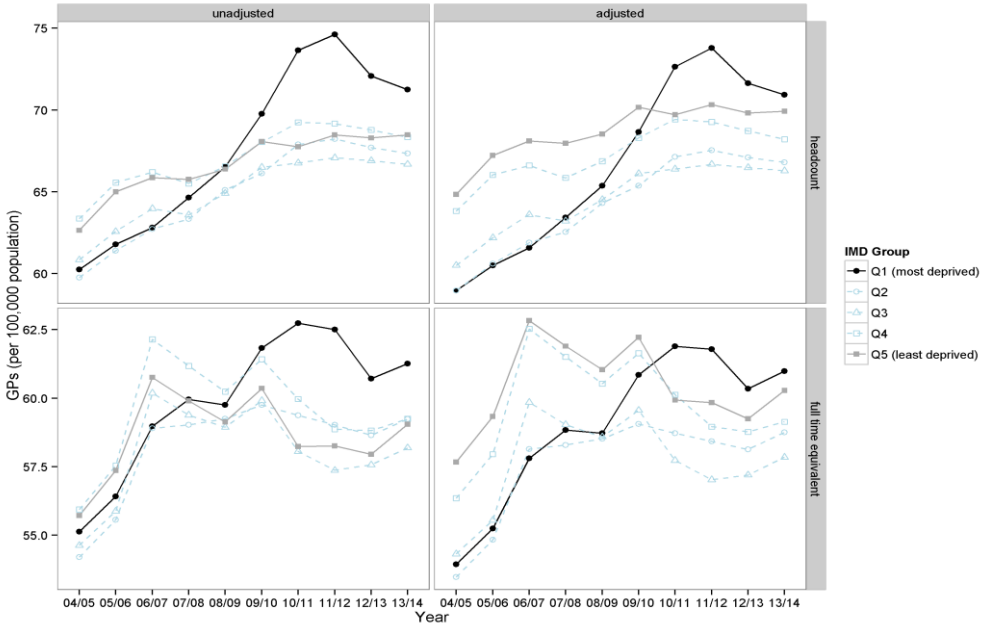


Figure A8.4: Trend in unadjusted and adjusted headcount and FTE GP supply over time excluding registrars and retainers practice level aggregation



Regression A8.1: Test for difference in slope index of inequality between 2006/07 and 2011/12

```
Call:
lm(formula = FTE_PER100K_ADJ ~ YEAR * IMD_DECILE, data = subset(deciles,
    YEAR %in% c("2006", "2011")))

Residuals:
    Min      1Q  Median      3Q     Max
-2.6158 -0.6283 -0.2555  0.8089  3.3422

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)           56.349      0.992  56.803  < 2e-16 ***
YEAR2011               3.934      1.403   2.804 0.012732 *
IMD_DECILE             7.054      1.599   4.412 0.000436 ***
YEAR2011:IMD_DECILE   -9.009      2.261  -3.985 0.001066 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.452 on 16 degrees of freedom
Multiple Adjusted R-squared:  0.5182
F-statistic: 7.811 on 3 and 16 DF,  p-value: 0.00196
```

Figure A8.5 Numbers of LSOA per GP Practice over Time

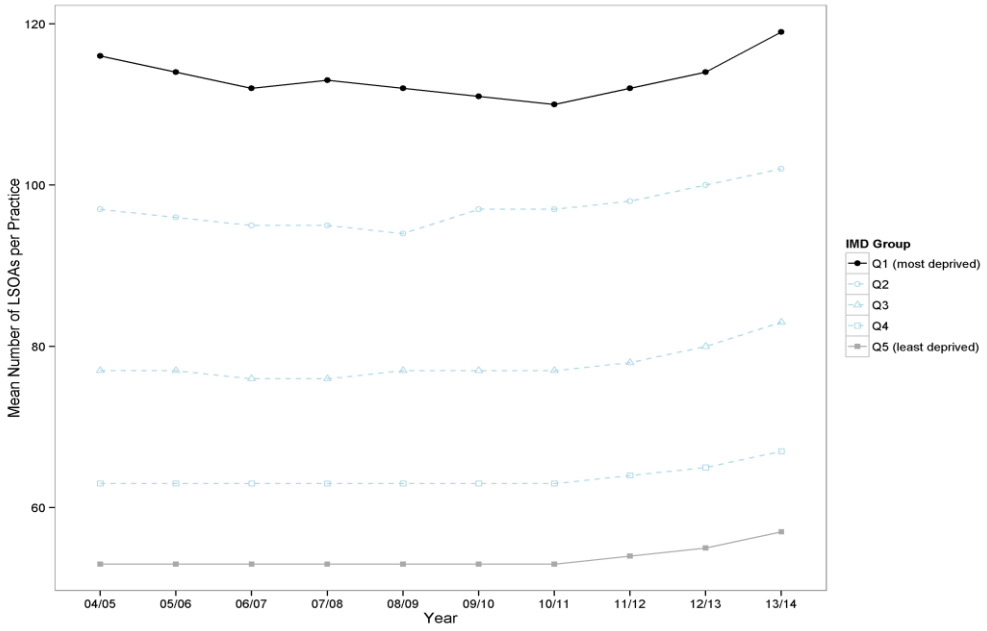
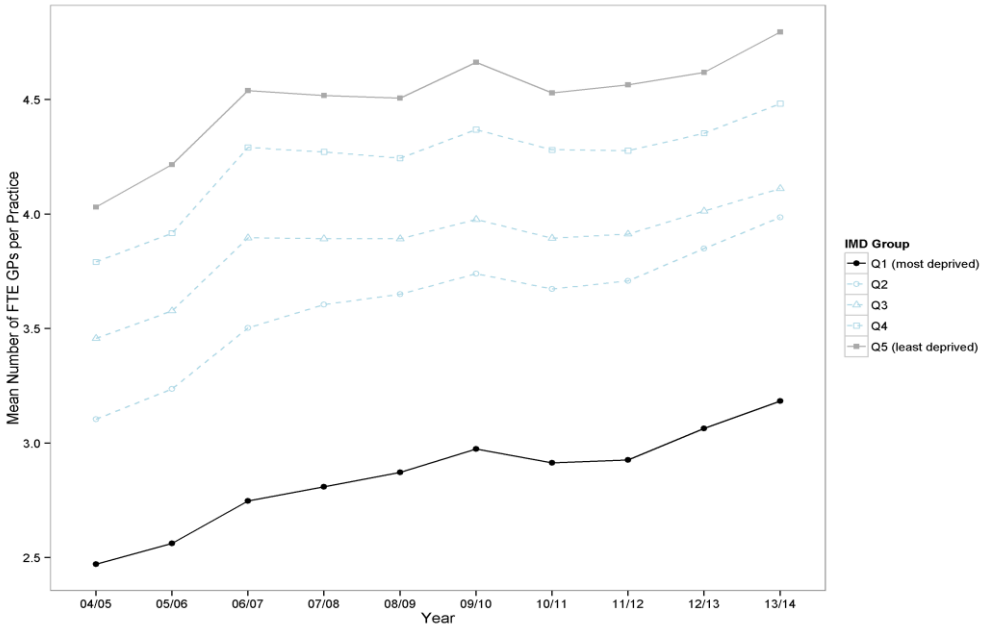


Figure A8.6 Numbers of FTE GPs per Practice over Time



Appendix Section 9

Results calculated by **attributing IMD scores to practices** and aggregating based on fifths of population weighted practices ranked by IMD score - all GPs including registrars and retainers included in the calculation

Figure A9.1: Trend in FTE GP supply over time including registrars and retainers practice level aggregation

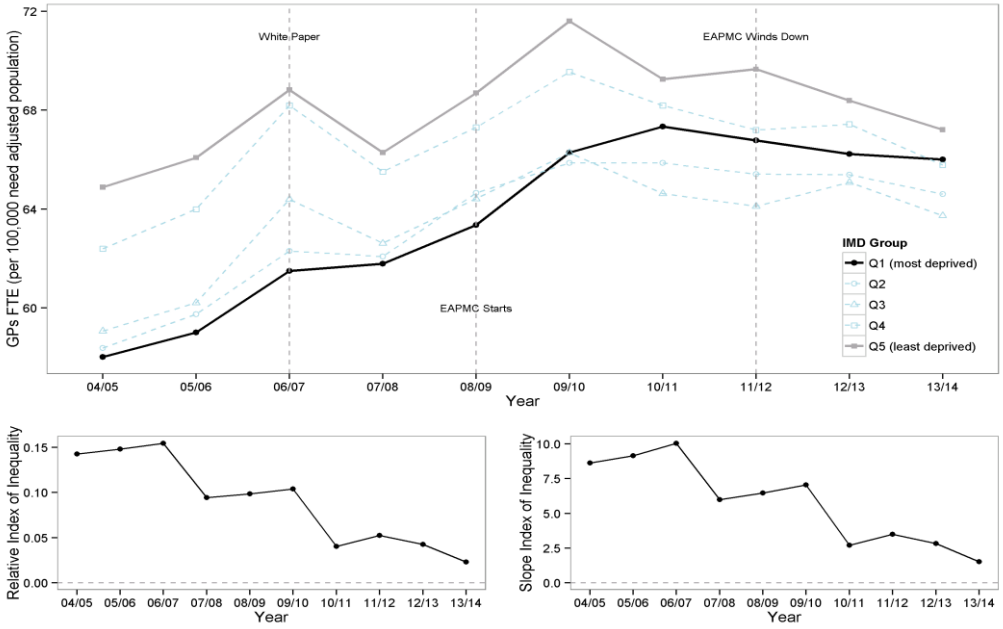


Figure A9.2: FTE GP supply in 2006/07 and 2011/12 including registrars and retainers practice level aggregation

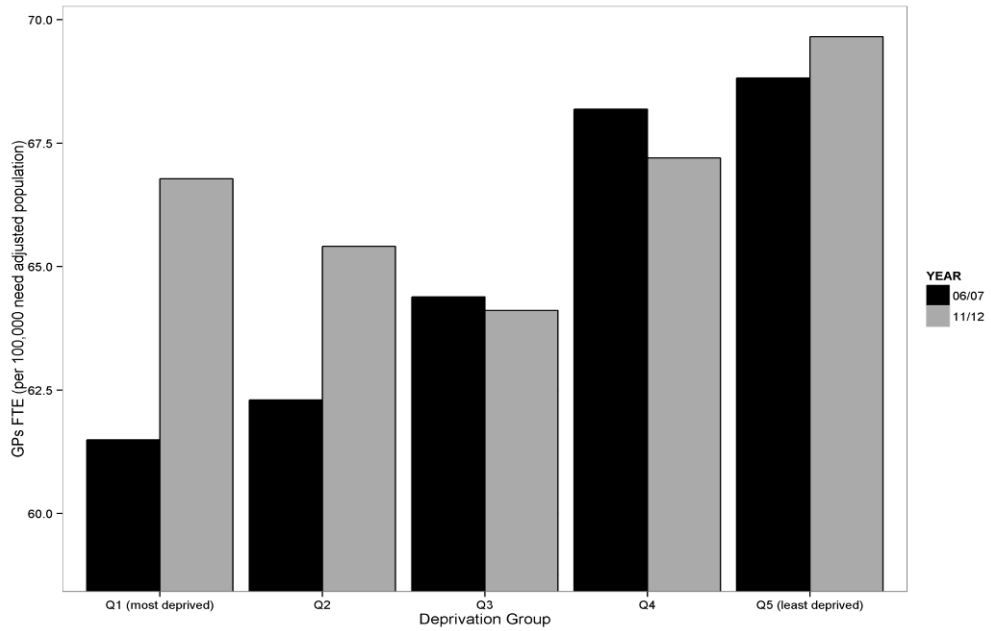


Figure A9.3: Trend in total headcount and FTE GP supply over time including registrars and retainers practice level aggregation

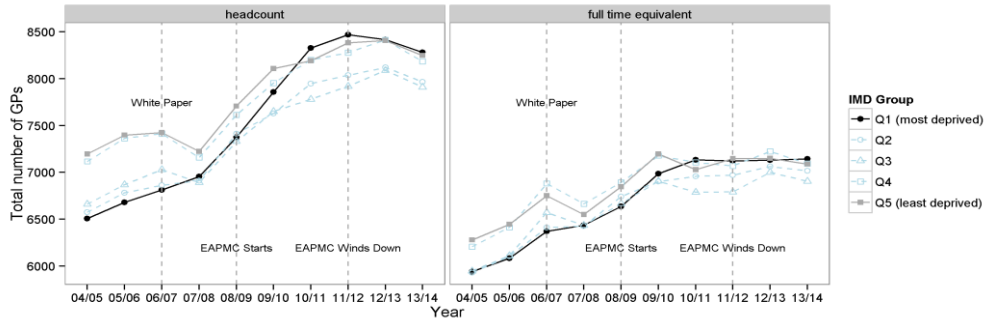
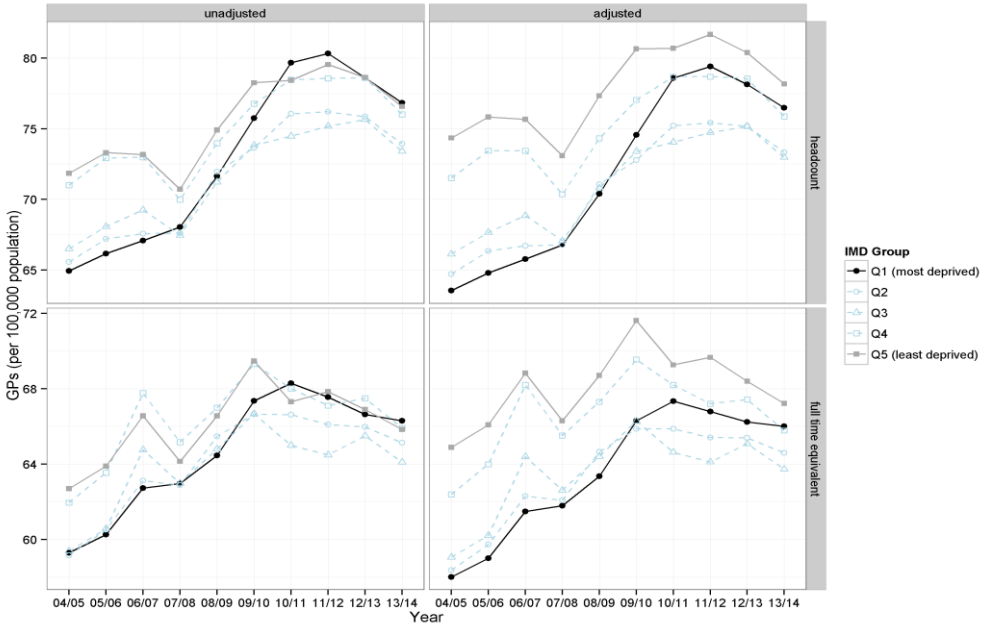


Figure A9.4: Trend in unadjusted and adjusted headcount and FTE GP supply over time including registrars and retainers practice level aggregation



Regression A9.1: Test for difference in slope index of inequality between 2006/07 and 2011/12

```
Call:
lm(formula = FTE_PER100K_ADJ ~ YEAR * IMD_DECILE, data = subset(deciles,
    YEAR %in% c("2006", "2011")))

Residuals:
    Min      1Q  Median      3Q     Max
-2.9198 -0.8870 -0.2299  1.1036  3.7836

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)           59.508      1.127  52.782  < 2e-16 ***
YEAR2011               5.210      1.594   3.268  0.00484 **
IMD_DECILE            10.056      1.817   5.535 4.53e-05 ***
YEAR2011:IMD_DECILE   -6.573      2.570  -2.558  0.02107 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.65 on 16 degrees of freedom
Multiple Adjusted R-squared:  0.6544
F-statistic: 12.99 on 3 and 16 DF,  p-value: 0.0001479
```

Appendix Section 10

Results calculated by attributing GP supply to LSOAs and aggregating based on fifths of LSOAs ranked by IMD score - **GP registrars and retainers excluded from the calculation - results for London**

Figure A10.1: Trend in FTE GP supply over time excluding registrars and retainers

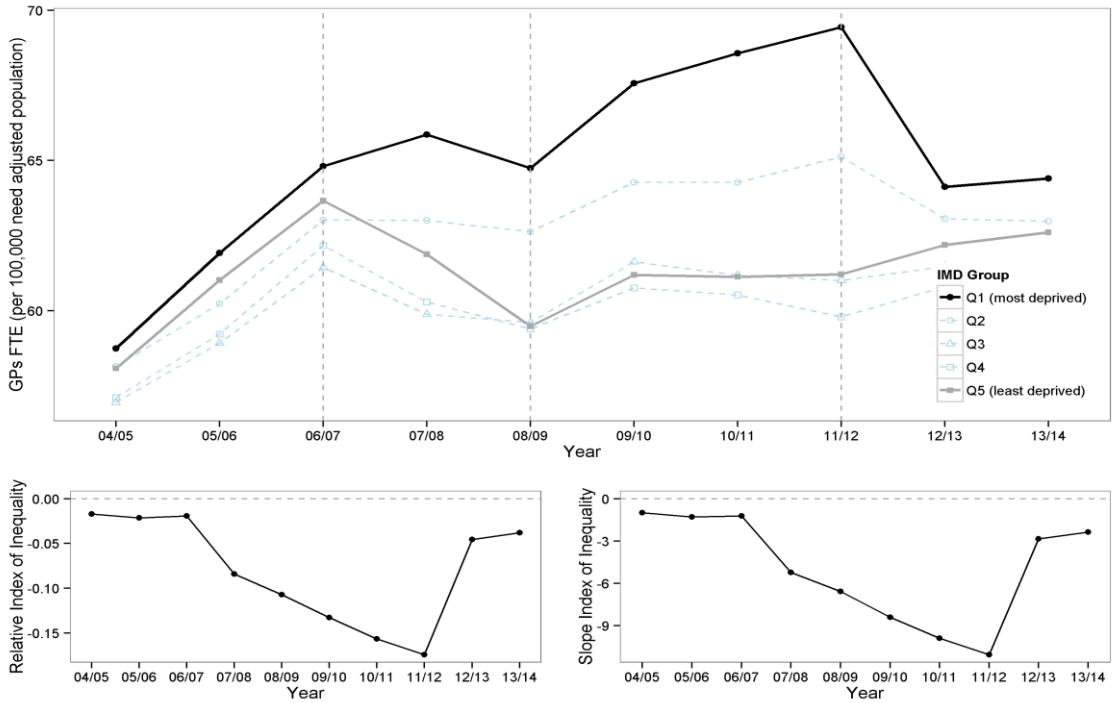


Figure A10.2: FTE GP supply in 2006/07 and 2011/12 excluding registrars and retainers

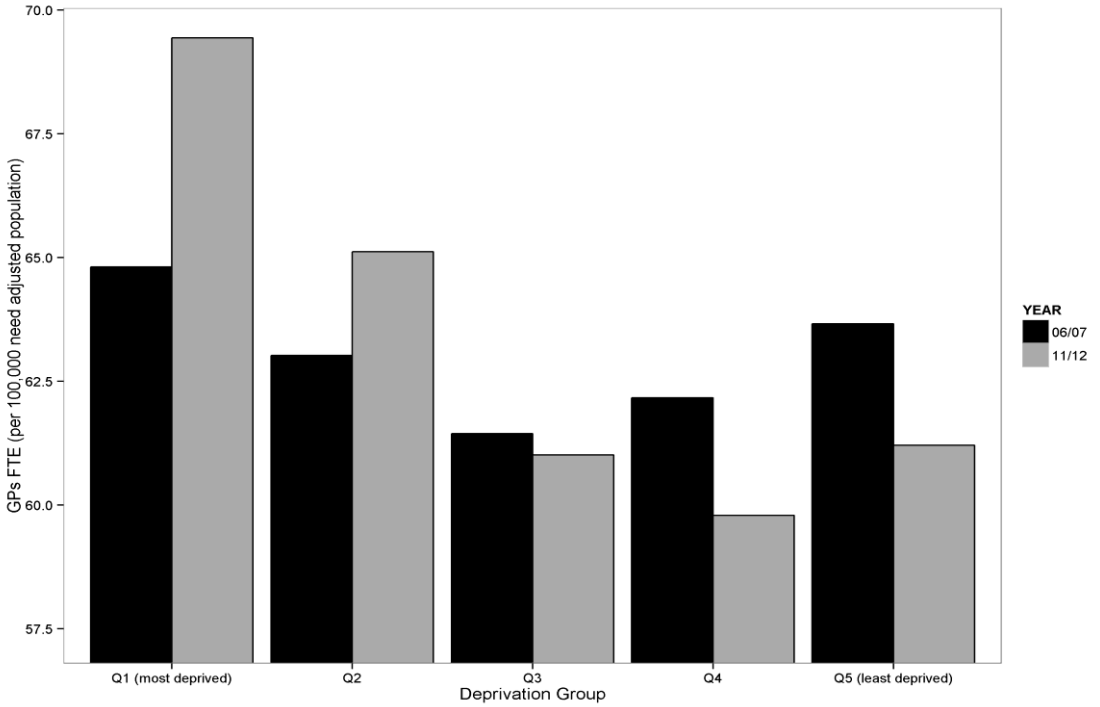


Figure A10.3: Trend in total headcount and FTE GP supply over time excluding registrars and retainers

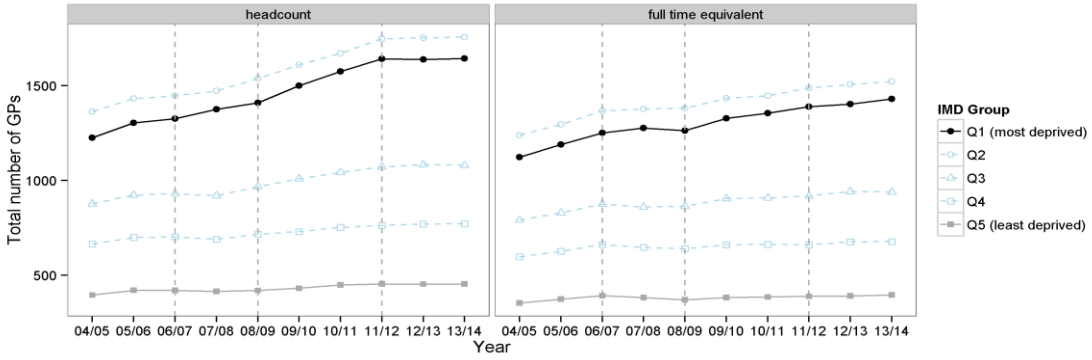
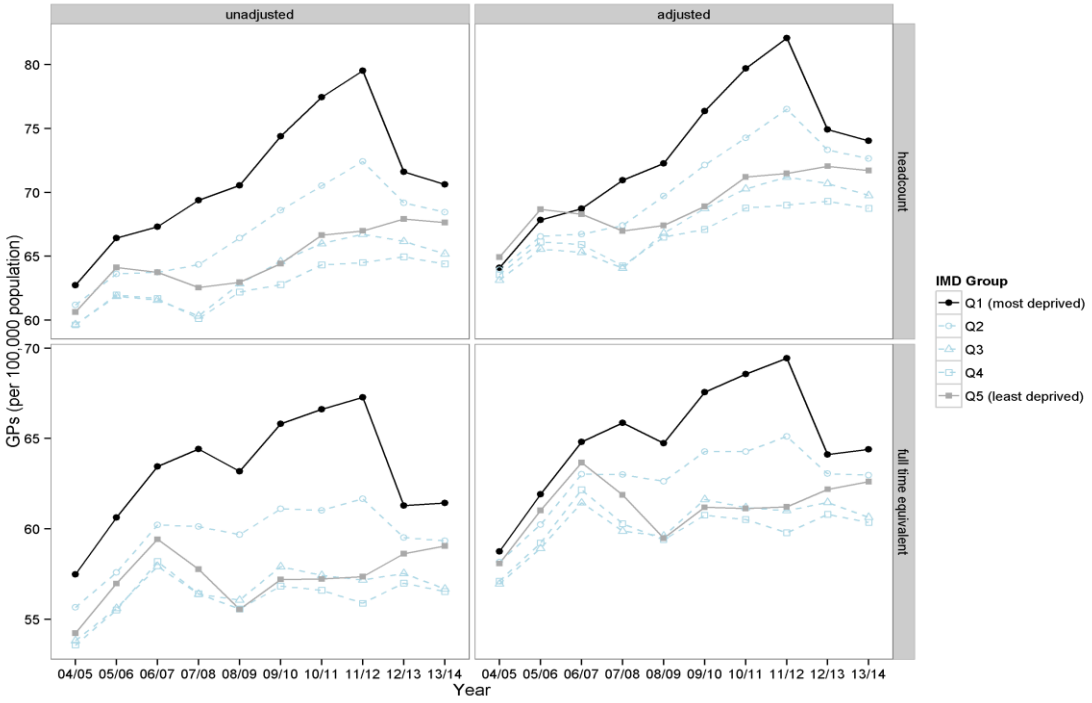


Figure A10.4: Trend in unadjusted and adjusted headcount and FTE GP supply over time excluding registrars and retainers



Regression A10.1: Test for difference in slope index of inequality between 2006/07 and 2011/12

```
Call:
lm(formula = FTE_PER100K_ADJ ~ YEAR * IMD_DECILE, data = subset(deciles,
    YEAR %in% c("2006", "2011")))

Residuals:
    Min      1Q  Median      3Q     Max
-2.4398 -1.1211 -0.2092  1.3358  3.4882

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)          63.687      1.257  50.664  < 2e-16 ***
YEAR2011              5.789      1.778   3.257  0.00495 **
IMD_DECILE           -1.215      2.026  -0.600  0.55704
YEAR2011:IMD_DECILE  -9.830      2.865  -3.431  0.00343 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.84 on 16 degrees of freedom
Multiple Adjusted R-squared:  0.5896
F-statistic:  10.1 on 3 and 16 DF,  p-value: 0.0005652
```

Appendix Section 11

Results calculated by attributing GP supply to LSOAs and aggregating based on fifths of LSOAs ranked by IMD score - **GP registrars and retainers excluded from the calculation - results for North of England**

Figure A11.1: Trend in FTE GP supply over time excluding registrars and retainers

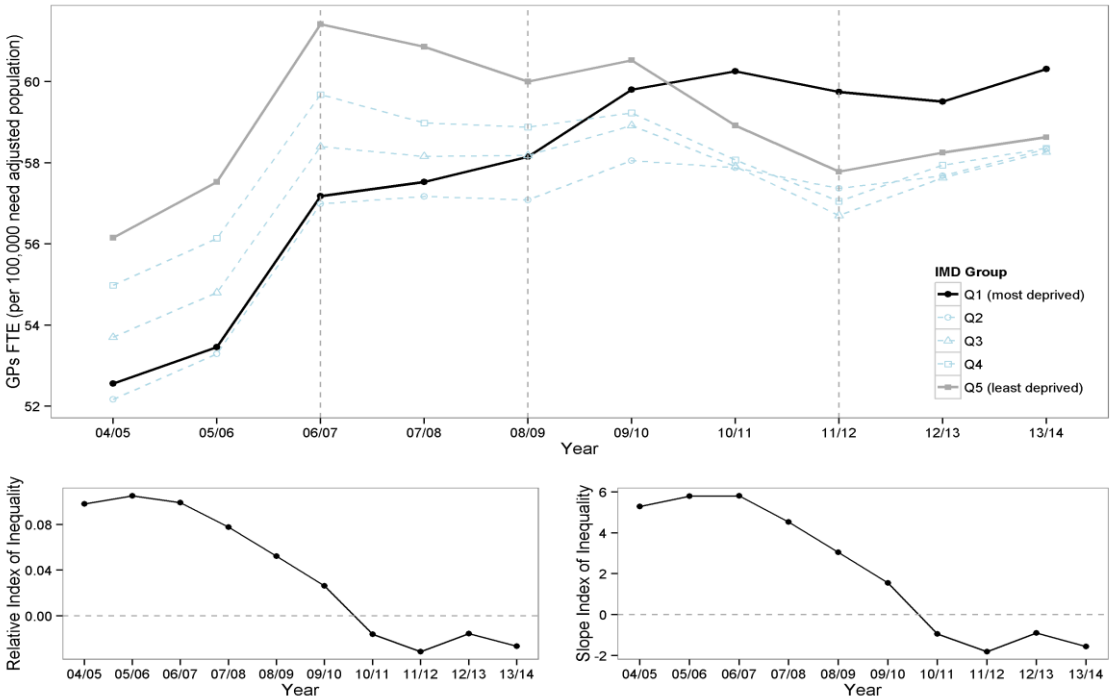


Figure A11.2: FTE GP supply in 2006/07 and 2011/12 excluding registrars and retainers

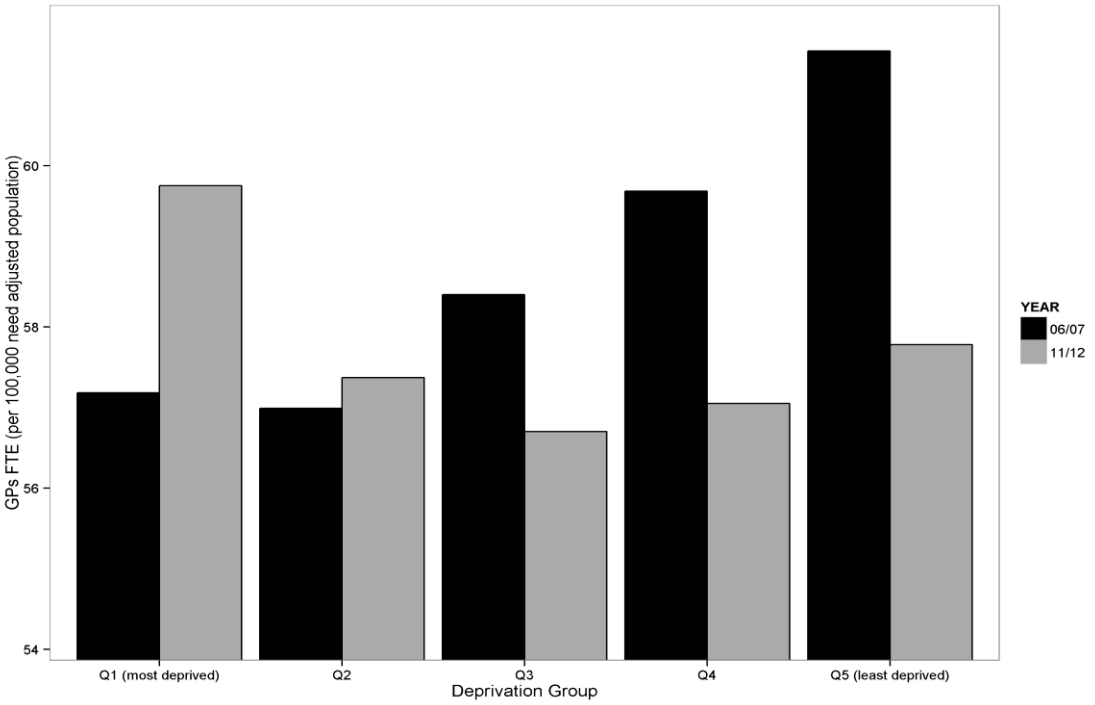


Figure A11.3: Trend in total headcount and FTE GP supply over time excluding registrars and retainers

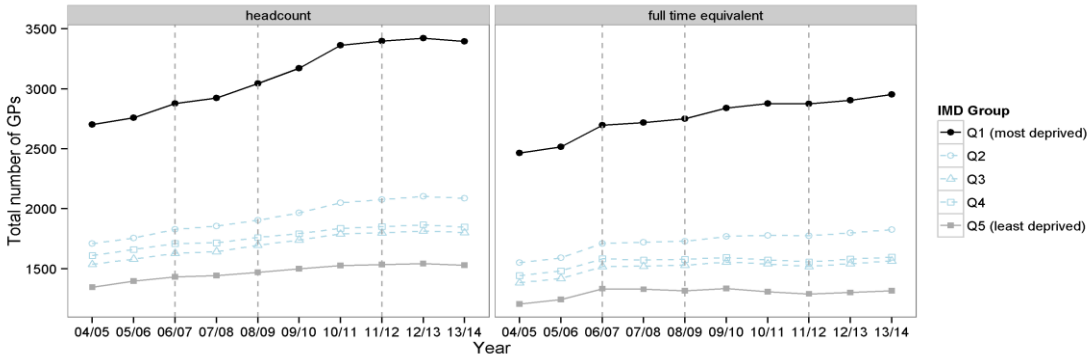
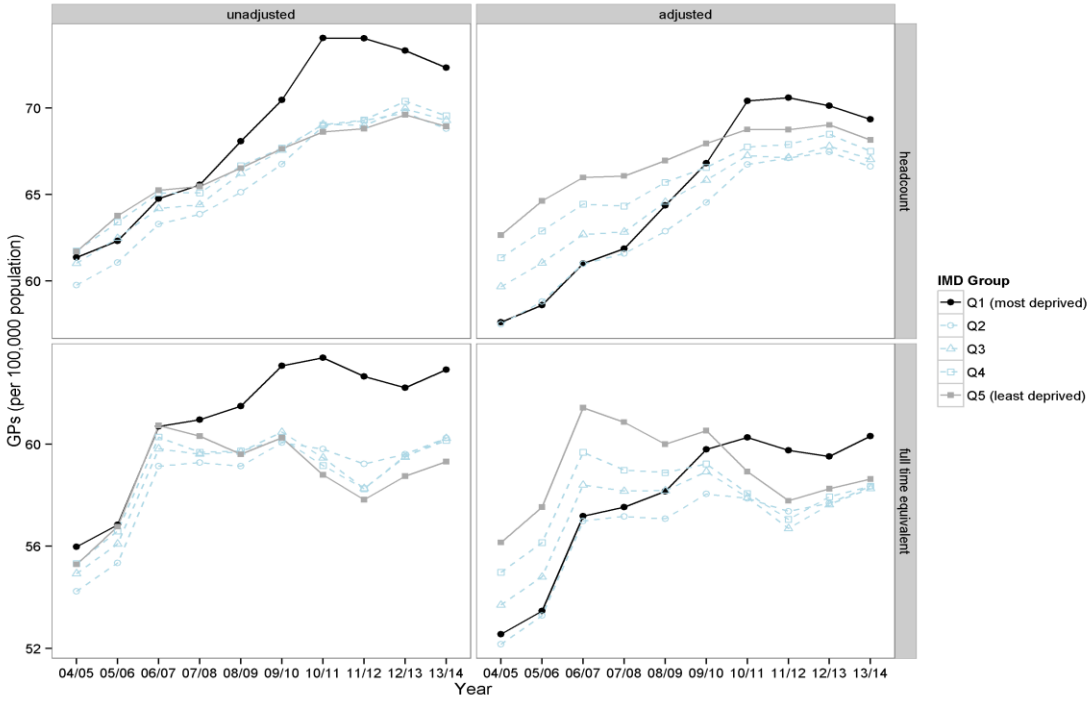


Figure A11.4: Trend in unadjusted and adjusted headcount and FTE GP supply over time excluding registrars and retainers



Regression A11.1: Test for difference in slope index of inequality between 2006/07 and 2011/12

```
Call:
lm(formula = FTE_PER100K_ADJ ~ YEAR * IMD_DECILE, data = subset(deciles,
    YEAR %in% c("2006", "2011")))

Residuals:
     Min       1Q   Median       3Q      Max
-1.38648 -0.67520 -0.01955  0.44667  2.18964

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)          55.5367     0.6595  84.211  < 2e-16 ***
YEAR2011              3.1447     0.9327   3.372 0.003885 **
IMD_DECILE            5.8152     1.0629   5.471 5.13e-05 ***
YEAR2011:IMD_DECILE  -7.6248     1.5031  -5.073 0.000113 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.9654 on 16 degrees of freedom
Multiple Adjusted R-squared:  0.6529
F-statistic: 12.91 on 3 and 16 DF,  p-value: 0.0001531
```

Appendix Section 12

Results calculated by attributing GP supply to LSOAs and aggregating based on fifths of LSOAs ranked by IMD score - **GP registrars and retainers excluded from the calculation - results for Midlands and East of England**

Figure A12.1: Trend in FTE GP supply over time excluding registrars and retainers

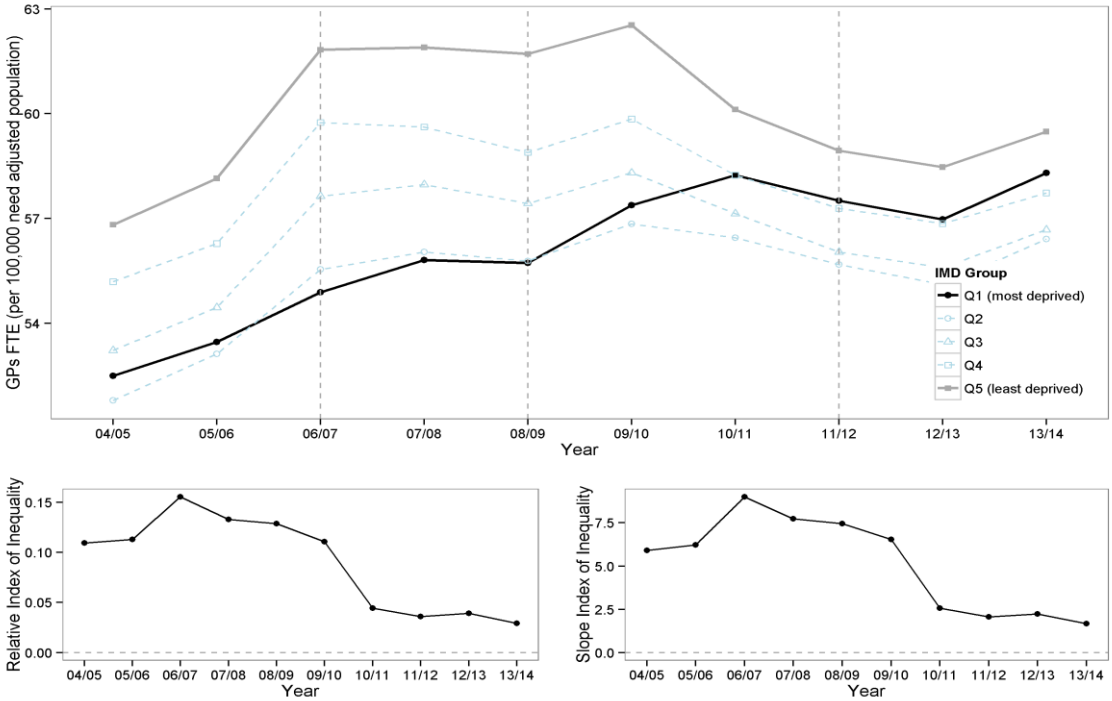


Figure A12.2: FTE GP supply in 2006/07 and 2011/12 excluding registrars and retainers

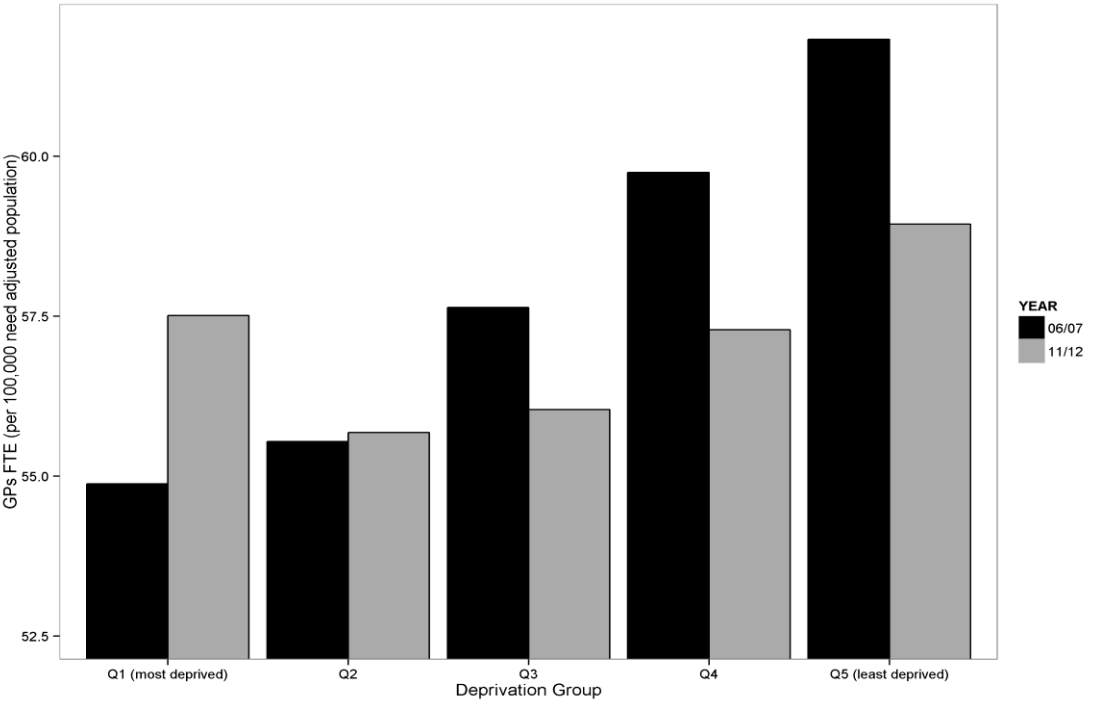


Figure A12.3: Trend in total headcount and FTE GP supply over time excluding registrars and retainers

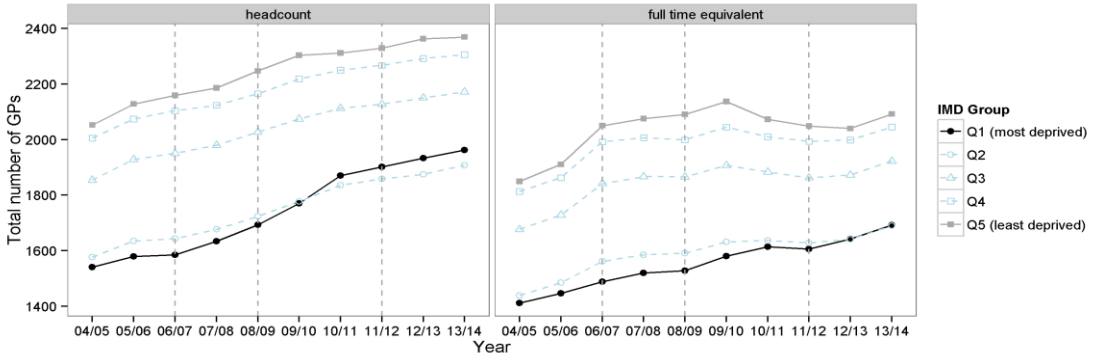
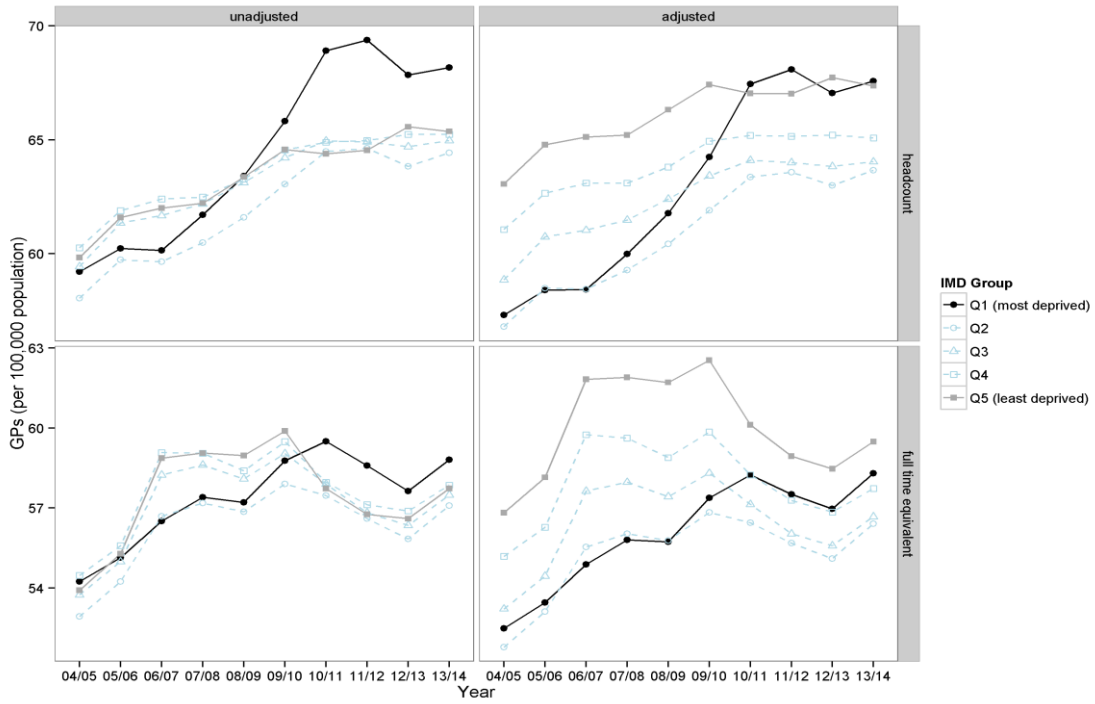


Figure A12.4: Trend in unadjusted and adjusted headcount and FTE GP supply over time excluding registrars and retainers



Regression A12.1: Test for difference in slope index of inequality between 2006/07 and 2011/12

```
Call:
lm(formula = FTE_PER100K_ADJ ~ YEAR * IMD_DECILE, data = subset(deciles,
    YEAR %in% c("2006", "2011")))

Residuals:
    Min      1Q  Median      3Q     Max
-1.2693 -0.5681 -0.2970  0.3750  2.8982

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)         52.9693     0.7386  71.718  < 2e-16 ***
YEAR2011             2.9867     1.0445   2.859 0.011358 *
IMD_DECILE           9.0067     1.1903   7.567 1.13e-06 ***
YEAR2011:IMD_DECILE -6.9485     1.6834  -4.128 0.000789 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.081 on 16 degrees of freedom
Multiple Adjusted R-squared:  0.7602
F-statistic: 21.07 on 3 and 16 DF,  p-value: 8.368e-06
```

Appendix Section 13

Results calculated by attributing GP supply to LSOAs and aggregating based on fifths of LSOAs ranked by IMD score - **GP registrars and retainers excluded from the calculation - results for South of England**

Figure A13.1: Trend in FTE GP supply over time excluding registrars and retainers

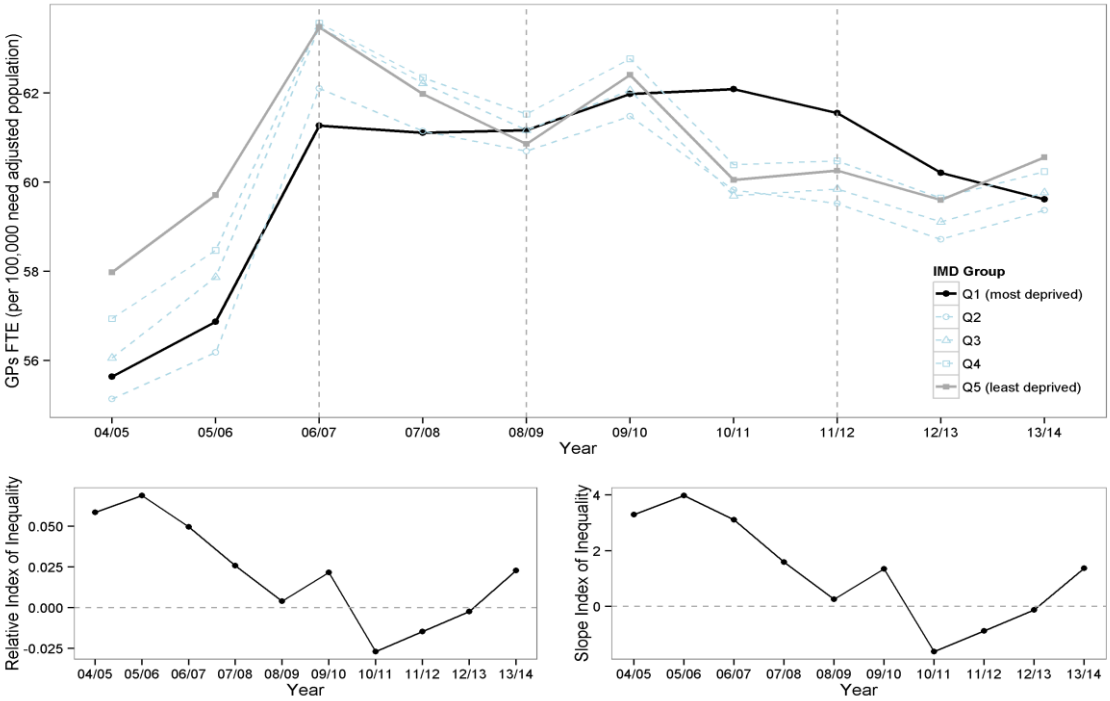


Figure A13.2: FTE GP supply in 2006/07 and 2011/12 excluding registrars and retainers

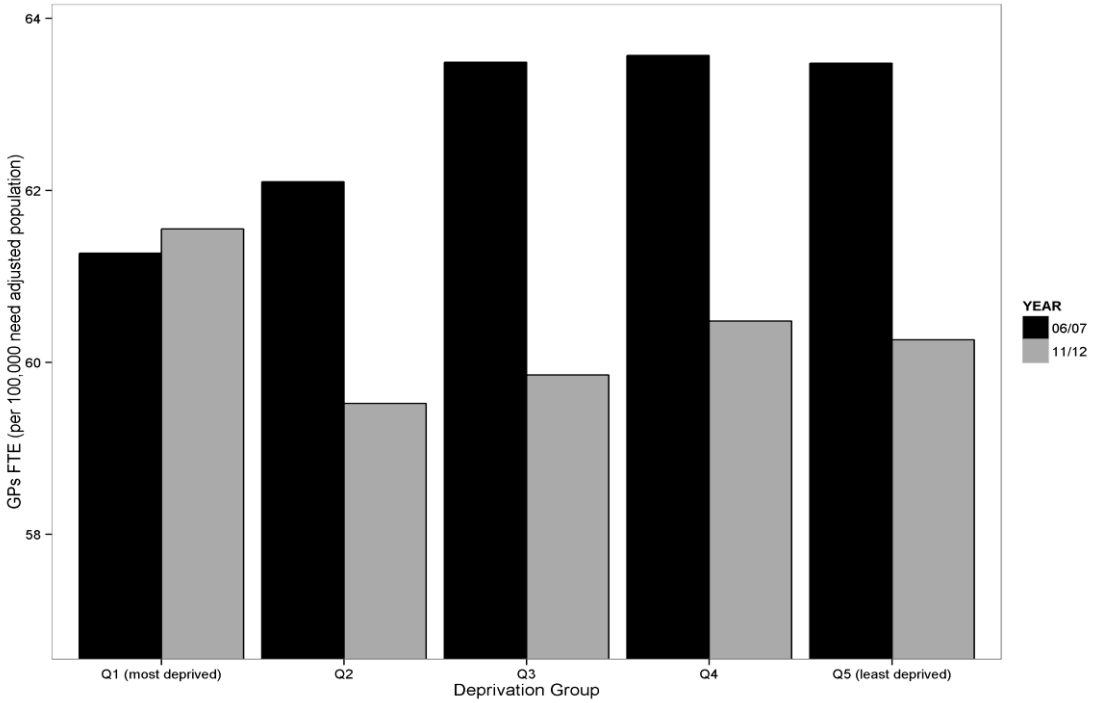


Figure A13.3: Trend in total headcount and FTE GP supply over time excluding registrars and retainers

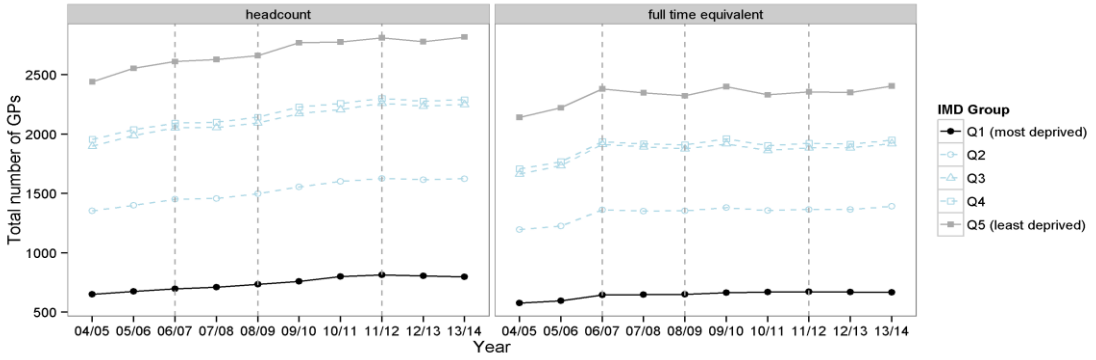
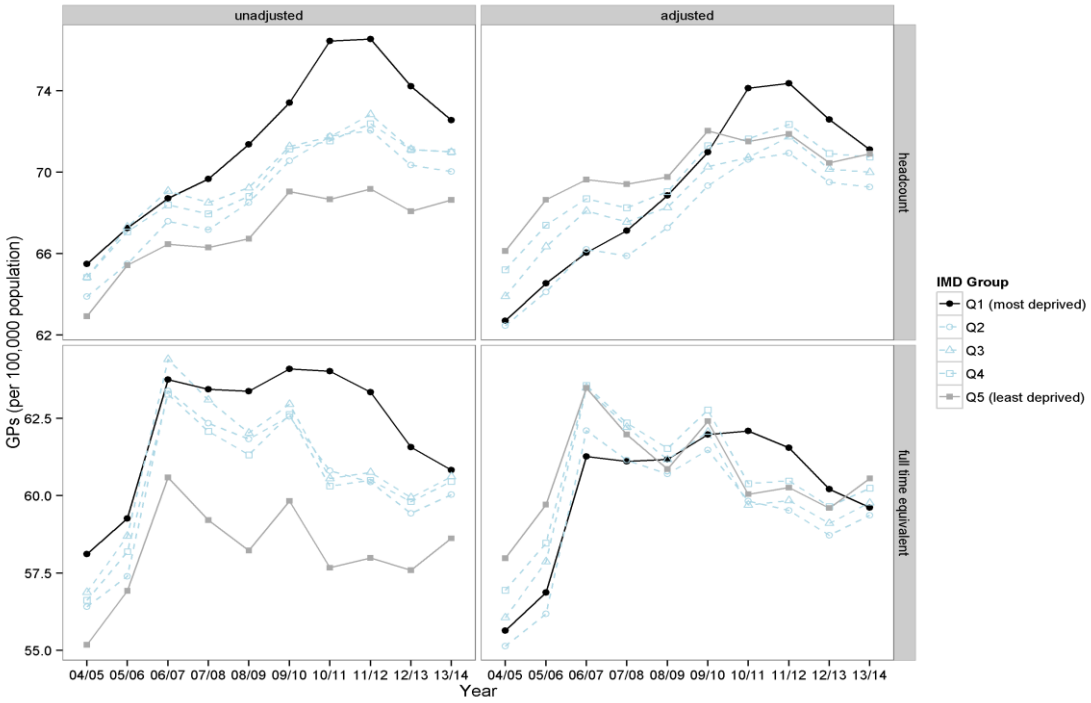


Figure A13.4: Trend in unadjusted and adjusted headcount and FTE GP supply over time excluding registrars and retainers



Regression A13.1: Test for difference in slope index of inequality between 2006/07 and 2011/12

```
Call:
lm(formula = FTE_PER100K_ADJ ~ YEAR * IMD_DECILE, data = subset(deciles,
    YEAR %in% c("2006", "2011")))

Residuals:
     Min       1Q   Median       3Q      Max
-1.38576 -0.55121  0.08591  0.48395  1.16764

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)          61.0387     0.5336 114.399  < 2e-16 ***
YEAR2011             -0.2180     0.7546  -0.289  0.77636
IMD_DECILE            3.1170     0.8599   3.625  0.00228 **
YEAR2011:IMD_DECILE  -4.0000     1.2161  -3.289  0.00462 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.7811 on 16 degrees of freedom
Multiple Adjusted R-squared:  0.7568
F-statistic:  20.7 on 3 and 16 DF,  p-value: 9.354e-06
```

Appendix Section 14

Results calculated by attributing GP supply to **PCTs** and aggregating based on population weighted fifths of PCTs ranked by IMD score - **GP registrars and retainers excluded from the calculation**

Figure A14.1: Trend in FTE GP supply over time excluding registrars and retainers

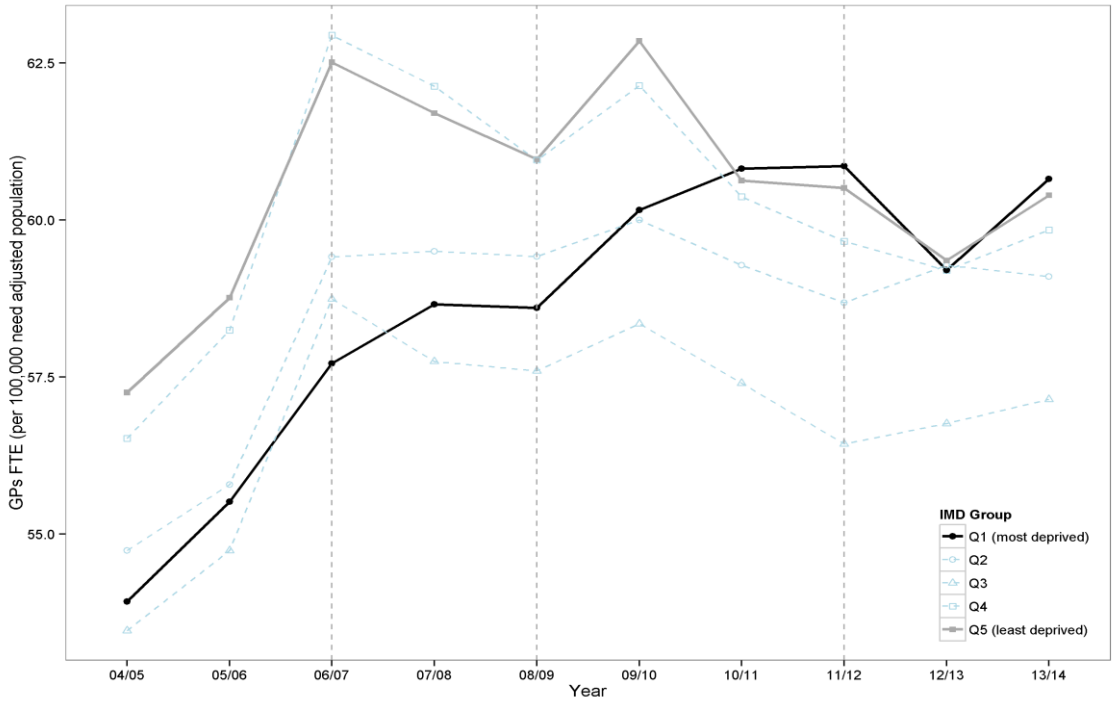


Figure A14.2: Trend in FTE nurse supply over time

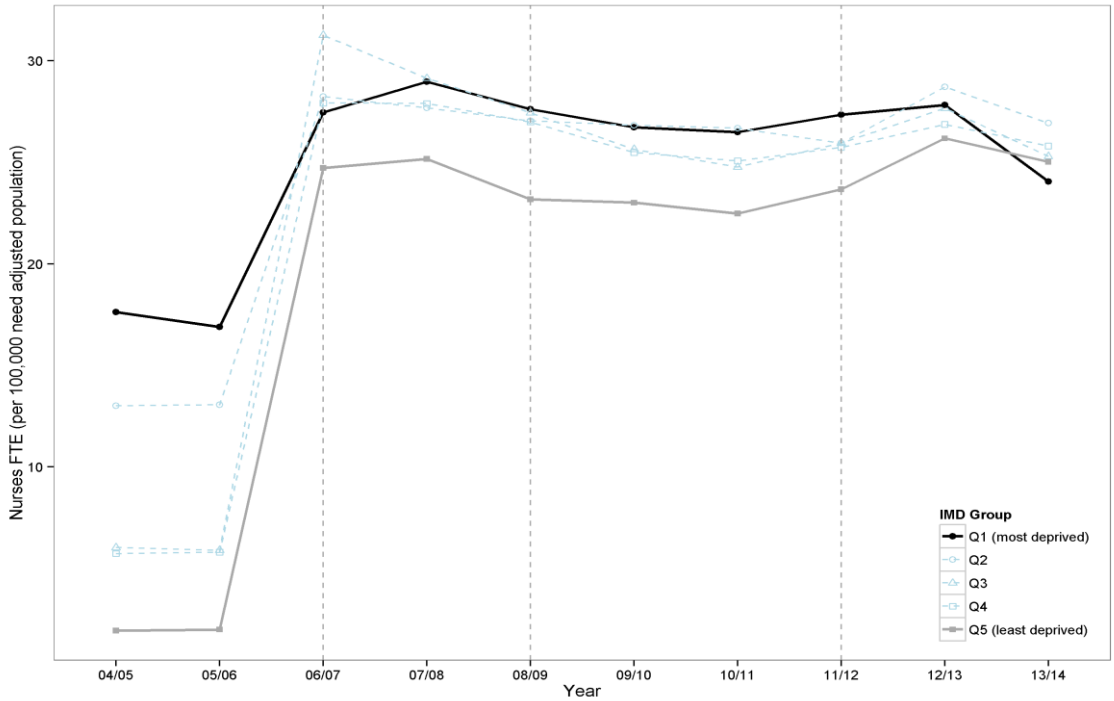
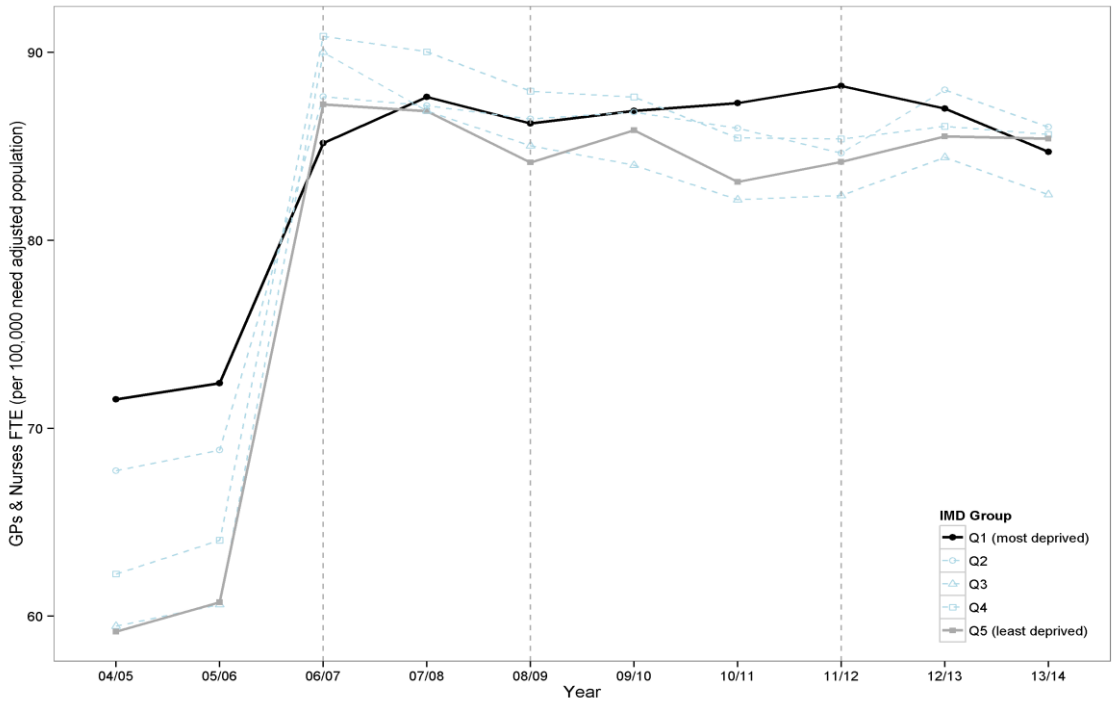


Figure A14.3: Combined trend in FTE GP and nurse supply over time



Appendix Section 15

Results calculated by attributing GP supply to **CCG**s and aggregating based on population weighted fifths of CCGs ranked by IMD score - **GP registrars and retainers excluded from the calculation**

Figure A15.1: Trend in FTE GP supply over time excluding registrars and retainers

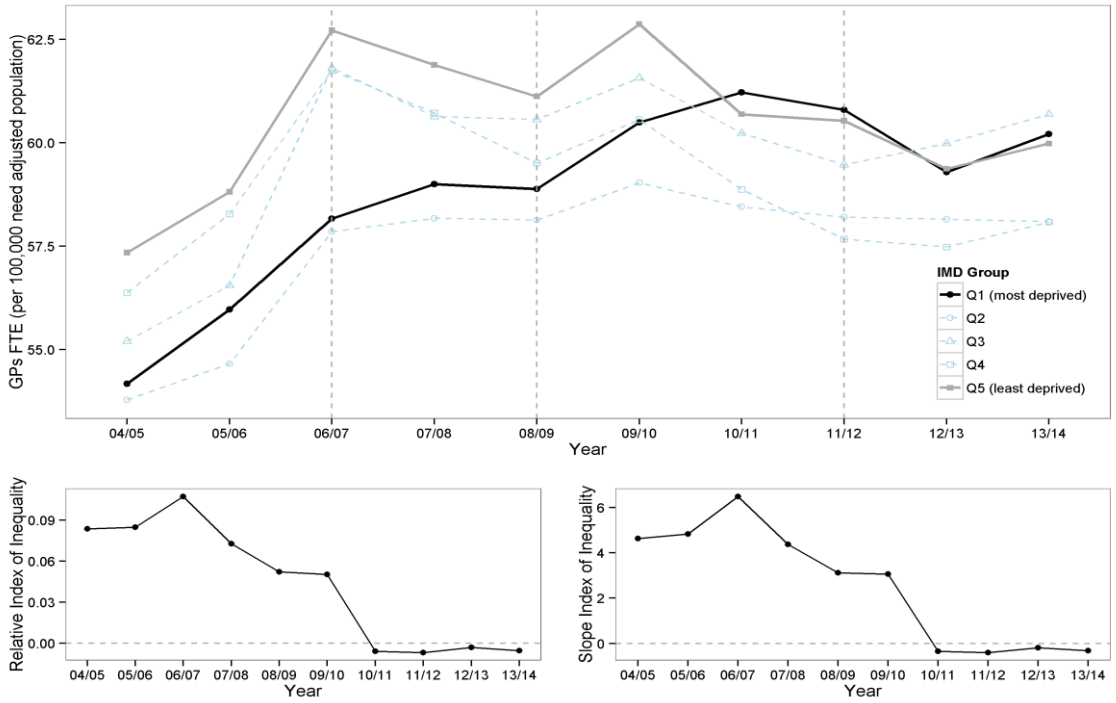


Figure A15.2: FTE GP supply in 2006/07 and 2011/12 excluding registrars and retainers

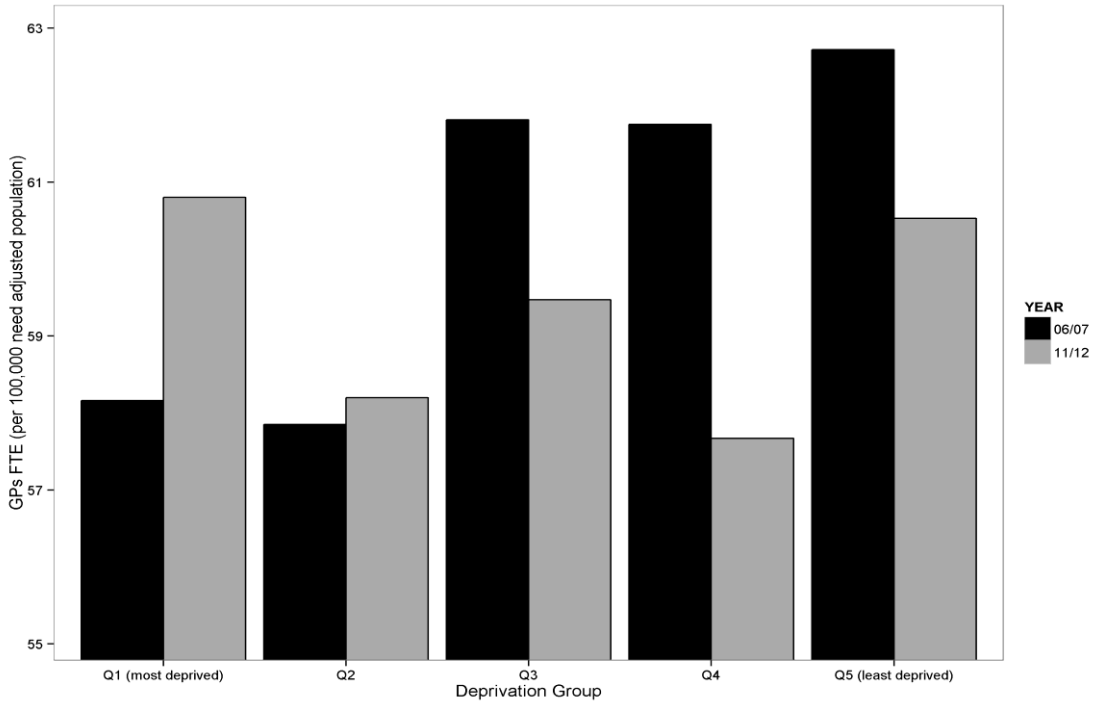


Figure A15.3: Trend in total headcount and FTE GP supply over time excluding registrars and retainers

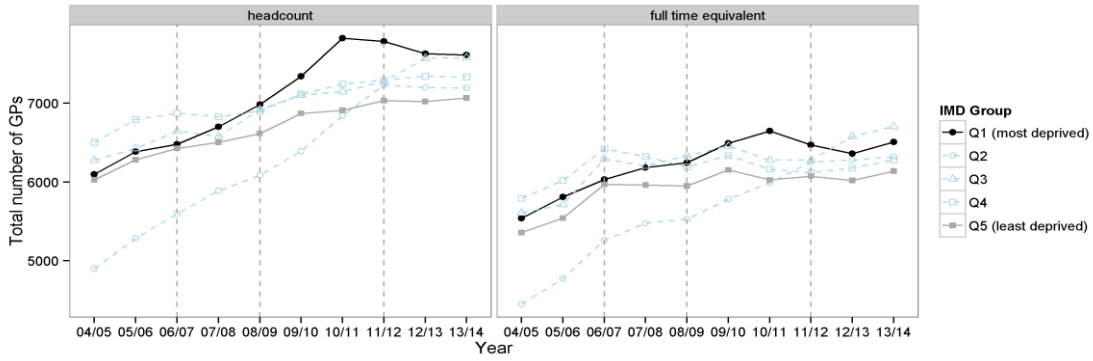
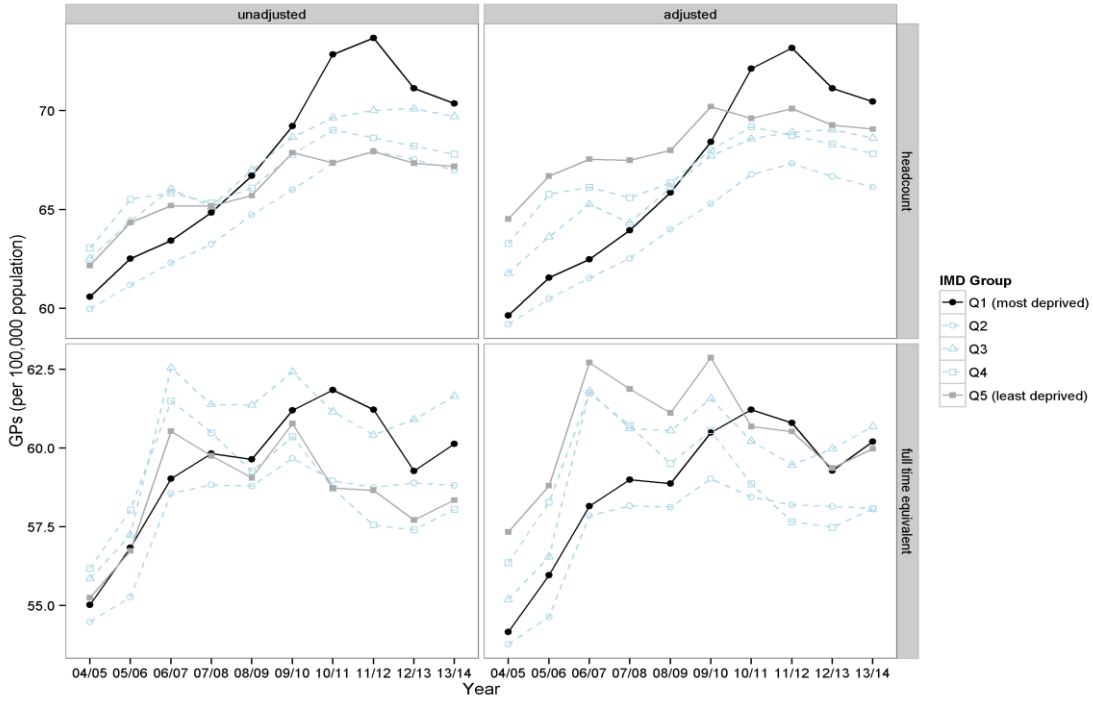


Figure A15.4: Trend in unadjusted and adjusted headcount and FTE GP supply over time excluding registrars and retainers



Regression A15.1: Test for difference in slope index of inequality between 2006/07 and 2011/12

```
Call:
lm(formula = FTE_PER100K_ADJ ~ YEAR * IMD_DECILE, data = subset(deciles,
    YEAR %in% c("2006", "2011")))

Residuals:
    Min      1Q  Median      3Q     Max
-3.9218 -0.9508  0.3906  1.1253  2.2385

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)          56.880      1.158  49.140  < 2e-16 ***
YEAR2011              2.683      1.637   1.639  0.12076
IMD_DECILE            6.487      1.865   3.478  0.00311 **
YEAR2011:IMD_DECILE  -6.888      2.638  -2.611  0.01891 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.694 on 16 degrees of freedom
Multiple Adjusted R-squared:  0.3723
F-statistic: 4.757 on 3 and 16 DF,  p-value: 0.0148
```

Appendix Section 16

Results calculated looking at opening and closing GP practices and their impact on GP FTE numbersby IMD score - **GP registrars and retainers excluded from the calculation**

Figure A16.1: Trend in GP practices opening

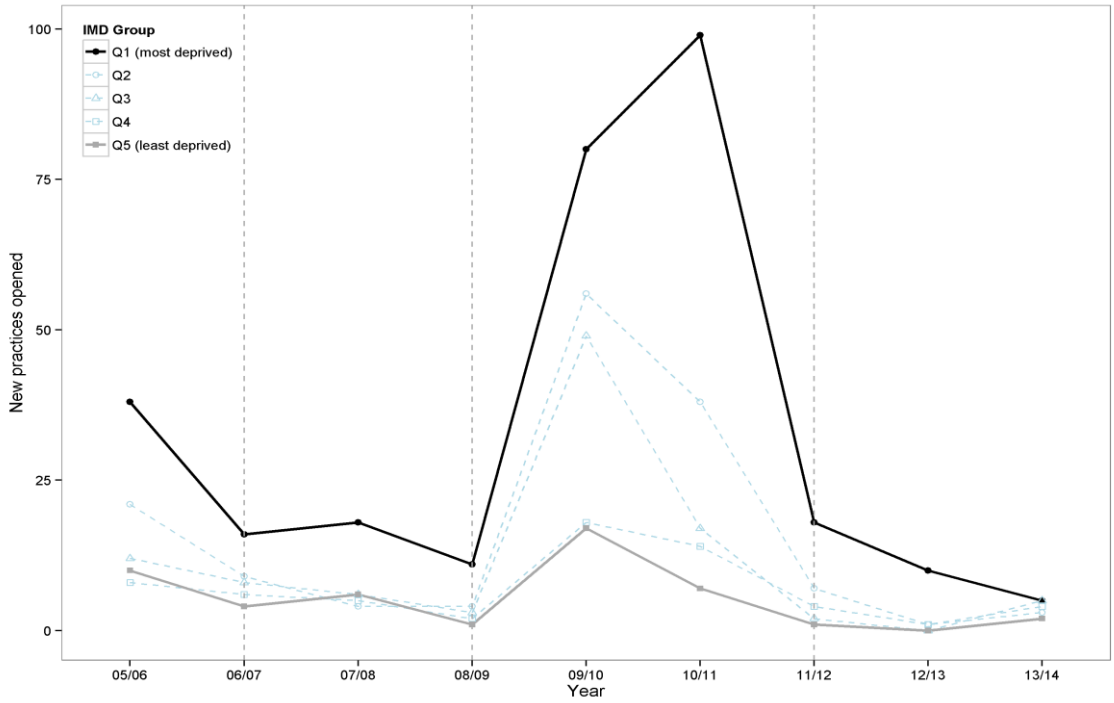


Figure A16.2: Trend in GP FTE due to GP practices opening

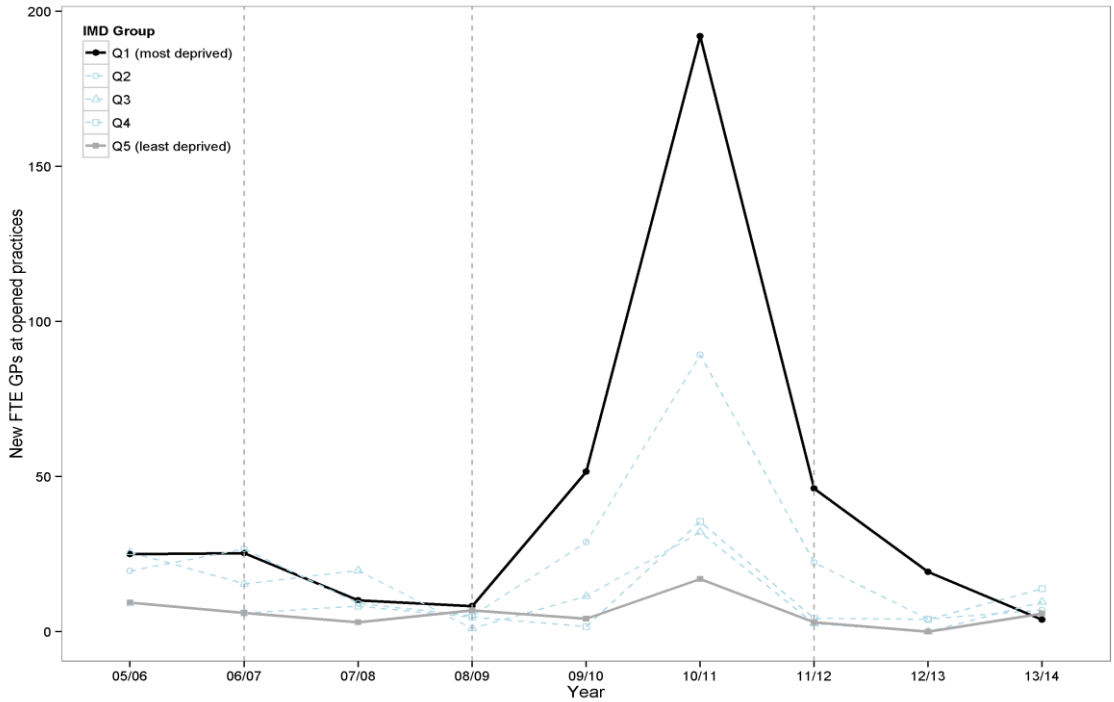


Figure A16.3: Trend in GP practices closing

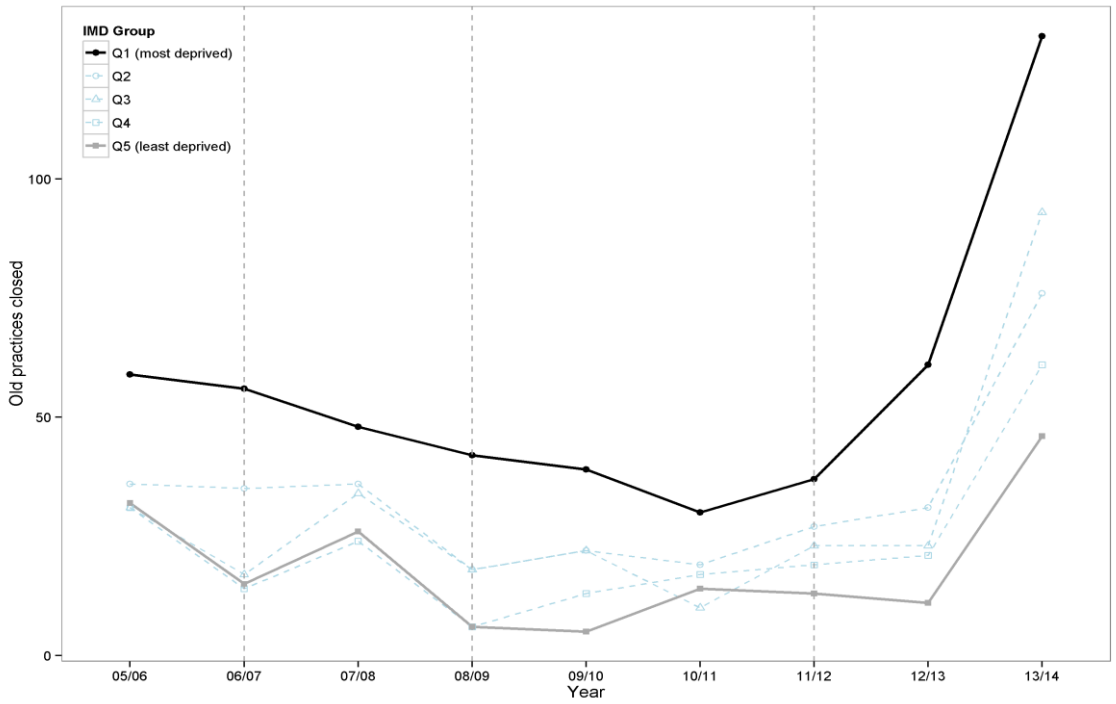


Figure A16.4: Trend in GP FTE due to GP practices closing

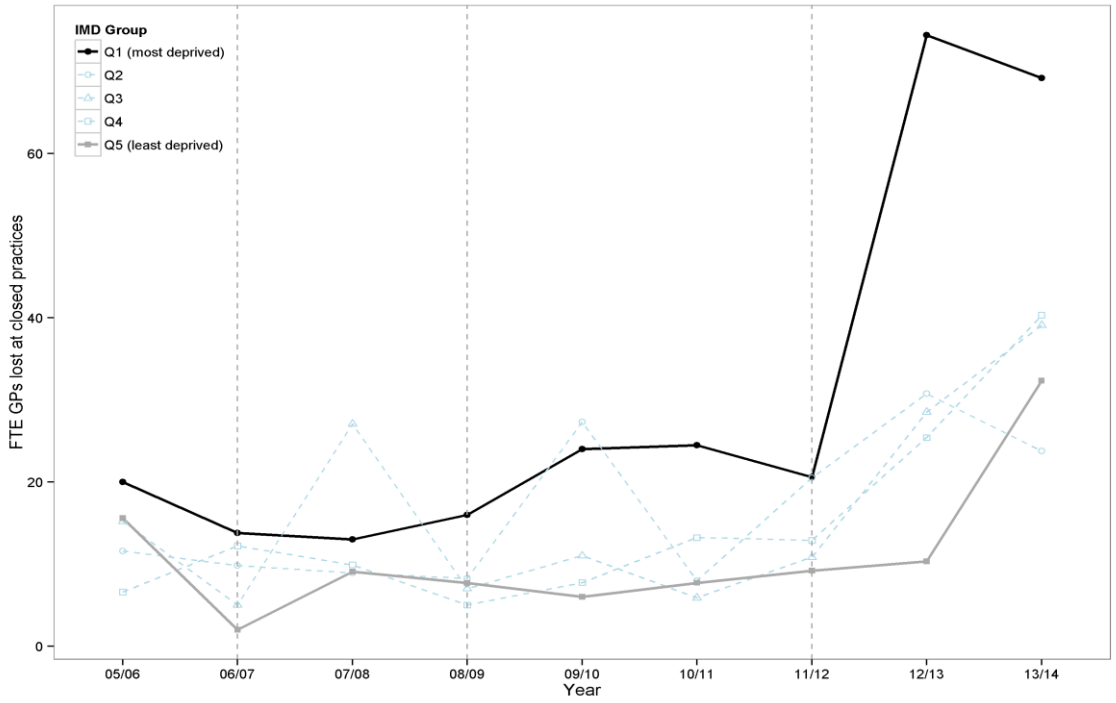


Figure A16.5: Trend in net change in GP practices

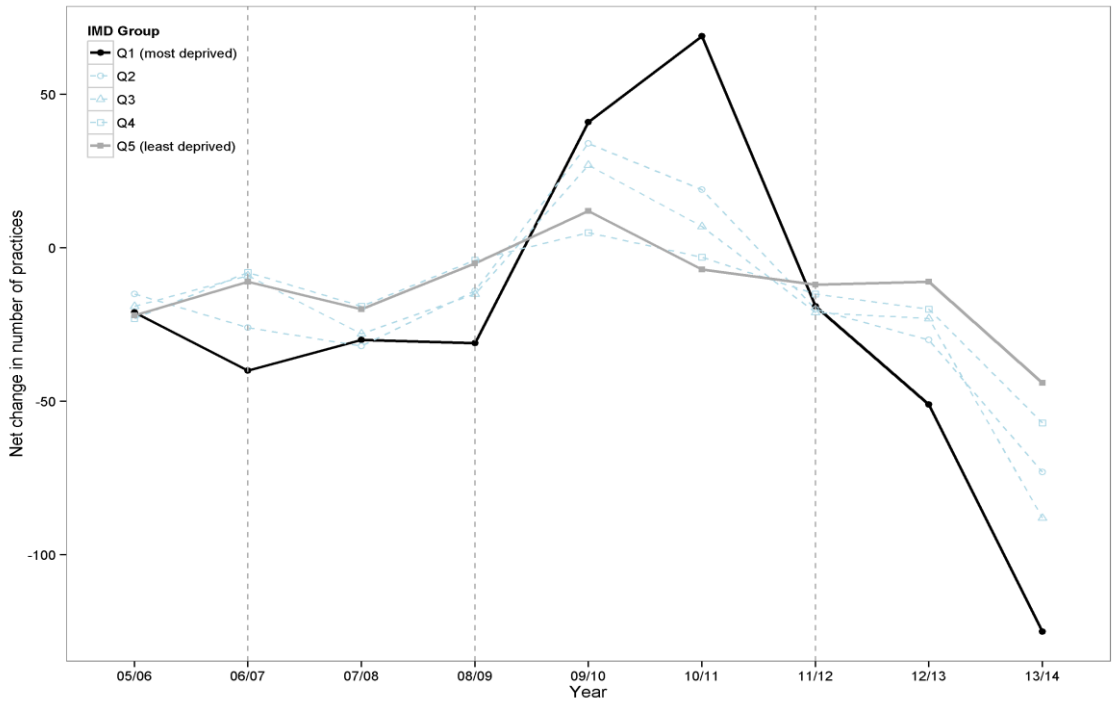
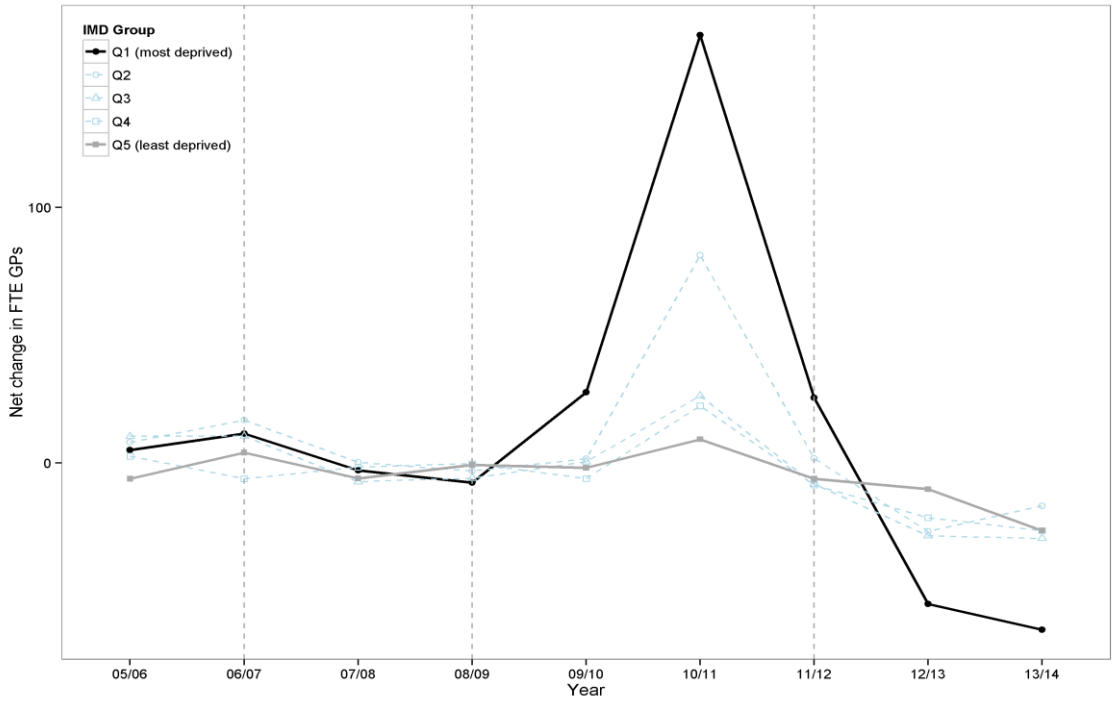


Figure A16.6: Trend in net change in GP FTE due to net change in practices



Appendix Section 17

Exploring the impact of need adjustment over time for the deprivation quintiles

Table A17.1: Carr-Hill Need Adjustment Workload Weights

Age-Sex weight		Registration status weight		IMD Health Domain score weight
Band	**Weight**	**Band**	**Weight**	**Weight**
Male 0-4 years	2.354	Registered with practice for 12 months+	1.000	The weight is calculated as: 1.054 to the power of the IMD Health Domain score associated with the patient's postcode)
Male 5-14 years	1.000			
Male 15-44 years	0.913			
Male 45-64 years	1.373			
Male 65-74 years	2.531	Registered with practice in last 12 months	1.689	
Male 75-84 years	3.254			
Male 85+ years	3.193			
Female 0-4 years	2.241			
Female 5-14 years	1.030			
Female 15-44 years	1.885			
Female 45-64 years	2.115			
Female 65-74 years	2.820			
Female 75-84 years	3.301			
Female 85+ years	3.090			

Source: Review of the Generla Medical Services global sum formula (2007) - Table 1 - http://www.nhsemployers.org/~/media/Employers/Documents/Primary%20care%20contracts/GMS/GMS%20Finance/Global%20Sum/frg_report_final_cd_090207.pdf

We were unable to get data on duration of registration with practice so this part of the calculation is ommited from our results

The formula was applied at LSOA level populations and adjusted populations were re-normalised to sum to the pre-adjusted total

The IMD Health Domain score ranges from -3.10 to 3.79 corresponding to pre-normalisation deprivation adustment weights of 0.85 and 1.22.

The biggest increase in LSOA population due to adjustment over the period of analysis was 165% and the smallest increase was 8%
After normalisation these changes reduced to an increase of 50% and a decrease of 38% respectively

Figure A17.1: Trend in Carr-Hill Relative Need Index Over Time - LSOA level IMD Quintile Aggregation

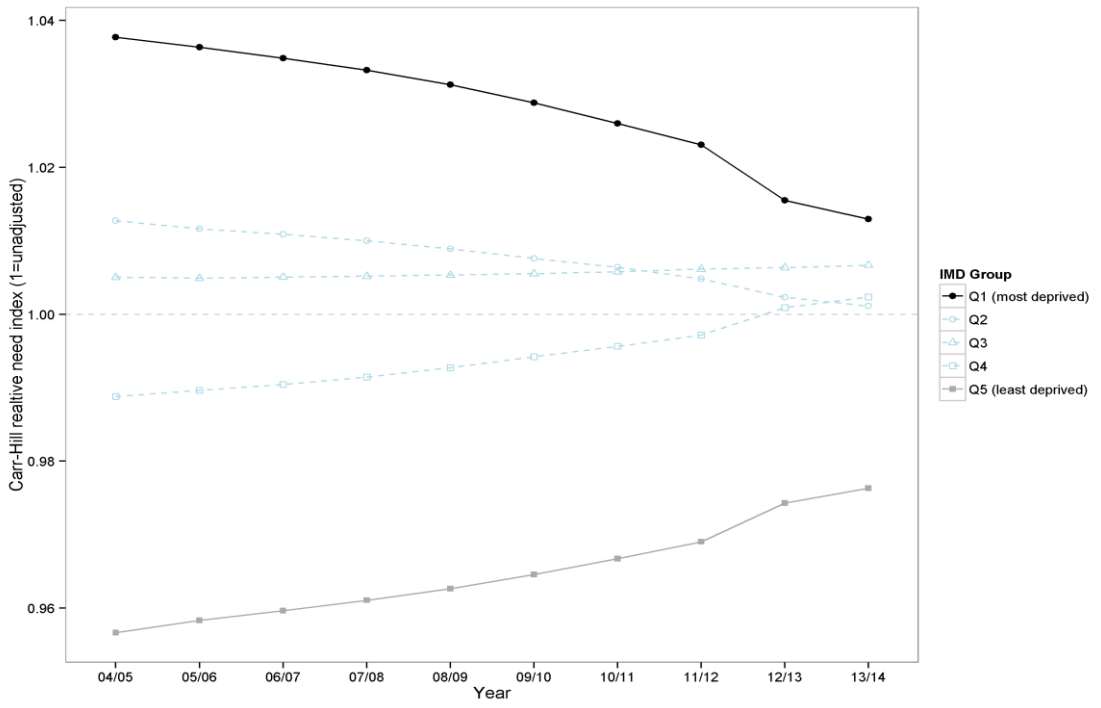
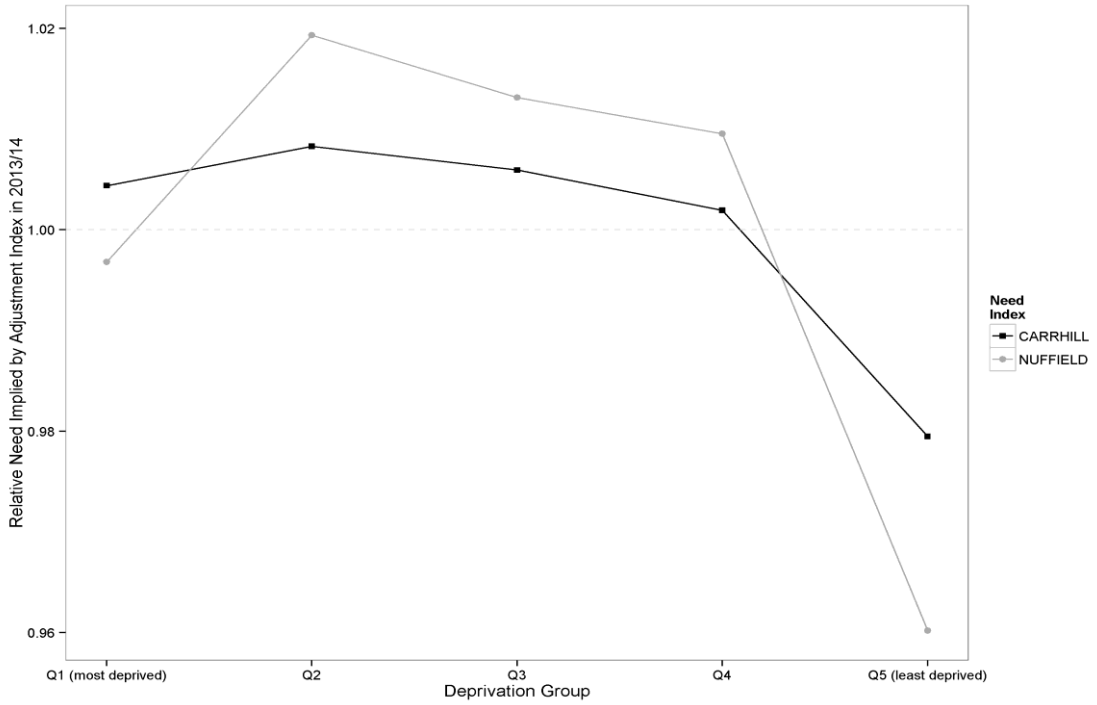
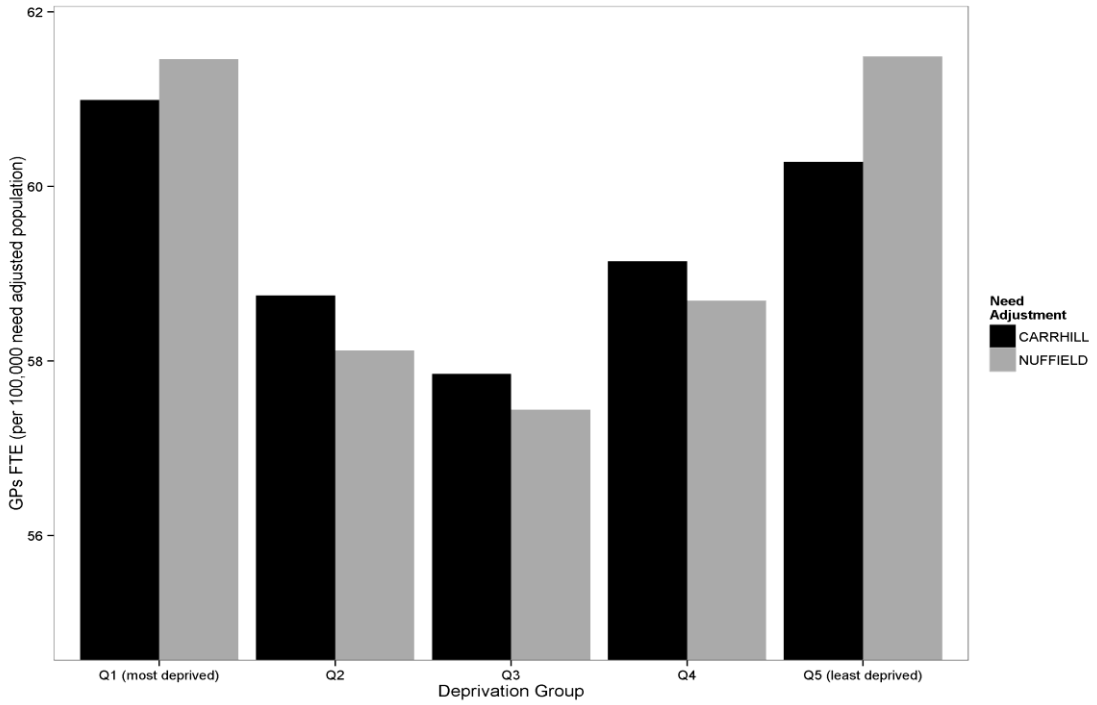


Figure A17.2: Comparing Carr-Hill and Nuffield PBRA Relative Need Index 2013/14 - Practice Level IMD Quintile Aggregation



Source: Nuffield Person Based Resource Allocation - Technical Guide to Clinical Commissioning Group and Area Team allocations 2014-15 and 2015-16: http://www.england.nhs.uk/2014/03/27/allocations-tech-guide/ speadsheet: http://www.england.nhs.uk/wp-content/uploads/2014/03/c-nph-gen-acute.xlsx

Figure A17.3: Impact of Carr-Hill and Nuffield PBRA Need Adjustment on GP FTE Excluding Registrars and Retianers 2013/14



Appendix C: Paper 3 - How a universal health system reduces inequalities: lessons from England

OPEN ACCESS

How a universal health system reduces inequalities: lessons from England

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ABSTRACT

Background Provision of universal coverage is essential for achieving equity in healthcare, but inequalities still exist in universal healthcare systems. Between 2004/2005 and 2011/2012, the National Health Service (NHS) in England, which has provided universal coverage since 1948, made sustained efforts to reduce health inequalities by strengthening primary care. We provide the first comprehensive assessment of trends in socioeconomic inequalities of primary care access, quality and outcomes during this period.

Methods Whole-population small area longitudinal study based on 32 482 neighbourhoods of approximately 1500 people in England from 2004/2005 to 2011/2012. We measured slope indices of inequality in four indicators: (1) patients per family doctor, (2) primary care quality, (3) preventable emergency hospital admissions and (4) mortality from conditions considered amenable to healthcare.

Results Between 2004/2005 and 2011/2012, there were larger absolute improvements on all indicators in more-deprived neighbourhoods. The modelled gap between the most-deprived and least-deprived neighbourhoods in England decreased by: 193 patients per family doctor (95% CI 173 to 213), 3.29 percentage points of primary care quality (3.13 to 3.45), 0.42 preventable hospitalisations per 1000 people (0.29 to 0.55) and 0.23 amenable deaths per 1000 people (0.15 to 0.31). By 2011/2012, inequalities in primary care supply and quality were almost eliminated, but socioeconomic inequality was still associated with 158 396 preventable hospitalisations and 37 983 deaths amenable to healthcare.

Conclusions Between 2004/2005 and 2011/2012, the NHS succeeded in substantially reducing socioeconomic inequalities in primary care access and quality, but made only modest reductions in healthcare outcome inequalities.

INTRODUCTION

Equity is widely accepted by the medical professions as a fundamental element of quality,[1 2] and providing equitable care is a priority for most national healthcare systems.[3] Provision of universal coverage is a necessary, but not sufficient, requirement for achieving this goal. In the USA, the Patient Protection and Affordable Care Act aims to provide near-universal access to healthcare coverage and to improve quality and value.[4] Recent state-level expansions of healthcare coverage have improved access to care for disadvantaged populations,[5] and have been associated with improvements in mortality for causes amenable to healthcare.[6] However, failure to address inequalities in care within the covered population will ultimately undermine wider programmes to improve quality of care and patient outcomes.[7]

In the UK, the National Health Service (NHS) has provided universal, comprehensive healthcare free at the point of delivery since 1948. Despite this, there are clear inequities in healthcare in the UK, and poorer access and worse patient outcomes remain strongly associated with social disadvantage.[8 9] Recognising this, in 2003 the UK Government made reducing health inequality a priority for the NHS in England, as part of a cross-governmental strategy with explicit national targets for reducing health inequality by 2010[10]—the world's first national strategy of this kind.[11] Strengthening primary care was central to these efforts, which included: (1) major investments in primary care supply and quality from 2004, including the world's largest primary care pay-for-performance programme[12]; (2) targeted investment in primary care supply in under-doctored areas of the country from 2008[13] and (3) national guidance and support for effective primary care interventions for chronic conditions in disadvantaged adults from 2007 to 2009.[14]

It is not known how far the NHS contributed to reducing health inequalities during this key period because socioeconomic inequalities in primary care access, quality and outcomes have not been routinely monitored.[15] This hampers efforts to improve equity, since what is not measured may be marginalised.[16] National health inequality targets introduced in the 2000s were limited from a healthcare quality perspective as they are related to local government areas, thus masking important inequalities within these areas. They also focused on life expectancy and infant mortality, over which healthcare providers have little direct control since they are strongly influenced by social and economic factors (eg, living and working conditions), and related lifestyle behaviours (eg, smoking, diet and exercise).

In this paper, we address these weaknesses by constructing a suite of four key summary measures relating to trends in socioeconomic inequality in healthcare access, quality and outcomes for which the healthcare system can plausibly be held to account. We present data describing trends in absolute as well as relative inequality in these indicators at small area level, and provide the first comprehensive assessment of trends in healthcare equity

performance during a key period of sustained effort by a national healthcare system to reduce socioeconomic inequalities in primary care access, quality and outcomes.

METHODS

Data sources

We extracted health data from four national administrative databases for financial years 2004/2005 to 2011/2012: (1) the annual NHS General and Personal Medical Services workforce census (physician supply); (2) the Quality and Outcomes Framework (QOF)—the national primary care pay-for-performance programme (primary care quality); (3) hospital episode statistics (hospital admissions) and (4) the Office for National Statistics (mortality). Data on physician supply and primary care quality were attributed from practice level to small area level using the NHS Attribution Data Set of GP-registered populations. Data on hospital activity and mortality were aggregated to small area level from individual level.

The basic geographical unit of analysis was the 2001 'lower super output area' (LSOA). There are 32 482 of these small area neighbourhoods, covering approximately 1500 people each (minimum 1000 and maximum 3000). We measured the population size of each neighbourhood by age–sex group using mid-year population estimates from the Office for National Statistics (ONS) for years 2004–2011. We measured the socioeconomic status of each neighbourhood using the index of multiple deprivation (IMD 2010).

Indicators

We aimed to provide a comprehensive assessment of socioeconomic inequalities of primary care access, quality and outcomes for which the NHS can be held accountable in its efforts to tackle health inequality. The indicator selection process included: reviewing existing indicators used by the NHS to monitor healthcare performance; consulting with health indicator experts about technical feasibility, and with clinical and policy experts about clinical and policy relevance; and a small-scale public consultation exercise. Four key indicators were selected:

1. Primary care supply

We defined primary care supply as patients per full-time equivalent (FTE) general practitioner (GP), excluding registrars and retainers. In line with previous studies, we focused on FTE GP principals and salaried GPs, who make up the vast majority of the workforce.[17] Neighbourhood populations were adjusted for their relative needs for primary care using the workload adjustment aspect of the Carr-Hill formula for primary care resource allocation.[18] This adjustment takes into consideration the age and sex structure and IMD 2010 'health deprivation and disability' score of each LSOA.

2. Primary care quality

We defined primary care quality using a modified version of the QOF-based public health impact score proposed by Ashworth *et al*.[19] Our indicator is a score between 0 and 100 calculated as a weighted average of clinical process quality from 16 QOF indicators that were collected on a consistent basis throughout our study period. Each of these QOF indicators measures the percentage of the relevant patient population achieving a particular clinical quality target. Weights used to combine these indicators into an overall score were proportional to their relative importance in terms of the estimated mortality reduction impact associated with improvement on the indicator. We measured practice-reported performance, which excludes patients reported as 'exceptions' (and therefore considered not to be appropriate for the quality targets).[20] In sensitivity analysis we included exception reported patients (see online supplementary appendix 3 for details).

3. Preventable hospitalisation

We defined preventable hospitalisation as the proportion of people with an emergency admission for a chronic ambulatory care sensitive condition—admissions that are potentially avoidable if these chronic conditions are appropriately managed in primary care—examples of such hospital admissions are those associated with asthma and diabetes.[21] We focused on chronic rather than acute ambulatory care sensitive conditions, as the former are likely to be more sensitive to changes in primary care supply and quality. We used the same list of chronic ambulatory care sensitive conditions as the NHS Outcomes Framework (Indicator 2.3i).[22] We indirectly standardised each year of data for age and sex at LSOA level.

4. Amenable mortality

We defined amenable mortality as the proportion of people dying from causes considered amenable to healthcare. We used the list of causes of death and age ranges where deaths from these causes are considered amenable to healthcare from the NHS Outcomes Framework (Indicator 1.1).[23] As with preventable hospitalisation, we indirectly standardised amenable mortality for age and sex at LSOA level.

The two healthcare outcome indicators are widely used, internationally, to monitor the performance of whole healthcare systems, and are particularly useful for monitoring the performance of primary care and the coordination of care between primary and secondary services.[24 25] Full details of the indicator definitions and the standardisation processes are provided in online supplementary appendices 1 and 2, respectively.

Analysis

Our primary measures of inequality were the slope index of inequality (SII) and relative index of inequality (RII), based on linear regression analysis at LSOA level. Each indicator was modelled as a linear function of LSOA level deprivation, entered as a continuous variable scaled from 0 to 1. The SII is the coefficient in this regression; the RII is that coefficient divided by the mean. The SII can be interpreted as the modelled absolute gap between the most and least-deprived small area, allowing for the whole socioeconomic gradient; the RII can be interpreted as the proportionate gap relative to the average. Alongside these quantitative measures we also visualised the relationship between deprivation and inequality graphically to aid in the understanding and interpretation of these measures.

We also computed the 'inequity gap', based on a counterfactual situation of full equality in which all neighbourhoods do as well as the least-deprived neighbourhood in terms of modelled achievement on the indicator. For primary care supply, the 'inequity gap' is calculated as the number of additional physicians required to achieve full equality. For primary care quality, it is the average deficit in quality attributable to socioeconomic inequality. For rates of preventable hospitalisation and amenable mortality it is the number of avoidable hospitalisations and deaths attributable to socioeconomic inequality.

Linear regression models were computed using pooled data for the first and last years, including interaction terms between year and deprivation to determine the magnitude of—and test for the statistical significance of—changes in inequality between the beginning and end of the analysis period.

RESULTS

Inequalities in 2004/2005

There were clear and substantial socioeconomic gradients in all four indicators in 2004/2005 (figure 1), with less favourable

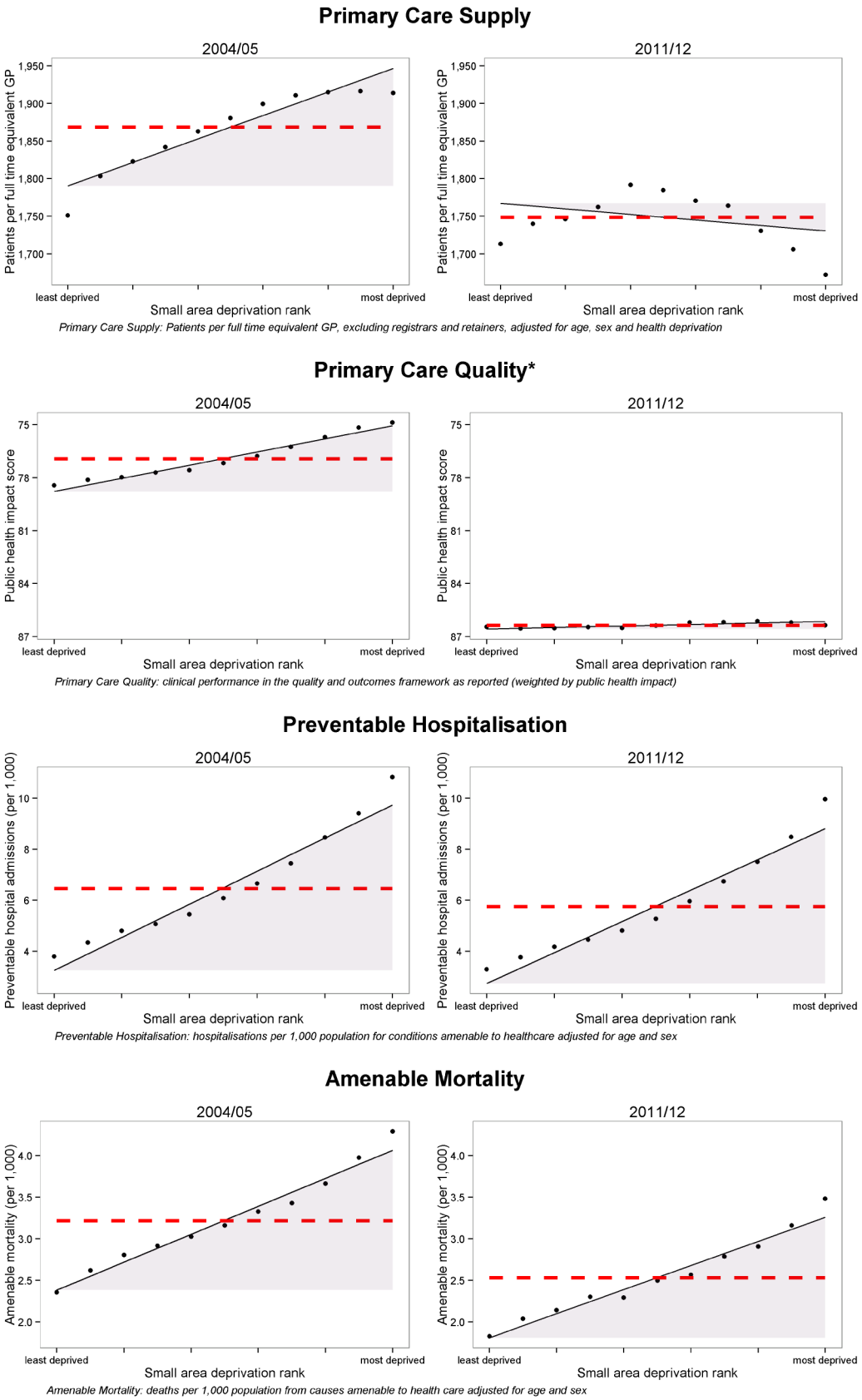

Figure 1 Scatter plots of indicators in 2004/2005 and 2011/2012. The black dots show deprivation decile groups of neighbourhoods (approximately 3200 neighbourhoods per dot); the solid black line shows a linear regression through all 32 482 neighbourhoods; the shaded area shows the inequality gap; and the dashed red line shows the national average level for the indicator. *Inverted axis on primary care quality to ease comparisons with other indicators, where decreasing implies improvement (GP, general practitioner).

primary care provision and health outcomes in more-deprived areas. For primary care supply, there were fewer GPs relative to measured need (and therefore, more patients per GP) in deprived neighbourhoods than in less-deprived neighbourhoods. This socioeconomic inequality was associated with a deficit of 1008 GPs (924 to 1093) nationally (table 1). In other words, equalising GP provision in all neighbourhoods to the modelled level of GP provision in the least-deprived neighbourhood would require an additional 1008 GPs in relatively deprived neighbourhoods. Socioeconomic inequality was also associated with a deficit of 1.86 percentage points (1.79 to 1.94) in primary care quality, 160 397 (158 090 to 162 703) preventable hospitalisations, and 41 433 (39 899 to 42 966) amenable deaths.

Changes in inequality between 2004/2005 and 2011/2012

All four indicators improved on average (ie, inequalities reduced) between 2004/2005 and 2011/2012. Inequalities in primary care supply and quality decreased substantially, to the extent of being virtually eliminated by the end of the period, whereas changes in the social gradient in preventable hospitalisation and amenable mortality were less pronounced (figure 1). By 2011/2012, the numbers of GPs had increased in all areas, with the greatest increases in the most-deprived areas, leaving neighbourhoods in the middle of the deprivation range with the fewest GPs per patient. Socioeconomic inequality had been reduced to such an extent that deprived neighbourhoods had slightly more GPs relative to need than less-deprived neighbourhoods, and socioeconomic inequality was associated with a surplus of 335 GPs (233 to 436), that is, equalising GP provision in all neighbourhoods to the level of the least-deprived neighbourhood would require losing 335 GPs from relatively deprived neighbourhoods.

By 2011/2012, socioeconomic inequality was also associated with an average deficit in primary care quality of 0.22 percentage points (0.18 to 0.26), 158 396 excess preventable hospitalisations (155 995 to 160 797), and 37 983 excess amenable deaths (36 552 to 39 415). Looking more closely at the trends in inequality in the indicators over the period (table 1 and figure 2) there is a clear trend of decreasing inequality in both absolute and relative terms for both primary care supply and primary care quality. By contrast, preventable hospitalisation and amenable mortality show a mixed pattern of decreasing absolute inequality but increasing relative inequality.

DISCUSSION

Our study presents the first comprehensive national picture of how far the NHS in England succeeded in reducing socioeconomic inequalities in primary care supply, quality and outcomes from 2004/2005 to 2011/2012. During this period, primary care supply, quality and outcomes for the average patient all improved. We find that socioeconomic inequalities in both primary care supply relative to need and primary care quality decreased substantially in absolute and relative terms. By the end of the period, inequality in primary care supply had been eliminated, and inequality in primary care quality had been nearly eliminated. By contrast, inequality trends in preventable hospitalisation and amenable mortality were mixed, showing decreasing absolute inequality but increasing relative inequality. By 2011/2012, deprived neighbourhoods had slightly better primary care supply than less-deprived neighbourhoods (relative inequality −2%), and only slightly worse primary care quality (relative inequality 1%). However, there remained large inequalities in preventable hospitalisation (relative inequality 106%) and amenable mortality (relative inequality 57%).

Strengths and weaknesses of the study

We used data on the entire population of England, including workload and quality data on virtually all primary care practices in England, and outcomes data on virtually all individuals in England. We used comprehensive indicators spanning the entire range of activities of the healthcare system, and inequality measures based on the entire socioeconomic gradient across all 32 482 small areas of England. We examined inequality in absolute and relative terms, because absolute and relative inequality can change in opposite directions when the mean is changing over time.[26] One of our measures—the RII—can also be

Table 1 Socioeconomic healthcare inequalities in England, comparing 2004/2005 with 2011/2012

Indicator	England mean (95% CI)	RII (95% CI)	SII (95% CI)	Inequality gap (95% CI)
Primary care supply				
2004	1814 (1814 to 1814)	0.09 (0.08 to 0.09)	156.1 (141.29 to 170.91)	1008 (924 to 1093)
2011	1689 (1689 to 1689)	−0.02 (−0.03 to −0.01)	−36.61 (−49.8 to −23.42)	−335 (−436 to −233)
Change 2011–2004	−125 (−125 to −125)	−0.11 (−0.12 to −0.1)	−192.71 (−212.55 to −172.87)	−1343 (−1473 to −1213)
Primary care quality				
2004	76.91 (76.91 to 76.91)	0.05 (0.05 to 0.05)	3.73 (3.58 to 3.87)	1.86 (1.79 to 1.94)
2011	86.34 (86.34 to 86.34)	0.01 (0.00 to 0.01)	0.44 (0.37 to 0.51)	0.22 (0.18 to 0.26)
Change 2011–2004	9.44 (9.44 to 9.44)	−0.04 (−0.05 to −0.04)	−3.29 (−3.45 to −3.13)	−1.64 (−1.72 to −1.56)
Preventable hospitalisation				
2004	6.43 (6.43 to 6.44)	1.01 (0.99 to 1.02)	6.48 (6.39 to 6.58)	160 397 (158 090 to 162 703)
2011	5.73 (5.73 to 5.74)	1.06 (1.04 to 1.07)	6.07 (5.97 to 6.16)	158 396 (155 995 to 160 797)
Change 2011–2004	−0.7 (−0.71 to −0.69)	0.05 (0.03 to 0.07)	−0.42 (−0.55 to −0.29)	−2000 (−5270 to 1284)
Amenable mortality				
2004	3.21 (3.21 to 3.22)	0.52 (0.5 to 0.54)	1.68 (1.62 to 1.74)	41 433 (39 899 to 42 966)
2011	2.53 (2.53 to 2.54)	0.57 (0.55 to 0.59)	1.45 (1.4 to 1.5)	37 983 (36 552 to 39 415)
Change 2011–2004	−0.68 (−0.69 to −0.67)	0.05 (0.02 to 0.08)	−0.23 (−0.31 to −0.15)	−3449 (−5516 to −1375)

The England means and the SII indices are measured in terms of patients per physician, average primary care quality, preventable hospitalisation per 1000, and amenable mortality per 1000. The RII indices are the SII indices as a proportion of the England means. The inequality gaps refer to the number of GPs required to eliminate inequality, the average quality loss attributable to inequality, the total excess hospitalisations attributable to inequality, and the total excess mortality attributable to inequality.
GP, general practitioners; RII, relative index of inequality; SII, slope index of inequality.

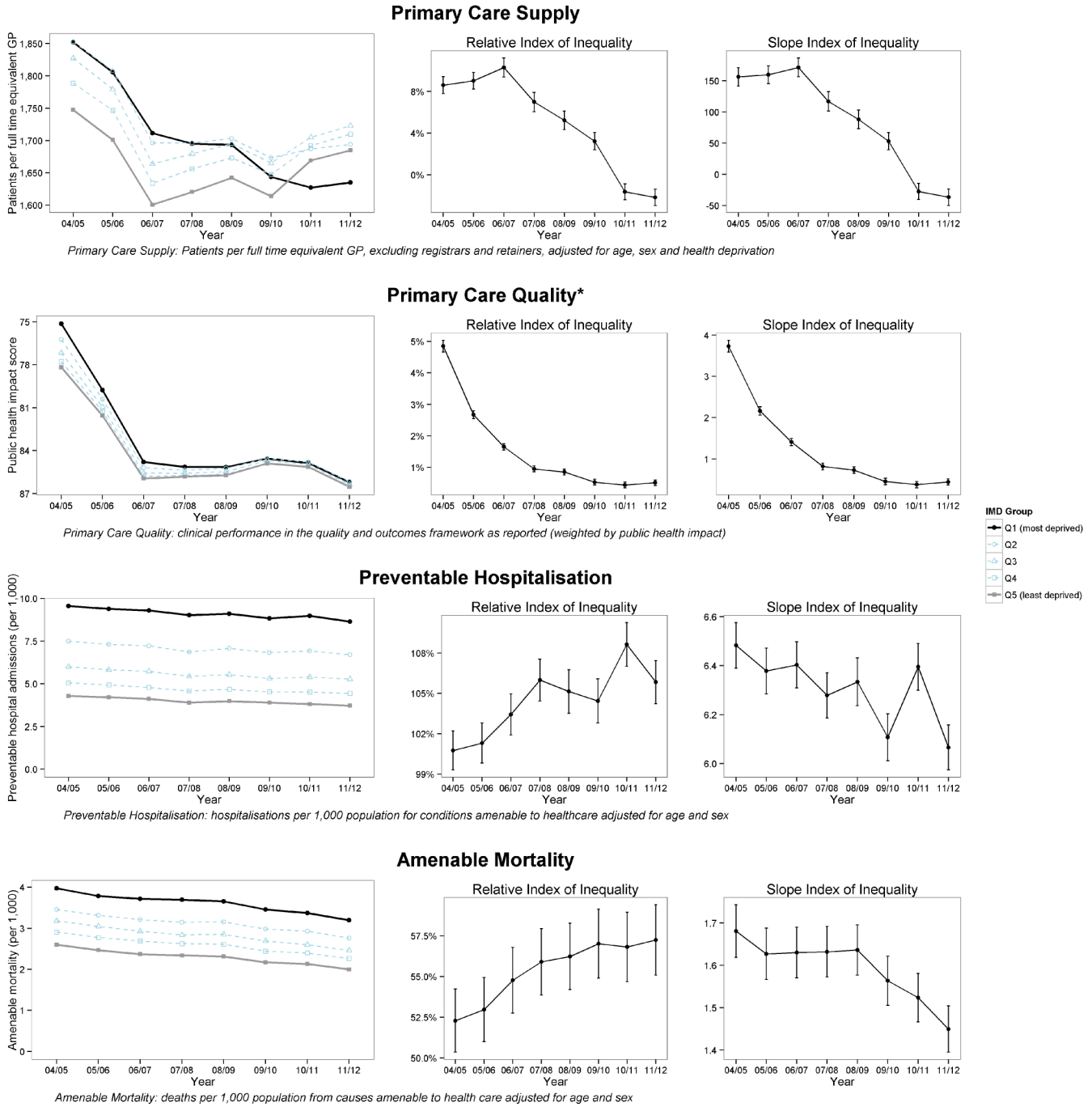

Figure 2 Inequality trends from 2004/2005 to 2011/2012. *Inverted axis on primary care quality to ease comparisons with other indicators, where decreasing implies improvement (GP, general practitioner; IMD, index of multiple deprivation).

compared between indicators measured on different scales to help assess the relative magnitude of different kinds of inequality.

However, our study does not include data on privately funded healthcare, which accounts for approximately 15% of total health expenditure in the UK.[27] We also lack detailed national data on changing patterns of multimorbidity at small area level. One consequence is that our study may underestimate additional needs for primary care in deprived neighbourhoods, which are likely to suffer from a greater burden of multimorbidity.[28] We also cannot assess how far observed trends in preventable hospitalisation and amenable mortality are due to trends in multimorbidity outside the control of the NHS. Another limitation is that the administrative health data sets do not contain information on individual socioeconomic characteristics. We therefore used the IMD, which assumes that individuals generally conform to the socioeconomic profile of their residential neighbourhood. Finally, our measure of primary care quality is based on indicators drawn from the UK primary care pay-for-performance scheme, which only captures part of clinical practice.[29] Under this scheme, improvements in quality were most rapid in practices with low baseline performance, and these practices were concentrated in more-deprived areas.[30] It is possible that aspects of primary care quality that were not financially incentivised and monitored did not follow the same pattern, and inequalities in these may have persisted or even widened.

Findings

The NHS succeeded in reducing inequality in primary care supply and quality from 2004/2005 to 2011/2012, eliminating the inequity in primary care supply and almost eliminating the inequity in primary care quality. These changes can partly be attributed to the substantial investments in primary care in the mid-2000s to late 2000s, including the QOF pay-for-performance programme from 2004/2005, and provision of additional funding for new GP practices in 'under-doctored' areas of the country from 2006.[13 31] However, the NHS did not have comparable success in reducing socioeconomic inequalities in healthcare outcomes. Although absolute inequalities in healthcare outcomes decreased slightly from 2004/2005 to 2011/2012, relative inequalities increased, and substantial inequalities remained in 2011/2012 in preventable hospitalisation and amenable mortality. While not wholly unexpected,[32 33] this is still perhaps disappointing, given that this was a period of sustained large-scale expenditure growth in the NHS in England,[34] and that tackling health inequality was a high priority for the NHS.[35] It is possible that non-NHS factors were acting to increase socioeconomic inequalities in healthcare outcomes during this period—evidence suggests that socioeconomic inequalities increased between 2003 and 2008 for smoking, poor diet, physical inactivity and other unhealthy behaviours.[36] It is also possible that changes in primary care supply and quality have not yet been given sufficient time to substantially reduce inequalities in healthcare outcomes, or that the national pay-for-performance programme overemphasised management of existing chronic diseases over primary prevention.

Comparison with other studies

One previous national study examined socioeconomic inequality in preventable hospitalisation in England covering years 2001/2002–2012/2013.[37] This study finds similar trends to those we observe, showing a gradual decrease in the rate of chronic ambulatory care sensitive emergency admissions for the average patient, and substantial and persistent socioeconomic inequalities in ambulatory care sensitive emergency admissions over the period. One previous national study examined socioeconomic trends in amenable mortality[38] in England from 2001/2002 to 2011/2012. However, this study was conducted at a large area level (324 local authorities) which may potentially mask changing patterns of inequality within these large areas, and it excluded mortality in people aged over 75 years. This study found both average levels and absolute measures of inequality in amenable mortality to have fallen over this period. Our finer grained analysis looking at much smaller areas (32 482 LSOAs) and following the ONS definition of amenable mortality, hence also including mortality for certain conditions such as HIV/AIDS and injuries in those over 75 years of age, confirms this basic pattern, though revealing a widening of relative inequality that was not apparent in the previous study. Furthermore, our inclusion of this older section of the population results in a higher overall rate of amenable mortality, and the more detailed level of analysis we employ reveals wider socioeconomic inequalities.

CONCLUSION

Reducing inequality in healthcare outcomes is more complex and challenging than reducing inequality of access to healthcare.[39] Socioeconomic inequalities in preventable hospitalisation and amenable mortality are not only due to inequalities in the supply of primary and hospital care. They are also attributable to socioeconomic-related differences in, and complex interactions between (1) multimorbidity; (2) patient behaviours including healthcare seeking, self-care and lifestyle; (3) informal social support networks; (4) social care supply and quality; (5) primary care provider behaviour; (6) secondary care provider behaviour and (7) the coordination of care between primary, secondary and social care providers. Reducing socioeconomic inequalities in healthcare outcomes is therefore likely to require complex interventions to improve the coordination of care between multiple actors within and outwith the healthcare system. There is a growing body of evidence about effective interventions to reduce preventable hospitalisation and amenable mortality, but little is known about how to reduce socioeconomic inequalities in these healthcare outcomes.[40 41] It is our hope that the indicators developed in this study can play a role in helping to develop the evidence base for reducing inequalities in healthcare outcomes through application to equity monitoring at local, national and international levels.

What is already known on this subject

- There are socioeconomic inequalities in primary care access, quality and outcomes even in high-income countries with universal healthcare systems.
- Reducing these inequalities by strengthening primary care was a key priority for the National Health Service (NHS) in England from 2004/2005 to 2011/2012, as part of the world's first cross-government strategy for reducing health inequality.
- It is not known how far the NHS succeeded in addressing this priority, since national trends in healthcare equity are still not routinely monitored.

What this study adds

- This study presents the first comprehensive assessment of national trends in socioeconomic inequalities in primary care access, quality and outcomes in England from 2004/2005 to 2011/2012.
- During this period, there were substantial reductions in socioeconomic inequalities in primary care supply and quality, but only modest reductions in preventable emergency hospitalisation and mortality amenable to healthcare.
- We have developed a suite of indicators that could be used in other countries to monitor the contribution of healthcare services to tackling wider inequalities in community health.

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Contributors MA accessed, extracted and assembled the data, conducted the main data analysis, contributed to study design, and drafted and revised the paper. RC initiated the collaborative project, had the original idea for the study, supervised the data assembly and analysis, and revised the paper. MA and RC are the joint guarantors. TD framed the policy context of the study and revised the paper. All

other authors contributed to the design of the work and interpretation of the results, and have commented on drafts of the paper and approved the final version. All authors, external and internal, had full access to all of the data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis.

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Competing interests ML reports grants from the NIHR during the conduct of this study. PG reports grants from Department of Health, grants from Public Health England and grants from British Medical Association during the conduct of the study. RC reports grants from NIHR during the conduct of the study and is a member of the NHS Outcomes Framework Technical Advisory Group. RR was supported by the National Institute for Health Research Collaboration for Leadership in Applied Health Research and Care, North Thames, at Bart's Health NHS Trust.

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Data sharing statement An extensive technical appendix with detailed instructions on how we constructed our indicators from routine administrative data sets is provided alongside the paper.

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Appendix 1: Indicator Definitions

Primary care supply

Definition:

Primary care supply is defined as the number of patients per full time equivalent GP, excluding registrars and retainers, adjusted for age, sex and neighbourhood ill-health using the Carr-Hill workload adjustment. This version of the formula was recommended in 2007 by the Formula Review Group established by NHS Employers and the BMA, and though never implemented in practice it remains the most authoritative and up-to-date analysis of the determinants of primary care workload in England.

The numerator is the total number of people alive at mid-point in the current financial year. In practice, we use ONS mid-year estimates of population which is equal to the population during the middle of the calendar year. The denominator is the number of FTE GPs excluding registrars and retainers attributed to each small area in the current indicator year.

Technical details:

Our data on primary care supply at GP practice level were obtained from the annual National Health Service General and Personal Medical Services workforce census, taken at 30th September each year, midway through the financial year. In keeping with standard measures of the GP workforce we exclude GP registrars and GP retainers from our measure.

We used this data to construct a whole-population national data set at small area (LSOA) level by using the NHS Attribution Data Set of GP-registered populations to attribute FTE GPs from GP practices to LSOAs. The attribution dataset details the LSOAs in which the patients registered with the practice live. We use this information to determine the proportion of the FTE GP workforce attached to the practice to attribute to each of the LSOAs that the patients registered with the practice live in. Applying this attribution calculation to each GP practice and then aggregating the GP supply attributed from the different practices at LSOA level gives us our measure of primary care supply at LSOA level. We linked practice level data on primary care supply for the ten years 2004/05 through 2011/12 with corresponding LSOA level data on population and deprivation. We use data from all 9,092 general practices in the English NHS that were open for at least one year of the study period.

We then need-weighted the population for each small area for age, sex and IMD 2010 health domain using the Carr-Hill formula workload adjustment (updated 2007 version) to upscale populations that are expected to require more primary care and downscale populations expected to require less (Formula Review Group 2007; Hippisley-Cox et al 2006). The "Carr-Hill" formula is used for distributing funding to GP practices. We do not adjust for temporary resident population, the fourth and final workload adjustment factor in the Carr-Hill formula, as the HSCIC were unable to provide us with the patient level data necessary to make this adjustment.

Primary care quality

Definition:

Primary care quality is a score between 0 and 100 defined as a weighted average of clinical process quality from 16 indicators in the national quality and outcomes framework (QOF). Each indicator measures the percentage of the relevant patient population for whom the quality target is achieved. The weights used to combine these indicators into a primary care quality score are proportional to importance of the individual indicators in terms of the estimated mortality reduction impact associated with improvement on the indicator.

Technical details:

GP practices record the number of patients with each condition who are listed in their practice registers. For each clinical indicator, the number of patients deemed appropriate for that indicator is the denominator and the number of patients for whom the indicator was met is the numerator. The reported achievement on the indicator is the percentage of relevant patients for whom the practice met the indicator quality target.

We started with a group of 20 QOF indicators identified by Ashworth et al [3] based on available evidence on mortality reduction. We then selected 16 out of the 20 indicators for which data were available throughout our period of analysis in a consistent format. Each indicator was then weighted based on importance in terms of the estimated number of lives saved per 100,000 patients. These weights were derived from Ashworth et al [3] who identified the highest level of evidence for risk reduction in all-cause mortality and converted risk reduction estimates into estimated mortality reduction rates per 100,000 population per annum (see table A.1.1 for details).

Numerators and denominators for the QOF indicators were attributed from GP practice to LSOA level in an identical manner to that used to attribute primary care supply as described above. The QOF indicators were then calculated at LSOA level and these were then combined using the weighting process described to give average performance in terms of primary care quality score at LSOA level.

We did not need to standardise this indicator, since it is a nationally comparable performance measure that already allows for case mix and other characteristics of the GP practice population. Factors such as the age, sex and disease prevalence of the GP practice population are not legitimate justifications for variation in GP performance on these measures.

Table A.1.1: List of conditions in the Quality and Outcomes Framework (QOF)

QOF indicator	Summary description of indicator	Crude prevalence per 100,000 registered patients, mean (SD)	Annual mortality reduction, per 100,000 registered patients
DM18	Diabetes: influenza vaccination	4420 (1881)	63.7
CHD12	CHD: influenza vaccination	3448 (1487)	61.6
BP5a	Hypertension: BP ≤150/90 mmHg	13 548 (5117)	48.2
CHD10a	CHD: beta-blocker treatment	3448 (1487)	45.9
STROKE10	Stroke/TIA: influenza vaccination	1649 (967)	28.1
DM23a	Diabetes: HbA1c ≤7.0%	4420 (1881)	26.5
COPD8	COPD: influenza vaccination	1626 (958)	24.9
CHD9a	CHD: aspirin or other antithrombotic therapy	3448 (1487)	24.8
CHD8a	CHD: cholesterol ≤5.0 mmol/l	3448 (1487)	15.8
STROKE12a	Stroke (non-haemorrhagic): aspirin or other antithrombotic therapy	1080 (649)	15.8
DM12	Diabetes: BP ≤145/85 mmHg	4420 (1881)	13.5
CHD6a	CHD: BP ≤150/90 mmHg	3448 (1487)	11.3
SMOKING4	CHD, stroke/TIA, hypertension, DM, CKD, COPD, asthma, psychosis: smoking cessation advice	3903 (2525)	10.9
DM25	Diabetes: HbA1c ≤9.0%	4420 (1881)	7.4
DM15a	Diabetes with proteinuria or microalbuminuria: ACEI or ARB therapy	505 (513)	3.4
CHD11a	CHD (myocardial infarction): ACEI or ARB therapy	572 (291)	1.5

Preventable hospitalisation

Definition:

Preventable hospitalisation is defined as the number of people per 1,000 population having one or more emergency hospitalisations for a chronic ambulatory care sensitive condition, adjusting for age and sex.

The numerator is the number of people with emergency hospital admissions (both finished and unfinished admission episodes, excluding transfers) for specific long-term conditions which should not normally require hospitalisation. This is derived from the Hospital Episode Statistics (HES) Admitted Patient Care (APC), provided by the Health and Social Care Information Centre (HSCIC).

The denominator is the total number of people alive at mid-point in the current financial year. The Office for National Statistics (ONS) mid-year England population estimates for the respective calendar years are used for this purpose.

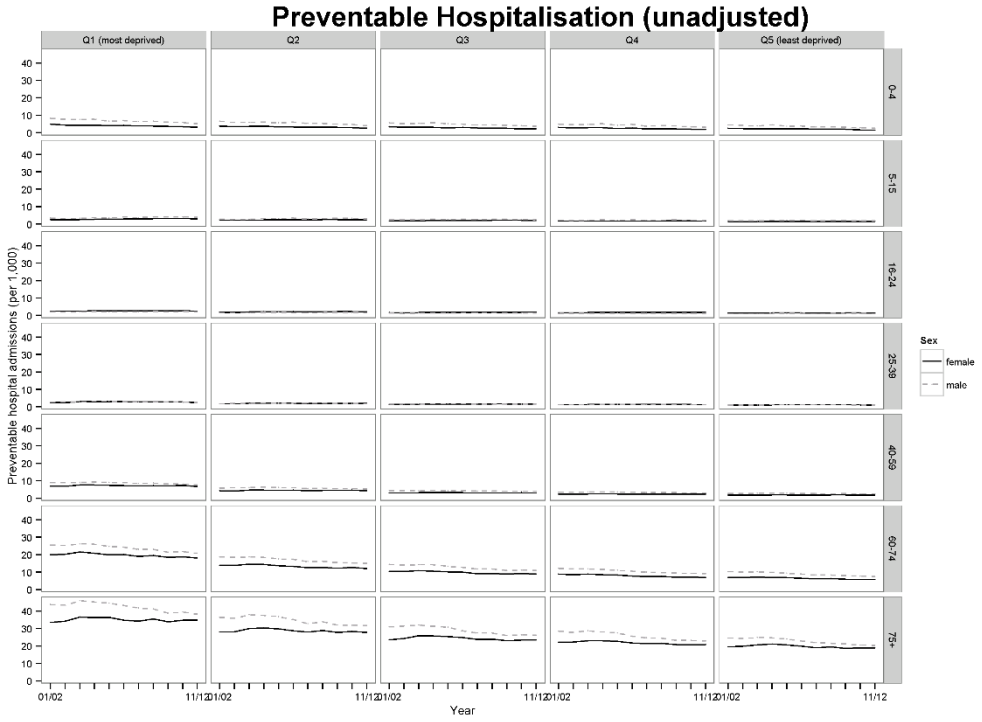
Technical details:

This indicator measures the number of people having an emergency hospital admission per 1,000 of population for specific long-term conditions considered amenable to health care. This is often used as an indicator of the performance of primary care and the interface between primary and secondary care. We use the list of conditions defined in the NHS outcomes framework indicator 2.3i (see Table A.1.2 below). Hospital admissions for all ages, including young children and people over 75, are included in this indicator.

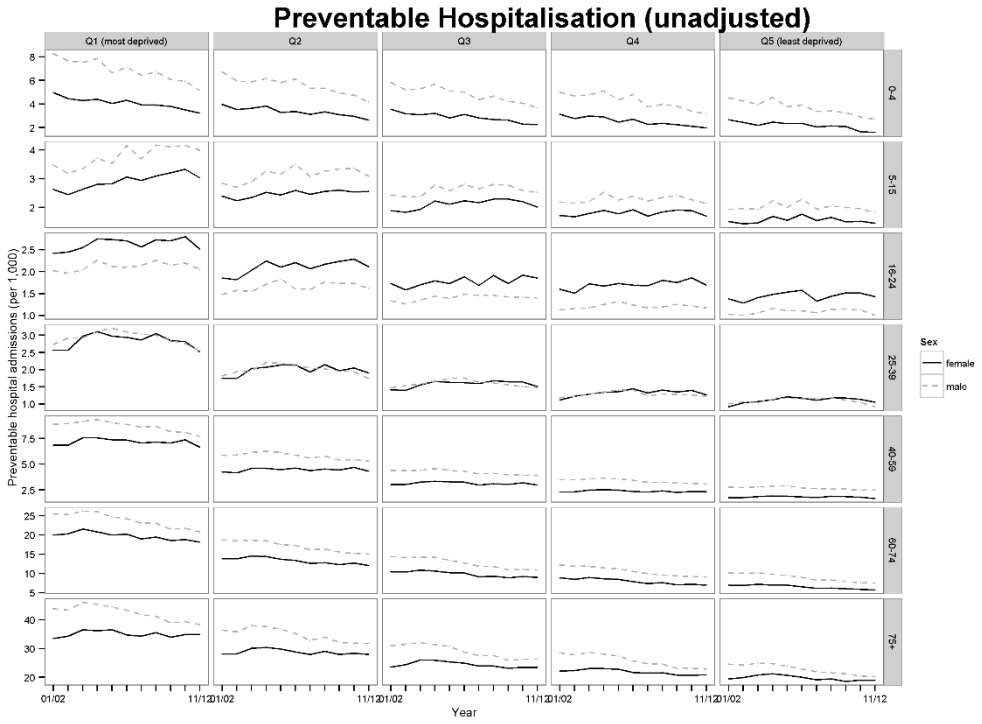
We calculate indirectly standardised emergency hospital admission rate for each small area to allow for differing age and sex structure by deprivation level. To do so, we start with individual level HES data on emergency admissions and aggregate up to small area level. We then compute the expected hospitalisation counts for each small area by applying national age-sex hospitalisation rates to small area level numbers of people in each age-sex group. We then compute the adjusted rate for each small area as the product of the ratio of observed over expected count for the small area and the national rate. We then compute the adjusted count for each small area as adjusted rate times the small area population. Finally, we aggregate up this adjusted count to quantile group level to present adjusted count per 1,000 people in each quantile group. The calculations are presented in Appendix 2.

Figure A.1.1 shows trends in preventable hospitalisation for each quintile group by age and sex.

Figure A.1.1: Trends in preventable hospitalisation (fixed x-axis for age group comparisons, then floating x-axis for deprivation quintile group comparisons)



Breakdown by age, sex, deprivation and year



Breakdown by age, sex, deprivation and year

Table A.1.2: ICD-10 codes for chronic ambulatory care sensitive conditions [4]
This is based on list produced by the ONS and adopted by the NHS Outcomes Framework.

Infections	
B18.1	Chronic viral hepatitis B without delta-agent
B18.0	Chronic viral hepatitis B with delta-agent
Nutritional, endocrine and metabolic	
E10	Insulin-dependent diabetes mellitus
E11	Non-insulin-dependent diabetes mellitus
E12	Malnutrition-related diabetes mellitus
E13	Other specified diabetes mellitus
E14	Unspecified diabetes mellitus
Diseases of the blood	
D50.1	Sideropenic dysphagia
D50.8	Other iron deficiency anaemias
D50.9	Iron deficiency anaemia, unspecified
D51	Vitamin B12 deficiency anaemia
D52	Folate deficiency anaemia
Mental and behavioural disorders	
F00	Dementia in Alzheimer disease
F01	Vascular dementia
F02	Dementia in other diseases classified elsewhere
F03	Unspecified dementia
Neurological disorders	
G40	Epilepsy
G41	Status epilepticus
Cardiovascular diseases	
I10X	Essential (primary) hypertension
I11.0	Hypertensive heart disease with (congestive) heart failure
I11.9	Hypertensive heart disease without (congestive) heart failure
I13.0	Hypertensive heart and renal disease with (congestive) heart failure
I20	Angina pectoris
I25	Chronic ischaemic heart disease
I50	Heart failure
I48X	Atrial fibrillation and flutter
J81X	Pulmonary oedema
Respiratory diseases	
J20	Acute bronchitis
J41	Simple and mucopurulent chronic bronchitis
J42X	Unspecified chronic bronchitis
J43	Emphysema
J44	Other chronic obstructive pulmonary disease
J45	Asthma
J46X	Status asthmaticus
J47X	Bronchiectasis

Amenable mortality

Definition:

Amenable mortality is defined as the number of deaths per 1,000 people from causes considered amenable to healthcare, allowing for age and sex. The numerator is the number of people who died in the current financial year due to a cause of death considered amenable to health care. The denominator is the total number of people alive at mid-point in the current financial year.

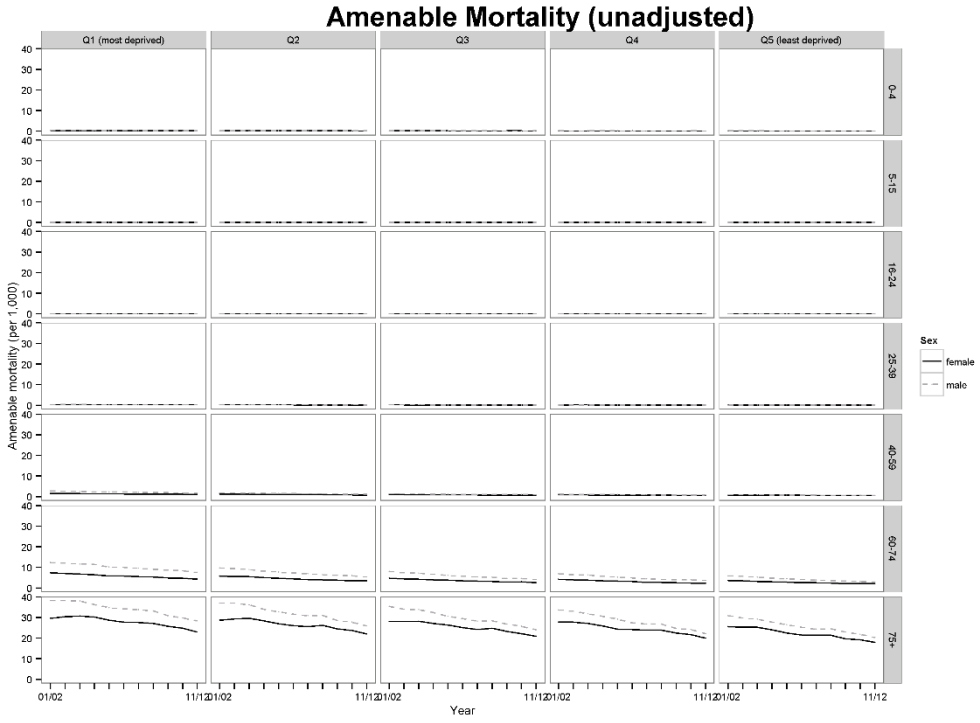
Technical details:

Amenable mortality was defined according to the conditions listed in the ONS Outcomes Framework (see table A.1.3). This includes conditions that are responsible for at least 100 deaths in a year and that have a clear link between the number of deaths and healthcare interventions. The classification takes account of appropriate age limits and each death is counted only once.

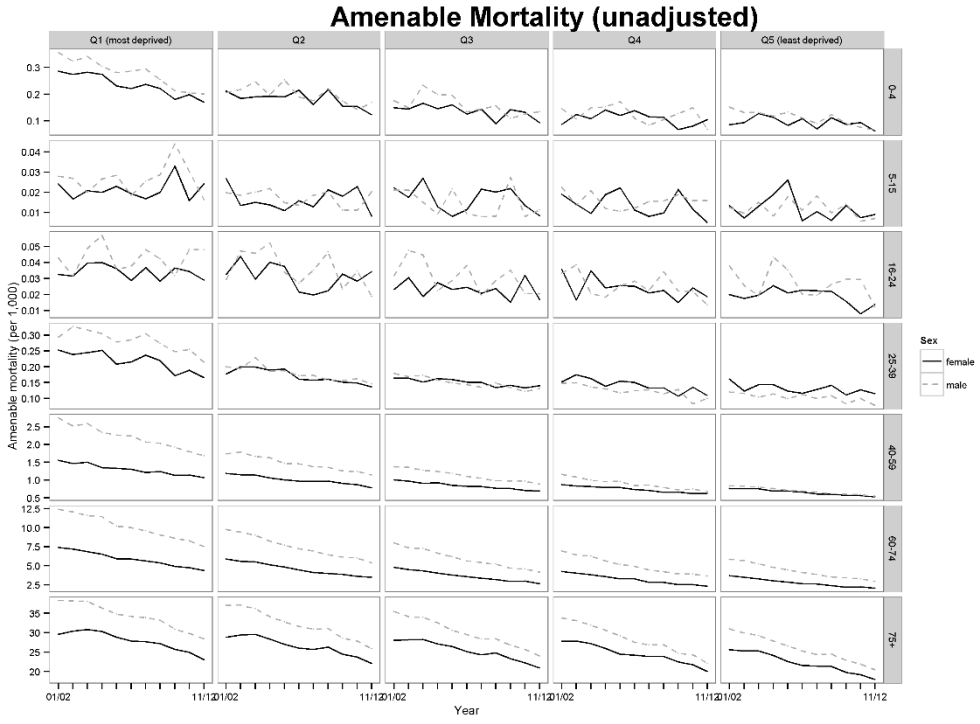
We calculate indirectly standardised amenable mortality rate for each small area to allow for differing age and sex structure by deprivation level. To do so, we start with individual-level ONS mortality data and aggregate up to small area level. We then compute the expected number of deaths in each small area by applying national age-sex mortality rates to small area level numbers of people in each age-sex group. We then compute the adjusted rate for each small area as the product of the ratio of observed over expected count for the small area and the national rate. We then compute the adjusted count for each small area as adjusted rate times the small area population. Finally, we aggregate up this adjusted count to quantile group level to present adjusted count per 1,000 people in each quantile group. The calculations are presented in Appendix 2.

Figure A.1.2 shows trends in amenable mortality for each quintile group by age and sex.

Figure A.1.2: Trends in amenable mortality (fixed x-axis for age group comparisons, then floating x-axis for deprivation quintile group comparisons)



Breakdown by age, sex, deprivation and year



Breakdown by age, sex, deprivation and year

Table A.1.3: ONS list of causes of death considered amenable to health care [5]
Note: ONS produce separate lists for "amenable" and "preventable" deaths, where the latter are considered preventable by wider public health activities outside the health care system. In line with the NHS Outcomes Framework, we use the former list i.e. "amenable".

Condition group and cause	ICD-10 codes	Age
Infections		
Tuberculosis	A15-A19, B90	0-74
Selected invasive bacterial and protozoal infections	A38-A41, A46, A48.1, B50-B54, G00, G03, J02, L03	0-74
Hepatitis C	B17.1, B18.2	0-74
HIV/AIDS	B20-B24	All
Neoplasms		
Malignant neoplasm of colon and rectum	C18-C21	0-74
Malignant melanoma of skin	C43	0-74
Mesothelioma	C45	0-74
Malignant neoplasm of breast	C50	0-74
Malignant neoplasm of cervix uteri	C53	0-74
Malignant neoplasm of bladder	C67	0-74
Malignant neoplasm of thyroid gland	C73	0-74
Hodgkin's disease	C81	0-74
Leukaemia	C91, C92.0	0-44
Benign neoplasms	D10-D36	0-74
Nutritional, endocrine and metabolic		
Disorders of thyroid gland	E00–E07	0–74
Diabetes mellitus	E10-E14	0-49
Neurological disorders		
Epilepsy and status epilepticus	G40-G41	0-74
Cardiovascular diseases		
Rheumatic and other valvular heart disease	I01-I09	0-74
Hypertensive diseases	I10-I15	0-74
Ischaemic heart disease	I20-I25	0-74
Cerebrovascular diseases	I60-I69	0-74
Respiratory diseases		
Influenza (including swine flu)	J09-J11	0-74
Pneumonia	J12-J18	0-74
Asthma	J45-J46	0-74
Digestive disorders		
Gastric and duodenal ulcer	K25-K28	0-74
Acute abdomen, appendicitis, intestinal obstruction, cholecystitis/lithiasis, pancreatitis, hernia	K35-K38, K40-K46, K80-K83, K85, K86.1-K86.9, K91.5	0-74
Genitourinary disorders		

Nephritis and nephrosis	N00-N07, N17-N19, N25-N27	0-74
Obstructive uropathy and prostatic hyperplasia	N13, N20-N21, N35, N40, N99.1	0-74
Maternal and infant		
Complications of perinatal period	P00-P96, A33	All
Congenital malformations, deformations and chromosomal anomalies	Q00-Q99	0-74
Injuries		
Misadventures to patients during surgical and medical care	Y60-Y69, Y83-Y84	All

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Appendix 2: Indirect age, sex standarisation of indicators at LSOA level

The indirect age sex standardisation process used to adjust the preventable hospitalisation and amenable mortality indicators:

$$adjusted\_count_{lsoa} = adjusted\_rate_{lsoa} \times population_{lsoa} \tag{1}$$

$$adjusted\_rate_{lsoa} = \frac{observed_{lsoa}}{expected_{lsoa}} \times rate_{national} \tag{2}$$

$$observed_{lsoa} = \sum^{sex}\sum^{age} events_{lsoa,age,sex} \tag{3}$$

$$expected_{lsoa} = \sum^{sex}\sum^{age} expected_{lsoa,age,sex} \tag{4}$$

$$expected_{lsoa,age,sex} = rate_{national,age,sex} \times population_{lsoa,age,sex} \tag{5}$$

$$rate_{national,age,sex} = \frac{\sum^{lsoa} events_{lsoa,age,sex}}{\sum^{lsoa} population_{lsoa,age,sex}} \tag{6}$$

$$rate_{national} = \frac{\sum^{lsoa}\sum^{sex}\sum^{age} events_{lsoa,age,sex}}{\sum^{lsoa}\sum^{sex}\sum^{age} population_{lsoa,age,sex}} \tag{7}$$

$$population_{lsoa} = \sum^{sex}\sum^{age} population_{lsoa,age,sex} \tag{8}$$

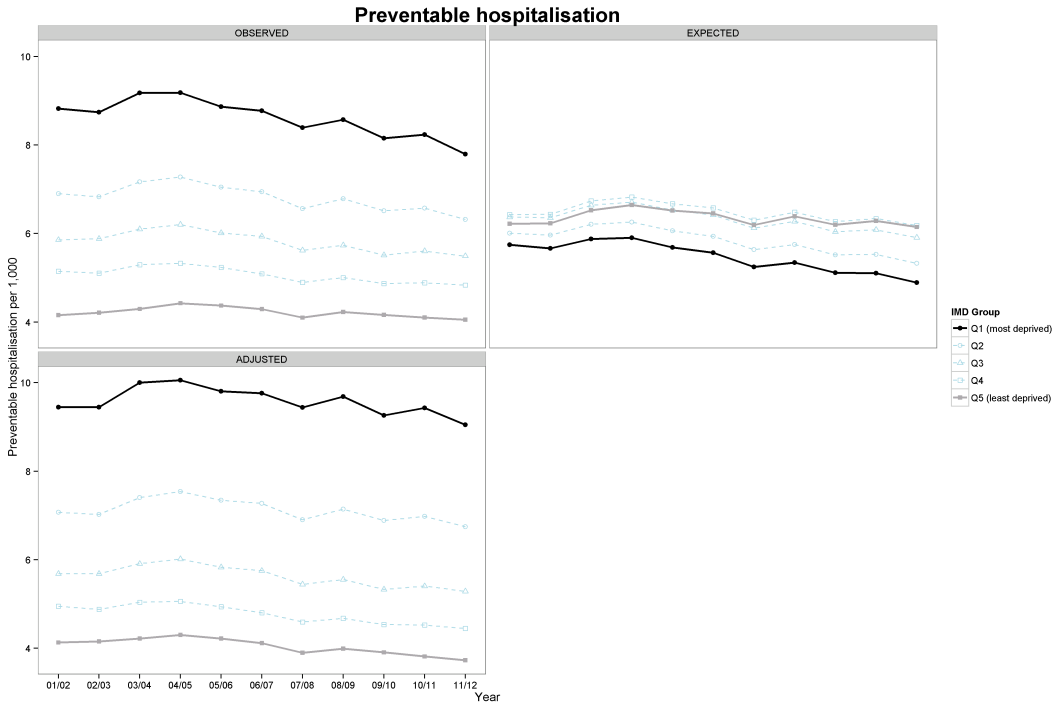


Figure 1: Preventable hospitalisation per 1,000 populations

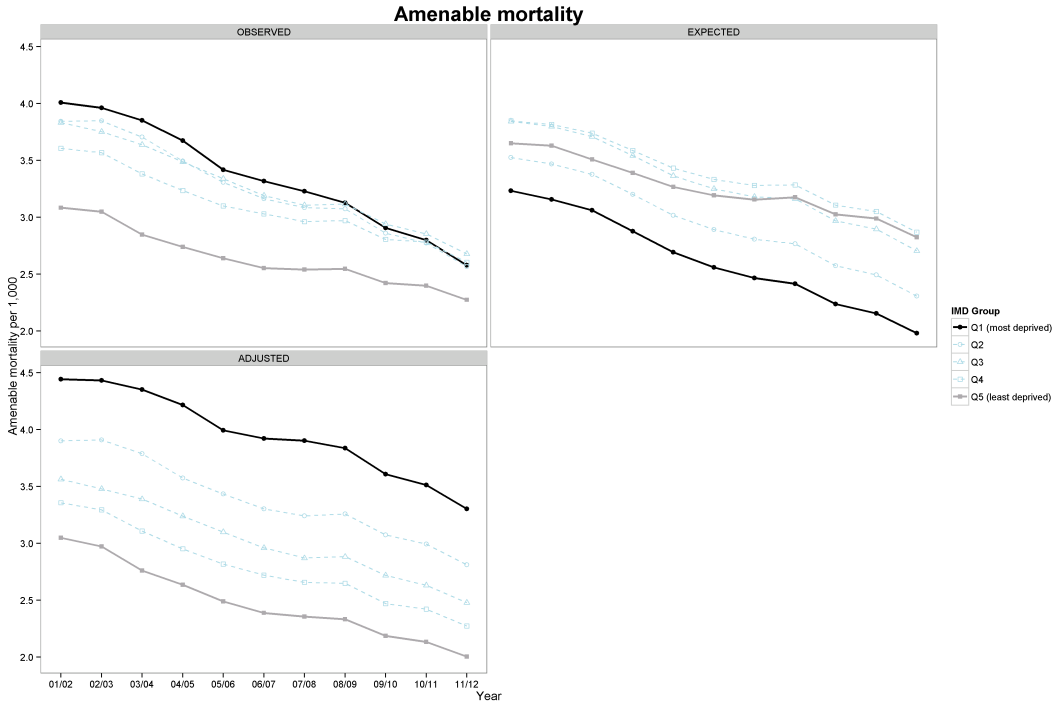


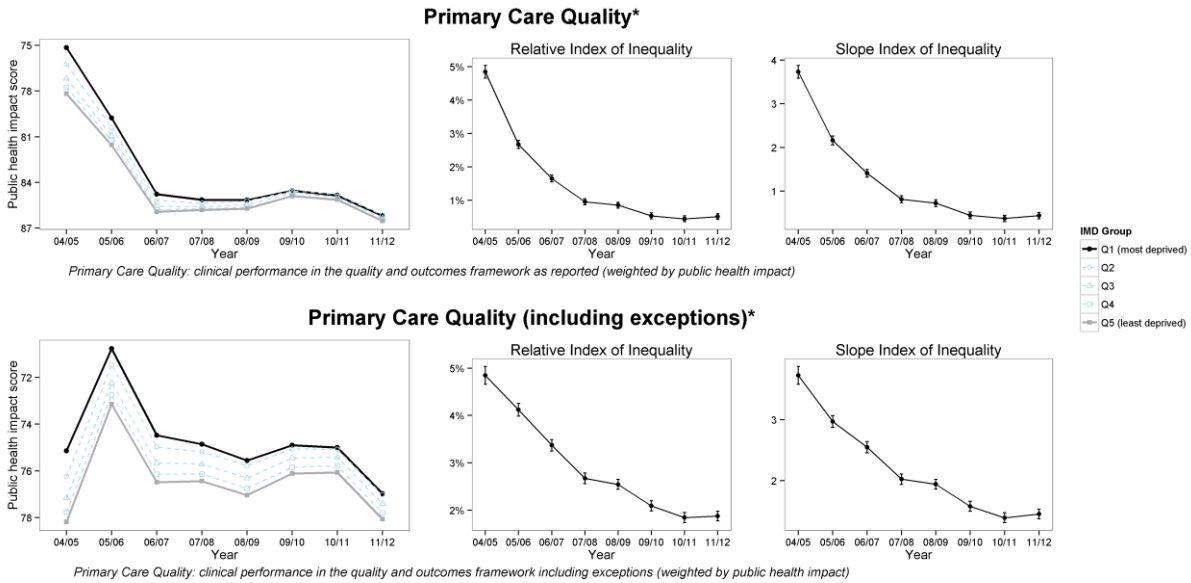
Figure 2: Amenable mortality per 1,000 population

Appendix 3: Robustness checks

Exception reporting

Figure A.3.1 shows trends in primary care quality in terms of public health impact score, relative index of inequality and slope index of inequality. The base case analysis shown in the top half of the panel was conducted using reported achievement, which excludes "exception reported" patients from the population denominator, the bottom half of the panel reports population achievement, which includes exceptions as poor quality. Data on "exception reported" patients was not available in the first year 2004/5 and so in the population achievement series average primary care quality for that year is artificially inflated, since "exception reported" patients could not be included in that year whereas in all other years "exception reported" patients were included as poor quality i.e. not achieving the QOF quality measures. Approximately 5% of patients were exception reported in years 2005/6 through 2011/12. As we can see despite the different absolute levels of performance as calculated by the two alternative calculation methods for this indicator the inequality trends in both absolute and relative terms are almost identical for the two alternative measures.

Figure A.3.1: Trends in Primary Care Quality



Change in neighbourhood deprivation

We used IMD 2010 (published in 2010 using data relating to 2007) for all years to ensure that our findings reflected real changes in health care delivery and outcomes, rather than artificial changes in the calculation of the deprivation index or the composition of neighbourhoods. This does raise the issue, however, of how accurately the deprivation of a neighbourhood in 2007

reflects its deprivation in 2004/5 and 2011/12. To assess this, we looked at cross tabulations of change over the seven year period between IMD 2004 (data for 2001) and IMD 2010 (data for 2007). These show that 84% of LSOAs in the most deprived fifth remained in the most deprived fifth, that 88% of neighbourhoods in the least deprived fifth remained in the least deprived fifth, and that only 14% of LSOAs changed rank by the equivalent of one quintile group or more.

Alternate model specification

In the paper we compute deprivation gradients across the four outcomes measured using linear regression methods. In this appendix we compare the deprivation gradients computed using linear regression with more sophisticated negative binomial models that have a closer fit to some of the indicators. These models were fit to each indicator in turn for each year of data in order to compute the SII and RII. Figures A.3.2 through A.3.5 show the results from this process. For the GP supply and GP quality indicators we see that the fit of the two models is indistinguishable with neither model fitting the data particularly well (these are displayed in figures A.3.2 and A.3.3). For the other two outcomes, preventable hospitalisations and amenable mortality, the negative binomial model captures the curvature in the data better than the linear model (these are displayed in figures A.3.4 and A.3.5). These results are summarised in figure A.3.6 which plots the SII and RII derived from these competing models over time. We can see from this figure that whilst the two models are indistinguishable for the primary care supply and quality indicators, for the preventable hospitalisation and amenable mortality indicators the better fit of the negative binomial model has resulted in a marginally higher measures of inequality with smaller confidence intervals. These differences however are small and leave the patterns and trends in these indicators unchanged. From this analysis we can conclude that our indicators and the conclusions that we draw from them are somewhat robust to model specification.

We chose to use the linear regression based indicators in our main analysis in the paper to make our measures as easy to compute and interpret as possible and hence maximise the likelihood of them being adopted in the NHS.

Figure A.3.2 Comparing models to calculate inequality in GP supply 2004-11

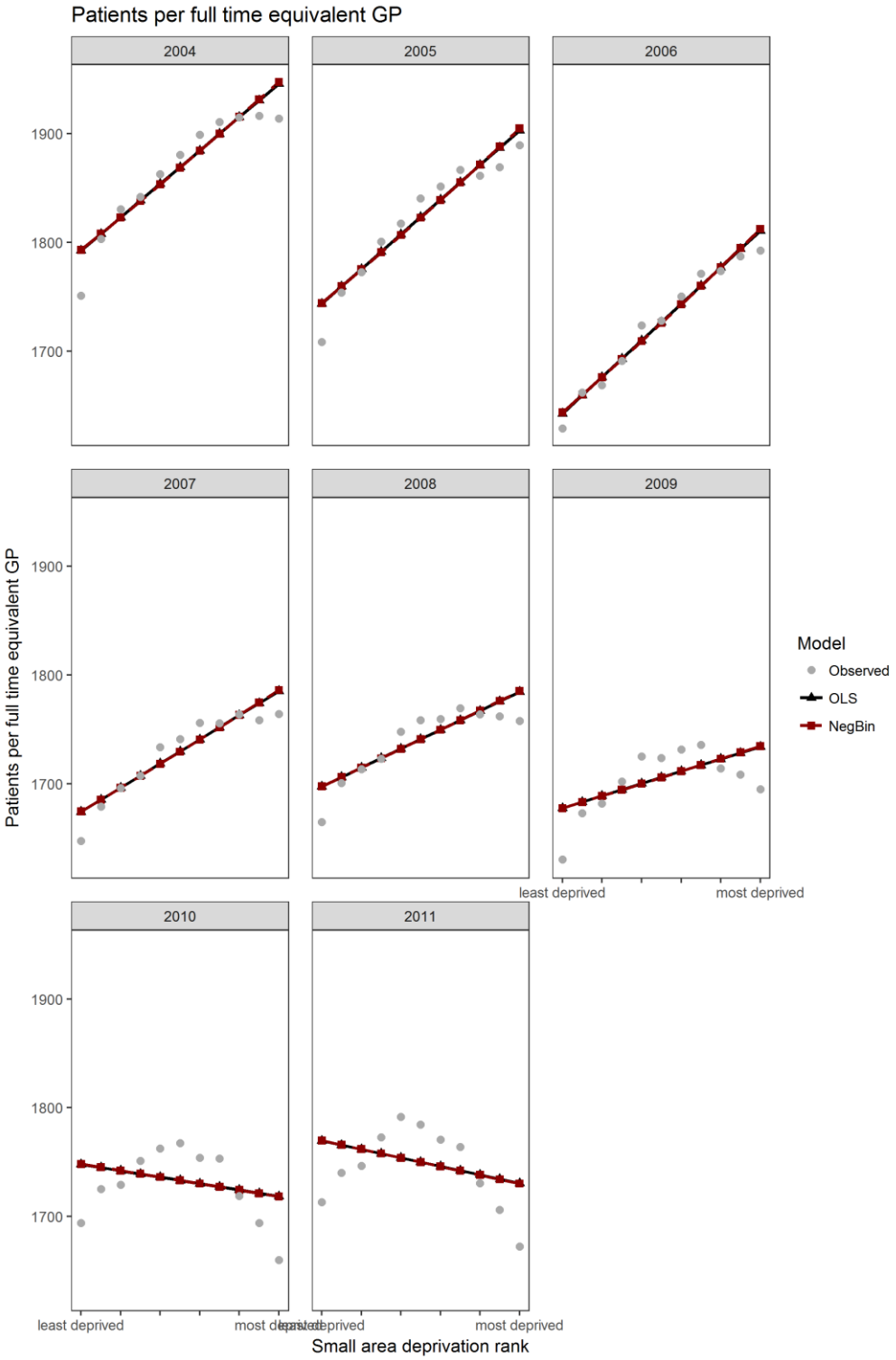


Figure A.3.3 Comparing models to calculate inequality in PHIS 2004-11

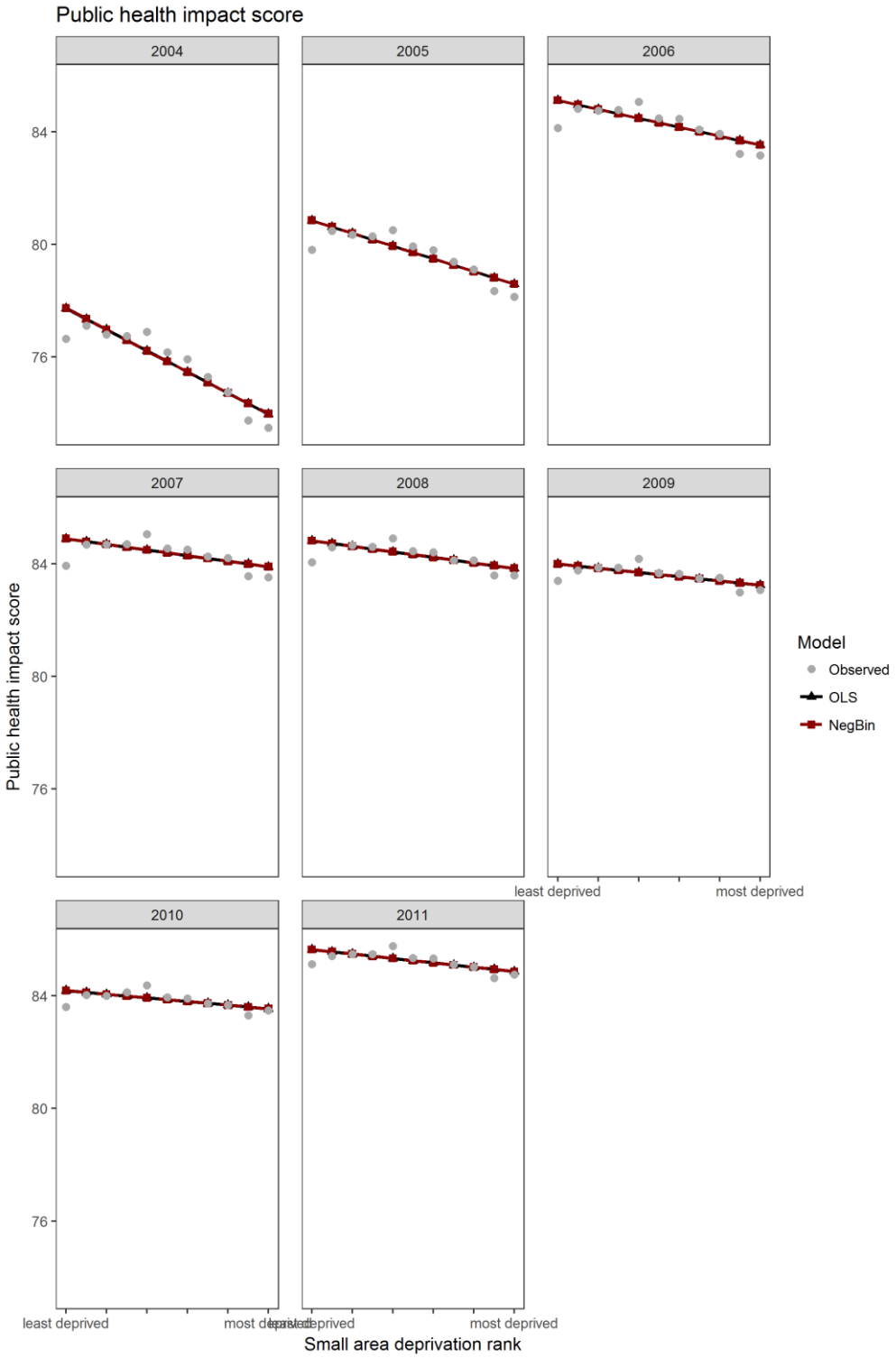


Figure A.3.4 Comparing models to calculate inequality in hospital admissions 2004-11

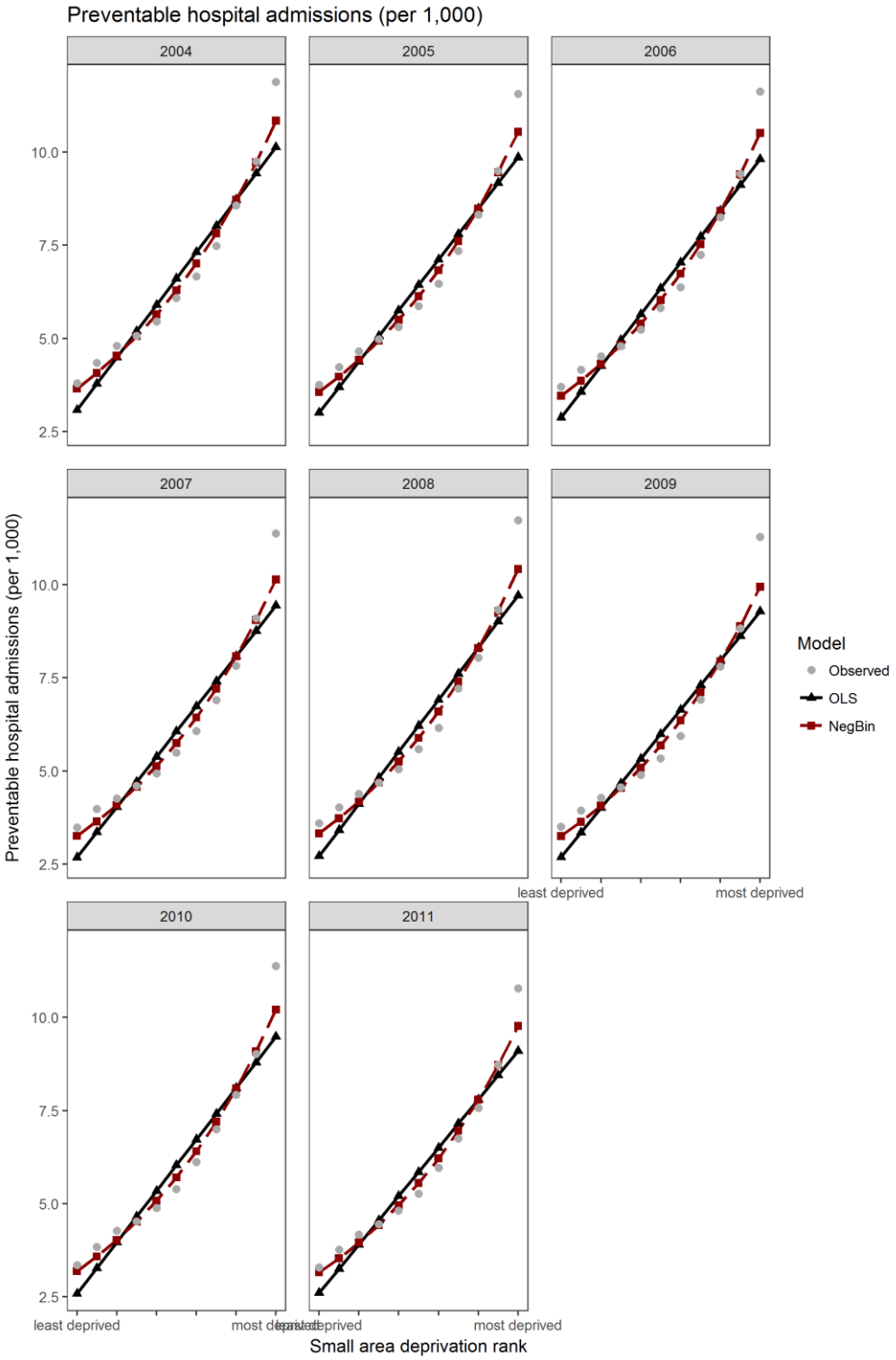


Figure A.3.5 Comparing models to calculate inequality in mortality 2004-11

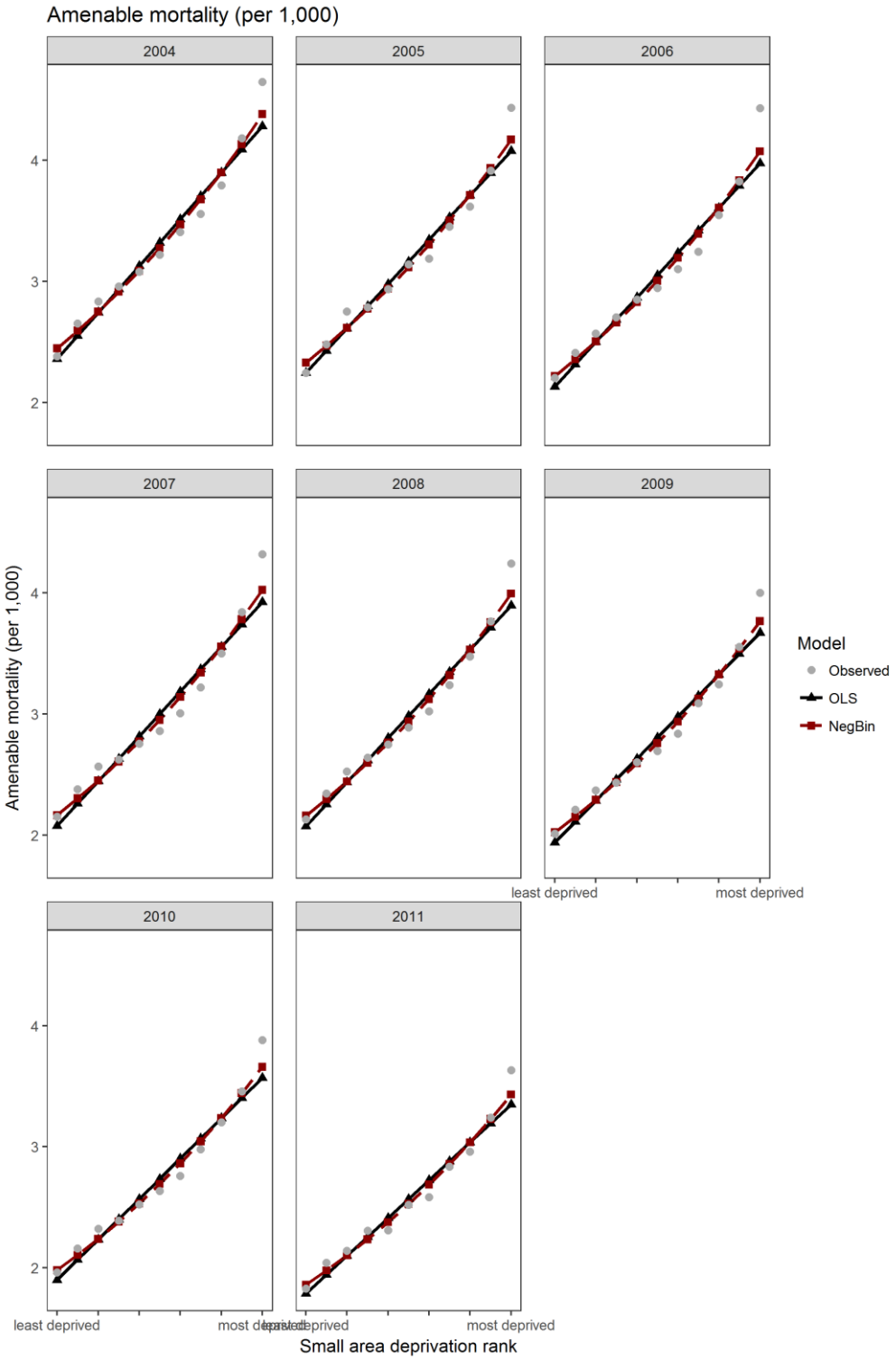
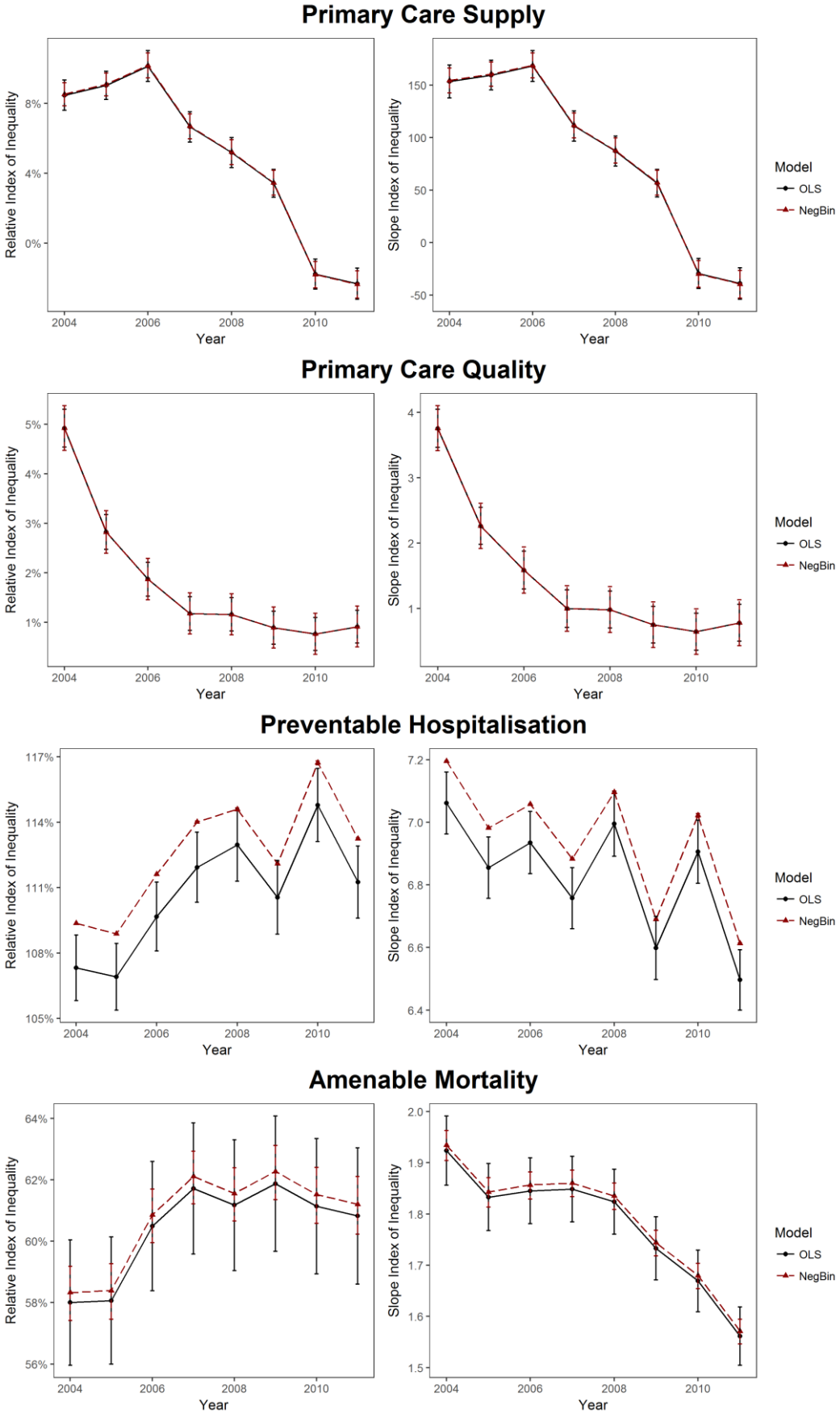


Figure A.3.6 Comparing models to plot trends over time in inequality indicators 2004-11



Appendix D: Paper 4 - Distributional Cost-Effectiveness Analysis of Health Care Programmes - A Methodological Case Study of the UK Bowel Cancer Screening Programme

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DISTRIBUTIONAL COST-EFFECTIVENESS ANALYSIS OF HEALTH CARE PROGRAMMES – A METHODOLOGICAL CASE STUDY OF THE UK BOWEL CANCER SCREENING PROGRAMME

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ABSTRACT

This paper presents an application of a new methodological framework for undertaking distributional cost-effectiveness analysis to combine the objectives of maximising health and minimising unfair variation in health when evaluating population health interventions. The National Health Service bowel cancer screening programme introduced in 2006 is expected to improve population health on average and to worsen population health inequalities associated with deprivation and ethnicity – a classic case of 'intervention-generated inequality'. We demonstrate the distributional cost-effectiveness analysis framework by examining two redesign options for the bowel cancer screening programme: (i) the introduction of an enhanced targeted reminder aimed at increasing screening uptake in deprived and ethnically diverse neighbourhoods and (ii) the introduction of a basic universal reminder aimed at increasing screening uptake across the whole population. Our analysis indicates that the universal reminder is the strategy that maximises population health, while the targeted reminder is the screening strategy that minimises unfair variation in health. The framework is used to demonstrate how these two objectives can be traded off against each other, and how alternative social value judgements influence the assessment of which strategy is best, including judgements about which dimensions of health variation are considered unfair and judgements about societal levels of inequality aversion. © 2014 The Authors. *Health Economics* published by John Wiley & Sons Ltd.

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KEY WORDS: health inequality; equity; cost-effectiveness analysis

1. INTRODUCTION

Cost-effectiveness analysis (CEA) is used to support health sector decisions about the allocation of limited resources with the objective of maximising health (Drummond *et al*., 2005). When dealing with population health interventions, we often have the additional objective of minimising 'unfair' health inequality (Cookson *et al*., 2009) and to this end are also interested in the social distribution of both health gains and health opportunity costs due to the intervention. In this paper, we propose a methodology for quantifying and combining these two objectives within an economic evaluation framework that highlights the social value judgements underpinning any particular conclusion. This 'distributional CEA' (DCEA) is demonstrated through a case study comparing potential redesign options to increase uptake of the National Health Service (NHS) bowel cancer screening programme (BCSP) in England.

Colorectal cancer (CRC) is the third most common cancer in the UK with approximately 40 000 new cases diagnosed annually resulting in almost 16 000 CRC-related deaths per year (ONS, 2012). Research has shown that using screening to diagnose and treat CRC earlier can significantly reduce the number of CRC deaths (Hewitson *et al*., 2008). The Department of Health launched the BCSP in 2006 and currently offers biennial

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screening with guaiac fecal occult blood test (gFOBT) to persons aged 60–74 years. Variable uptake of screening has been observed among the first 2.6 million invitees to the national BCSP, with overall uptake averaging only 54% ranging from 61% in the least deprived areas to 35% in the most deprived areas, and showing a similar gradient in terms of small area-based ethnic diversity measures (Logan *et al*., 2012; Von Wagner *et al*., 2011). Furthermore, for those individuals with positive screening results, there is also evidence of inequality in the uptake of follow-up colonoscopy (Morris *et al*., 2012). It is reasonable to expect that these inequalities in the uptake of the screening programme will exacerbate the already unequal distribution of health in the population, with the screening programme disproportionately benefiting more advantaged groups (for whom uptake is highest) – a classic case of 'intervention-generated inequality' (Lorenc *et al*., 2012).

Prior to the introduction of the BCSP, a number of possible screening options were evaluated to help NHS decision makers determine whether a screening programme was worthwhile and if so the form that it should take. To that end, a model was developed to assess the total resource implications and health impacts of screening by simulating the natural history of CRC and the impact of screening on that natural history (Tappenden *et al*., 2007). This model was later refined and updated to reflect data emerging from the BCSP (Whyte *et al*., 2012; Whyte *et al*., 2011). In this paper, we build on the latest version of this economic evaluation model and use it to estimate the distribution of health associated with alternative screening strategies. We then compare these health distributions using our DCEA framework to determine the strategy that best addresses the dual objectives of maximising health and minimising health inequality. The focus of our analysis is on the quantity and distribution of health gains related to increased participation in the screening programme; other potentially competing objectives of screening programmes such as the promotion of informed choice are not addressed in this paper.

2. METHODS

2.1. Cost-effectiveness analysis

While recognising that in reality there are an almost infinite number of screening strategies that could be designed, in order to demonstrate the framework, we simplify the comparison by considering four mutually exclusive options in our analysis:

- 'No screening'.
- 'Standard screening' as implemented in the BCSP in 2006.
- 'Targeted reminder': screening plus a targeted enhanced reminder letter (personal GP-signed letter and tailored information package) sent only to those living in the most income deprived 40% of small areas (index of multiple deprivation (IMD) 4 and IMD5) and to those living in areas with the highest proportion of inhabitants from the Indian subcontinent (IS5). This targeted subgroup comprises of approximately half of the total population invited for screening. The costs of this strategy per person targeted are estimated to be £7 resulting in an estimated increase in average uptake of gFOBT among the targeted population of 12%.
- 'Universal reminder': screening plus a universal basic reminder letter (sending a GP-endorsed reminder letter to all eligible patients). The costs of this strategy per person are estimated to be £3.50 resulting in an estimated increase in average uptake of gFOBT of 6%.

We characterise the alternative reminder strategies in such a way as to ensure that both have approximately equal additional intervention costs and equal impact on the total screening uptake, while having very different distributional impacts. Although these reminder strategies are somewhat stylised constructed to highlight the trade-offs between health improvement and health inequality, the potential costs and increases in uptake because of the strategies are estimates based on studies of similar interventions (Shankaran *et al*., 2007; Hewitson *et al*., 2011).

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The economic evaluation model follows a cohort of 1 million 30 year olds through their lifetimes (allowing it to simulate the adenoma–carcinoma sequence) with screening invitations being sent out biennially to individuals between the ages of 60 and 74 years. The model is run probabilistically to incorporate the uncertainty around the input parameters.

2.2. Inequality analysis

The CEA allows us to identify which of the strategies maximises total health. In order to extend this analysis to allow us to evaluate our other key objective, that of minimising unfair health inequality, we require descriptions of the estimated distributions of health produced by the interventions being compared. To produce these estimates, we condition the model input parameters on factors associated with inequalities in health and inequalities in the effect of screening. We then perform subgroup analyses according to these factors in order to estimate differential cost and health impacts. The health impact per person within each subgroup is scaled by the size of the subgroup in order to describe the total population distribution of health.

The distribution of changes in health attributed to an intervention are informed not only by the distribution of the health gains among recipients of the intervention but also by the distribution of health opportunity costs among those who would have received the displaced activities that the money spent on this intervention would otherwise have been spent on. These opportunity costs are unlikely to fall in proportion to the intervention costs or benefits for particular recipients, and those who would otherwise have benefited from the displaced activities may also include nonrecipients of the intervention.

2.2.1. Estimating a baseline population health distribution. We estimate baseline inequality in the population distribution of expected lifetime health by extending the economic model to incorporate differential all-cause mortality rates by level of socioeconomic deprivation in addition to age and gender. As estimates are based on the Office for National Statistics longitudinal study data (ONS, 2007), we map social class groupings to deprivation measures. We additionally include the differences in morbidity by using health-related quality of life data by age and gender based on UK norms for EQ-5D (Kind *et al*., 1999) and further adjust for deprivation using the differences between life expectancy and disability-free life expectancy as observed in the Office for National Statistics general lifestyle survey (Smith *et al*., 2010). Using this data in the model, we estimate a baseline population health distribution in terms of quality-adjusted life expectancy (QALE) at birth. As the ethnic diversity measure that we use in this study is not a variable that is routinely included in the administrative datasets used to estimate baseline QALE, we assume a baseline QALE adjusted for gender and deprivation that does not further vary by ethnic diversity.

2.2.2. Estimating the distribution of uptake of the bowel cancer screening programme. Analysis of the pilot study of the BCSP suggests that screening uptake (the proportion of those invited to screening who participate) varies by area level deprivation, area level ethnic diversity and gender (Weller, 2009). Area level deprivation is based on quintile groups of the IMD 2004, and ethnic diversity is derived from area-based quintiles measuring the proportion of people originating from IS. Significant differences in uptake are observed in the data between all IMD quintile groups and between the most ethnically diverse quintile group (IS5) and the four least ethnically diverse quintile groups (IS1-4). Area level variables are based on data at lower super output area level; these are small areas containing approximately 1500 individuals. Multivariate analysis of the pilot study results provides the independent effect of each characteristic on uptake (Weller, 2009), allowing us to calculate the average uptake of gFOBT and follow-up colonoscopy for each of our 20 distinct subgroups, comprising all possible combinations of the two genders, five deprivation levels and two ethnic diversity levels. We are unable to estimate the proportion of the population in each of the 20 groups from this data as correlation between characteristics was not reported. Therefore, for the base case analysis, we simply assume independence in the distribution of the characteristics. Data from the pilot are used to extrapolate to the population at large by further assuming that the population in the pilot study is representative of the population in general.

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2.2.3. Estimating the distribution of opportunity cost. Additional costs of screening and related downstream diagnostic and treatment costs come out of a fixed health budget, and the health opportunity cost due to the disinvestment of these funds from other uses within NHS is assumed to be one quality-adjusted life year (QALY) per £20 000, in line with current practice in NHS. Owing to the absence of further information on how these opportunity costs are distributed, in the base case analysis, we assume that they are distributed equally across all population subgroups. We then perform sensitivity analyses by exploring two extreme assumptions around the distribution of opportunity cost: first, where the entire opportunity cost is borne by the healthiest of our 20 subgroups (women living in the least deprived and ethnically diverse areas), and second, where the entire opportunity cost is borne by the least healthy of our 20 subgroups (men living in the most deprived and ethnically diverse areas).

2.2.4. Assuming all other factors equally distributed. We are able to estimate a modelled distribution of health net of opportunity costs by incorporating the three sets of adjustments to the model that we have described previously, namely, the following: (i) the distribution of factors impacting baseline health; (ii) the distribution of factors impacting screening uptake; and (iii) the distribution of opportunity cost. In so doing, however, we assume that all other factors in the model remain constant between the different subgroups of interest. In particular, a key assumption is that CRC incidence and severity levels are equal across the relevant subgroups. This assumption was made because of data limitations and is supported by limited evidence suggesting that variation in CRC incidence by social class is small (National Cancer Intelligence Network, 2004).[1]

2.2.5. Measuring inequality in the resulting health distributions. Inequality in health distributions can be quantified in a variety of ways, and we present a battery of measures in order to be able to inform different inequality concerns from different stakeholders. We start with relative measures of inequality – those that measure the proportional changes in health across the distribution. These range from simple measures focusing only on the extremes of the distribution, such as the relative gap index, to more sophisticated measures assessing the entire distribution and allowing for different levels of relative inequality aversion. An example of the latter is the Atkinson index, shown in the succeeding texts for a population of n individuals with h_i representing the health of individual i, $\overline{h}$ representing mean health in the population and ε representing the level of constant relative inequality aversion (Atkinson, 1970).

$$A_\varepsilon = 1 - \left[\frac{1}{n}\sum_{i=1}^{n}\left[\frac{h_i}{\overline{h}}\right]^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}$$

We also look at absolute measures of inequality – those that measure the absolute changes in health across the distribution. These also range from simple extreme group measures, such as the absolute gap index, to more sophisticated measures assessing the entire distribution and allowing for different levels of absolute inequality aversion. An example of the latter is the Kolm index shown in the succeeding texts with α representing the level of constant absolute inequality aversion (Kolm, 1976).

$$K_\alpha = \left(\frac{1}{\alpha}\right) log\left(\frac{1}{n}\sum_{i=1}^{n} e^{\alpha[\overline{h}-h_i]}\right)$$

2.3. Social welfare analysis

Having separately quantified average population health and the level of health inequality resulting from each of our four screening strategies, we next combine concerns for maximising population health and concerns for

[1]Note that the stage of detection will be on average later in those groups with lower uptake, and so modelled cancer-related mortality does differ between subgroups.

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minimising health inequality using social welfare analysis. We first check for distributional dominance in a very general sense using the idea of generalised Lorenz dominance (Shorrocks, 1983) to compare the estimated health distributions and eliminate dominated strategies. Health distribution A can be said to generalised Lorenz dominate health distribution B if the Lorenz curve for health in A multiplied by the mean level of health in A dominates the Lorenz curve for health in B multiplied by the mean level of health in B. To compare the remaining, nondominated strategies, we turn to more restricted social welfare indices that explicitly trade-off increases in the mean health against greater equality in the distribution of health (Wagstaff, 2002). These indices are calibrated on the same scale by calculating an 'equally distributed equivalent' (EDE) level of health for the health distribution: the level of health each person in the population would receive in a hypothetically perfectly equal health distribution such that society would be indifferent between that equal distribution of health and the actual unequal distribution of health. We focus on two such social welfare indices constructed by combining the mean level of health with the Atkinson and Kolm inequality indices, respectively.

$$h_{ede} = (1 - A_{\varepsilon})\overline{h}$$
$$h_{ede} = \overline{h} - K_{\alpha}$$

In the case of no concern for inequality ($\alpha = \varepsilon = 0$), the social welfare indices just collapse to the mean level of health. The difference between mean health and EDE health for a given level of inequality aversion indicates the average decrement in health per person society is willing to sacrifice in order to achieve a perfectly equal distribution of health conditional on the level of inequality in the current health distribution. Calculating and comparing the EDEs for the predicted health distributions allows us to rank these strategies over a range of possible inequality aversion levels.

2.4. Adjustment for alternative social value judgements

If inequality concern does not apply to all sources of variation in health – for example, if some determinants of individual ill health are deemed to be a matter of unavoidable bad luck or individual responsibility – then further analysis is required in order to isolate just the variation in health deemed to be unfair.

We can isolate this health distribution of interest by undertaking multivariate analysis on our raw health distribution, to control for 'fair' variation in health in order to leave a distribution of health reflecting only the 'unfair' variation. The adjustment process we use here has been referred to as 'direct unfairness' in the literature (Fleurbaey and Schokkaert, 2009). This 'fairness-adjusted' distribution of health is then evaluated in place of the unadjusted distribution, using the same inequality and social welfare index approaches. Alternative judgements about which variation in health is considered fair or unfair can lead to different conclusions as to which intervention strategy is preferred, and so the sensitivity of the decision to alternative sets of reasonable social value judgements regarding fairness should be assessed. In the current case study, the social variables of interest are gender, area-based level of deprivation and area-based ethnic diversity. There are eight possible permutations of social value judgements we can make on whether or not each of these three social variables represents a fair or unfair source of variation in health, ranging from all three being deemed unfair to all three being deemed fair (resulting in the trivial case where there is no variation in health in the adjusted distribution).

For our base case analysis, we characterise all variation in health as unfair. We then check the sensitivity of the ranking of strategies to each of the other seven possible social value judgements that can be made in this example. To apply these alternative social value judgements, we adjust our health distribution to only reflect unfair variation in health by using reference values for the fair variables while preserving the actual values for the unfair variables.

In cases where dominance rules, such as generalised Lorenz dominance, do not provide a complete ordering of strategies, additional social value judgements are required to assess trade-offs between improving total population health and reducing unfair health inequality. The key additional social value judgements that need to be made relate to the choice of inequality measures underpinning social welfare and the level of inequality

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aversion. We calculate our results for relative (Atkinson) and absolute (Kolm) inequality indices at both high and low levels of inequality aversion and check the sensitivity of our decision across a range of inequality aversion levels in order to identify the thresholds at which each strategy would be preferred.

3. RESULTS

3.1. Cost-effectiveness results

Table I shows the population level cost-effectiveness results for the four different strategies. The results are based on a lifetime model of a cohort of 1 million 30 year olds, and net health benefits are calculated at a cost-effectiveness threshold of £20 000 per QALY.

The screening programme in any form improves population health and has positive net health benefits as compared with no screening. On the basis of these cost-effectiveness results, if the objective is solely to maximise population health, we should choose screening with the addition of the universal reminder.

3.2. Inequality results

The baseline distribution of health measured in QALE is shown in Figure 1. We can see from this distribution that in the absence of any screening programme, there are substantial inequalities in the population health distribution.

We next look at the impact of the three screening options on this baseline health distribution. Figure 2 shows the impact of each option in terms of screening uptake by baseline population health. Figure 3 shows how uptake translates into changes in the health distribution.

It is evident from Figure 2 that there is a positive monotonic relationship between baseline health and gFOBT uptake, with uptake being higher for those who are already more healthy, regardless of the specific form of the screening programme under consideration. The universal reminder results in a parallel shift in gFOBT uptake as compared with the standard screening programme, with uptake increasing by the same amount (6%) in each health quintile. The targeted reminder flattens the uptake gradient between the health quintiles, resulting in a higher uptake in the lower health quintiles and a lower uptake in the higher health quintiles as compared with the universal reminder strategy.

Figure 3a shows the changes to the population health distribution associated with each of our three screening strategies relative to no screening, and Figure 3b looks more closely at the impact of the two redesign strategies as compared with the standard screening programme.

Compared with no screening, the screening programme in any of the three forms improves health across the distribution and widens health inequality in absolute terms, improving the health of the healthiest most and the least healthy least. Looking to Figure 3b, we see that compared with standard screening, the universal reminder is health improving across the distribution and further exacerbates absolute health inequality. By contrast, the targeted reminder as compared with standard screening reduces absolute health inequality by focussing additional benefits on the least healthy. It also reduces the health of some of the more healthy groups who benefit very little from the targeted reminder but still bear the health losses because of the opportunity cost of the strategy.

Table I. Standard cost-effectiveness results

	Bowel cancer-related cost (£)	Life years	QALYs	Incremental net health benefit (QALYs)[a]
No screening	278 793 874	50 577 384	41 762 818	—
Standard screening	350 872 069	50 634 273	41 806 794	40 372
Screening + targeted reminder	400 936 962	50 639 192	41 810 506	41 581
Screening + universal reminder	385 268 692	50 639 452	41 810 784	42 642

Results based on a lifetime model for a cohort comprising of 1 million 30 year olds.
[a]Incremental to no screening.

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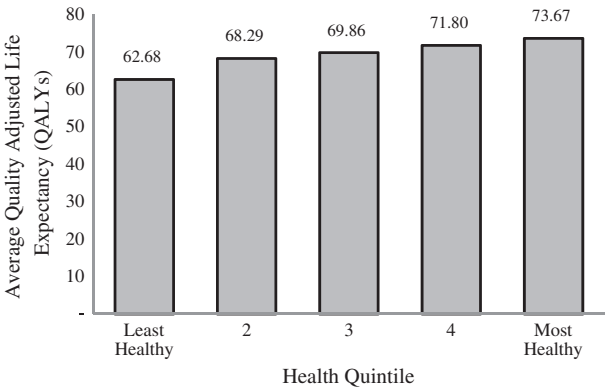

Figure 1. Baseline health distribution

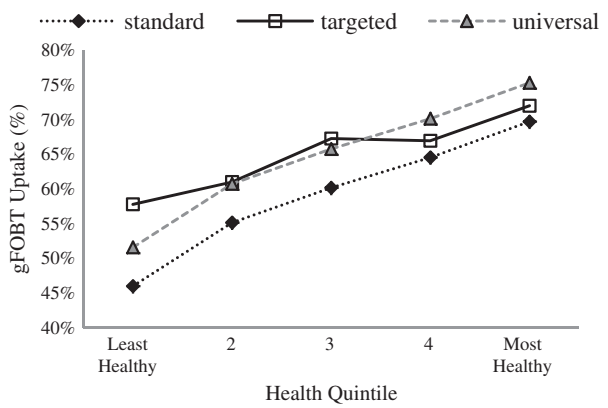

Figure 2. Guaiac fecal occult blood test (gFOBT) uptake distribution

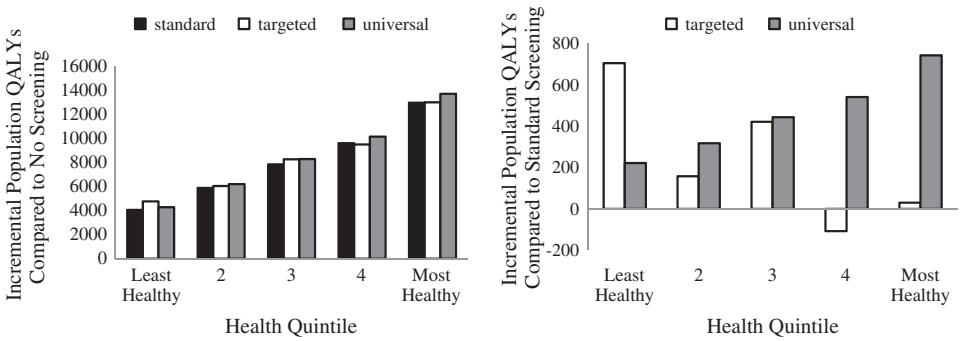

Figure 3. (a) Health compared with no screening (per million of population invited for screened). (b) Health compared with standard screening (per million of population invited for screening)

Combining the baseline health distribution and the estimated distribution of health changes associated with each of our screening strategies provides the overall health distribution associated with each strategy. Table II reports a range of absolute and relative inequality measures calculated for each strategy.

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Table II. Measures of inequality

Relative inequality indices	No screening	Standard	Targeted reminder	Universal reminder
Relative gap index (ratio)	0.17527[a]	0.17592	0.17586	0.17596
Relative index of inequality	0.18607[a]	0.18674	0.18668	0.18678
Gini index	0.03101[a]	0.03112	0.03111	0.03113
Atkinson index ($\varepsilon = 1$)	0.00171[a]	0.00172	0.00172	0.00172
Atkinson index ($\varepsilon = 7$)	0.01330[a]	0.01337	0.01337	0.01338
Atkinson index ($\varepsilon = 30$)	0.06253[a]	0.06281	0.06279	0.06283
Absolute inequality indices	**No screening**	**Standard**	**Targeted reminder**	**Universal reminder**
Absolute gap index (range)	10.98604[a]	11.03064	11.02726	11.03325
Slope index of inequality	12.88747[a]	12.94123	12.93691	12.94438
Kolm index ($\alpha = 0.025$)	0.20281[a]	0.20430	0.20416	0.20439
Kolm index ($\alpha = 0.1$)	0.87801[a]	0.88429	0.88371	0.88467
Kolm index ($\alpha = 0.5$)	4.56391[a]	4.58739	4.58587	4.58883

$\varepsilon = 1$ represents low relative inequality aversion, while $\varepsilon = 30$ represents high relative inequality aversion.
$\alpha = 0.025$ represents low absolute inequality aversion, while $\alpha = 0.5$ represents high absolute inequality aversion.
[a]Indicates the most equal strategy.

All relative and absolute inequality measures calculated across a range of inequality aversion levels rank no screening as the least unequal and the universal reminder as the most unequal of the four strategies.

3.3. Social welfare results

We next combine our concerns for maximising health and minimising health inequality using social welfare analysis. We find that the estimated health distributions associated with both no screening and standard screening are generalised Lorenz dominated by those associated targeted and universal reminder strategies. This implies that both reminder strategies deliver more population health on average and a fairer distribution of health than the dominated strategies. Dominance does not apply between the targeted and universal reminder strategies, however, so we turn to our social welfare indices evaluated across a range of inequality aversion levels. The values of these indices are reported in Table III.

The social welfare indices show that where there is little or no concern for inequality, the universal reminder is the preferred strategy. However, as inequality aversion increases, the targeted reminder becomes the preferred strategy.

The results thus far have assumed an equal distribution of opportunity cost. Table IV reports the sensitivity of these results to alternative extreme assumptions. When all opportunity costs are borne by the least healthy subgroup, no screening and standard screening are no longer dominated.

Although the distribution of opportunity cost does not impact mean health, it does impact the distribution of health, and this is reflected in the social welfare measures. This is particularly evident at intermediate levels of

Table III. Measures of social welfare

Social welfare indices	Targeted reminder	Universal reminder
Mean health ($\varepsilon = \alpha = 0$)	69.30127	69.30233[a]
Atkinson EDE ($\varepsilon = 1$)	69.18238	69.18331[a]
Atkinson EDE ($\varepsilon = 7$)	68.37503	68.37510[a]
Atkinson EDE ($\varepsilon = 30$)	64.94991[a]	64.94796
Kolm EDE ($\alpha = 0.025$)	69.09711	69.09794[a]
Kolm EDE ($\alpha = 0.1$)	68.41756	68.41767[a]
Kolm EDE ($\alpha = 0.5$)	64.71541[a]	64.71350

EDE, equally distributed equivalent.
[a]Indicates the strategy yielding the highest social welfare.

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Table IV. Sensitivity to opportunity cost distribution

	All opportunity cost borne by least healthy subgroup				All opportunity cost borne by healthiest subgroup	
Social welfare indices	No screening	Standard	Targeted reminder	Universal reminder	Targeted reminder	Universal reminder
Mean health	69.25969	69.30006	69.30127	69.30233[a]	69.30127	69.30233[a]
Atkinson EDE ($\varepsilon = 1$)	69.14152	69.18056	69.18147	69.18252[a]	69.18286	69.18373[a]
Atkinson EDE ($\varepsilon = 7$)	68.33888	68.36800[a]	68.36610	68.36734	68.37799[a]	68.37769
Atkinson EDE ($\varepsilon = 30$)	64.92865[a]	64.91468	64.89302	64.89892	64.95627[a]	64.95350
Kolm EDE ($\alpha = 0.025$)	69.05688	69.09486	69.09556	69.09660[a]	69.09793	69.09866[a]
Kolm EDE ($\alpha = 0.1$)	68.38168	68.41112[a]	68.40958	68.41074	68.42046[a]	68.42020
Kolm EDE ($\alpha = 0.5$)	64.69578[a]	64.68086	64.65951	64.66532	64.72148[a]	64.71879

EDE, equally distributed equivalent.
[a]Indicates the strategy yielding the highest social welfare.

inequality aversion ($\varepsilon = 7$ or $\alpha = 0.1$) where we see that the preferred screening strategy changes from standard screening when all the opportunity cost is borne by the least healthy group, to universal reminder when opportunity cost is equally distributed, to targeted reminder where all the opportunity cost is borne by the healthiest group.

3.4. Adjustment for alternative social value judgements results

Our results so far have assumed all inequality is unfair; Table V reports the sensitivity of our results to all eight possible sets of social value judgements regarding which inequalities are deemed unfair that can be made in this example.

The sensitivity analysis suggests that in this example, value judgements around the fairness of variation associated with area level deprivation are pivotal in determining the preferred strategy.

Finally, we explore the sensitivity of our social welfare indices calculated for the nondominated strategies to the choice of inequality aversion level as shown in Figure 4a and b. These figures show the difference between the EDE of the alternative strategies. The threshold level of inequality aversion at which the targeted reminder becomes the preferred strategy is eight for the Atkinson EDE and 0.12 for the Kolm EDE. At these levels of inequality aversion, a decision maker would be willing to sacrifice 1000 potential QALYs among the population of 1 million 30 year olds in order to achieve the more equal distribution of health offered by the targeted screening strategy.

Table V. Sensitivity of preferred screening strategy decision to the choice of social value judgements

Social value judgment			Preferred strategy based on social welfare index					
IMD	Ethnic diversity	Gender	Atkinson EDE ($\varepsilon = 1$)	Atkinson EDE ($\varepsilon = 7$)	Atkinson EDE ($\varepsilon = 30$)	Kolm EDE ($\alpha = 0.025$)	Kolm EDE ($\alpha = 0.1$)	Kolm EDE ($\alpha = 0.5$)
Fair	Fair	Fair	U	U	U	U	U	U
Fair	Unfair	Fair	U	U	U	U	U	U
Fair	Fair	Unfair	U	U	U	U	U	U
Fair	Unfair	Unfair	U	U	U	U	U	U
Unfair	Fair	Fair	U	U	T	U	U	T
Unfair	Unfair	Fair	U	U	T	U	U	T
Unfair	Fair	Unfair	U	U	T	U	U	T
Unfair	Unfair	Unfair	U	U	T	U	U	T

IMD, index of multiple deprivation; EDE, equally distributed equivalent; U, universal reminder; T, targeted reminder.

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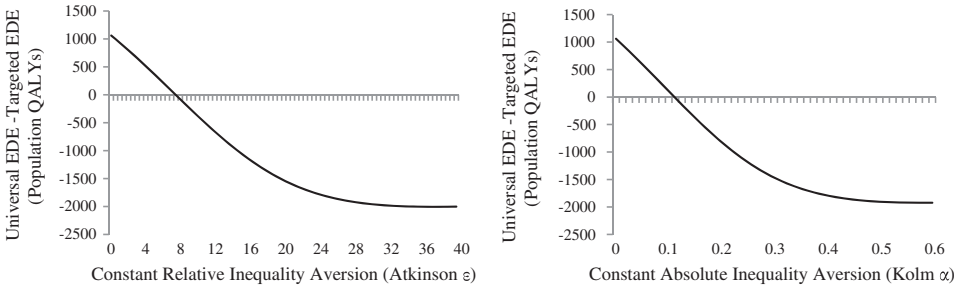

Figure 4. (a) Sensitivity to level of relative inequality aversion. (b) Sensitivity to level of absolute inequality aversion

4. DISCUSSION

4.1. Distributional cost-effectiveness analysis

The results from the model show that although the national BCSP has a small per person benefit, this benefit is substantial at a population level. This is to be expected for a population health intervention such as this, where the majority of people screened will not have bowel cancer, and some of the people who develop bowel cancer may not participate in screening. So despite large individual benefits accruing to people who participate in screening and have their bowel cancer detected early, these benefits accrue to only a relatively small number of people and are averaged across the whole population, giving a small expected per person benefit among the general population.

Targeted and universal reminder strategies to increase uptake of bowel cancer screening both appear to be worthwhile in terms of improving population health. In the base case analysis, both would be viewed as welfare increasing compared with no screening or standard screening for a broad range of social welfare functions reflecting different views on health inequality. The universal reminder resulted in a greater population health improvement than the targeted reminder but was less attractive in terms of its impact on increasing health inequalities. In our base case analysis, the universal reminder would be the preferred intervention at the lower end of the range of inequality aversion values considered, but the targeted reminder could become preferred at high levels of health inequality aversion.

Although all three configurations of the screening programme are health inequality increasing compared with no screening, augmenting the current screening programme with a targeted reminder reduces health inequality. By contrast, augmenting the current screening programme with a universal reminder slightly increases health inequality as compared with the standard screening programme alone. Some aspects of the intervention-generated inequality due to the screening programme arise because of inequalities in uptake of gFOBT and follow-up colonoscopy. However, some of the health inequality impact arises through differing rates of morbidity and other-cause mortality (not related to bowel cancer directly). Because we are interested in lifetime health, as measured here using QALE, detecting cancer earlier and thereby preventing a cancer-related fatality will inevitably deliver a larger health gain in social groups with relatively high QALE (Hauck *et al.*, 2002).

4.2. Sensitivity analyses

No screening and standard screening could be ruled out on the basis of generalised Lorenz dominance, but this was sensitive to an assumption about the distribution of the opportunity cost. The ranking produced by social welfare indices was sensitive to the type and level of inequality aversion. Furthermore, alternative social value judgements about the fairness of variation associated with the different population characteristics impact our choice of preferred strategy.

4.3. Other approaches

A number of methods have previously been proposed in the literature for including health inequality concerns in economic evaluation. These typically involve either weighting health gains differently for different groups in

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the population (Nord *et al.*, 1999) or weighting overall health gains directly against overall changes in health inequality in the context of 'multicriteria decision analysis' (Baltussen and Niessen, 2006). Both these types of method can be replicated using the DCEA framework by imposing the relevant restrictions on the fairness adjustment process and on the form and parameters of the social welfare function. We therefore see DCEA as encompassing these previous equity weighting methods within a more general framework that provides decision makers with more detailed information about health inequality impacts, rather than as a rival alternative approach.

An important emerging source of empirical literature on incorporating health inequality impacts into economic evaluation in low and middle income countries is the 'extended CEA' framework (Verguet *et al.*, 2014). This approach is similar in spirit to DCEA, although simplifies the analysis by (i) focusing on a single distributional variable (wealth quintile group) rather than analysing multiple distributional variables, (ii) setting aside the issue of opportunity costs falling on the health budget by assuming the intervention is funded by the tax system, and (iii) presenting results as a disaggregated 'dashboard' of costs and consequences by social group rather than using inequality indices and social welfare functions to explicitly analyse trade-offs between improving health and reducing unfair health inequality.

4.4. Conclusion

The DCEA framework outlined in this paper demonstrates how concerns for unfair health inequality can be taken into account when evaluating health care interventions funded within a fixed health budget. Transparency about value judgements and sensitivity analysis to reflect alternative value judgements is a key feature of the proposed framework. This form of analysis is particularly relevant when considering redesign options for preventive health care programmes to ameliorate intervention-generated inequalities, as in the case of the NHS BCSP. Data requirements for such analyses are nontrivial. However, credible DCEAs are currently feasible in at least some real-world settings, and further analyses will become possible in future as more evidence on distributional outcomes starts to emerge in the era of 'big data'. Evidence on distributional outcomes can be obtained through evidence synthesis research exploiting networks of patient-level trial datasets, as well as the application of heterogeneous treatment effect estimators to large observational datasets. Research is needed, for example, to synthesise evidence on the social distribution of the effects of different approaches for increasing the uptake of screening and other forms of preventive care, with a view to gauging how far estimates can be generalised from one setting to another. More empirical work is also required to determine a realistic distribution of opportunity costs (plausibly reflecting the impact of likely disinvestment decisions in the health service) and to elicit reasonable ranges of values for societal levels of absolute and relative inequality aversion as well as social value judgements on what should be deemed as fair and unfair variations in health.

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Appendix E: Paper 5 - Distributional Cost-Effectiveness Analysis: A Tutorial

Distributional Cost-Effectiveness Analysis: A Tutorial

Miqdad Asaria, MSc, Susan Griffin, PhD, Richard Cookson, PhD

Distributional cost-effectiveness analysis (DCEA) is a framework for incorporating health inequality concerns into the economic evaluation of health sector interventions. In this tutorial, we describe the technical details of how to conduct DCEA, using an illustrative example comparing alternative ways of implementing the National Health Service (NHS) Bowel Cancer Screening Programme (BCSP). The 2 key stages in DCEA are 1) modeling social distributions of health associated with different interventions, and 2) evaluating social distributions of health with respect to the dual objectives of improving total population health and reducing unfair health inequality. As well as describing the technical methods used, we also identify the data requirements and the social value judgments that have to be made. Finally, we demonstrate the use of sensitivity analyses to explore the impacts of alternative modeling assumptions and social value judgments. ***Key words:*** *cost-effectiveness analysis; economic evaluation; efficiency; equality; equity; fairness; health distribution; health inequality; inequality measures; opportunity cost; social value judgments; social welfare functions; tradeoff.* ***(Med Decis Making 2016;36:8–19)***

INTRODUCTION

When designing and prioritizing interventions, health care decision makers often have concerns about reducing unfair health inequality as well as improving total population health. However, the economic evaluation of such interventions is typically conducted using methods of cost-effectiveness analysis (CEA), which focus exclusively on maximizing total population health. These standard methods of CEA do not provide decision makers with information about the health inequality impacts of the interventions evaluated, or the nature and size of any tradeoffs between improving total population health and reducing unfair health inequality.

To address these shortcomings, we have developed a framework for incorporating health inequality impacts into CEA, which we call *distributional cost-effectiveness analysis* (DCEA).[1] DCEA is suitable for health sector decisions concerning the design and prioritization of any type of health care intervention with an explicit health inequality reduction objective—potentially including treatments as well as preventive health care such as programs of health promotion, screening, vaccination, case finding, primary and secondary prevention of chronic disease, and so on. However, like standard CEA, it focuses exclusively on health benefits and opportunity costs falling on the health sector budget. DCEA therefore does not provide a fully general framework of distributional economic evaluation for the health and income inequality impacts of cross-government public health programs with important nonhealth benefits and opportunity costs falling outside the health sector budget.

The DCEA framework has 2 main stages: 1) modeling social distributions of health associated with each intervention, and 2) evaluating social

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distributions of health. The main steps in the modeling stage are

1a. estimating the baseline health distribution;
1b. modeling changes to this baseline distribution due to the health interventions being compared, allowing for the distribution of opportunity costs from additional resource use; and
1c. adjusting the resulting modeled health distributions for alternative social value judgments about fair and unfair sources of health variation.

And the main steps in the evaluation stage are

2a. using the estimated distributions to quantify the change in total population health and unfair health inequality due to each intervention;
2b. ranking the interventions based on dominance criteria; and, finally,
2c. analyzing any tradeoffs between improving population health and reducing unfair health inequality, allowing for alternative specifications of the underlying social welfare function.

We have previously applied the DCEA framework to analyze 4 possible options for promoting increased uptake of the National Health Service (NHS) Bowel Cancer Screening Programme (BCSP) in England.[2] In this tutorial, we work through this applied example to describe the key steps in conducting a DCEA.

The BCSP is a biennial self-test-based screening program targeted at 60–74 year olds that aims to detect and treat colorectal cancer (CRC) early, and it has been shown to reduce CRC-related mortality risk by a substantial proportion. Individuals in the relevant age range are sent a guaiac fecal occult blood test (gFOBT) kit in the mail and are expected to complete the test by collecting 3 stool samples during a period of a few days and post them back for laboratory analysis. Those individuals testing positive are invited for further diagnostic testing (follow-up colonoscopy) and, when appropriate, treatment.

Analysis of the BCSP pilots and early data from the rollout of the BCSP have indicated large variations in uptake of the screening program patterned by the social variables of area deprivation, sex, and ethnicity. This variation in uptake can be modeled to estimate its impact on mortality and morbidity for the different socioeconomic subgroups in the population, and hence to describe the impact of the screening program on both the average level of health and the social distribution of health in the population.

METHODS

Stage A: Modeling Social Distributions of Health

Estimating the baseline health distribution

The first step in DCEA is to describe the baseline distribution of health, taking into account variation in both length and health-related quality of life. This baseline distribution will need to include the full general population, and not just the population of recipients of the intervention. This is for 2 reasons. First, the full general population is typically the relevant population for characterizing policy concerns with health inequality. Second, within the context of a national, budget-constrained system such as the NHS, additional resources used by recipients of an intervention will displace activities that could have been provided to anyone within the full general population.

This baseline distribution of health should be able to describe variation in health among multiple different subgroups in the population as defined by relevant population characteristics, allowing for the correlation structure among these various characteristics. The relevant population characteristics include not only dimensions of direct equity concern (e.g., income and ethnicity) but also characteristics that are necessary to estimate expected costs and effects and that may generate further equity concern (e.g., sex). The latter of these is standard for any cost-effectiveness analysis (CEA), whereas the former we discuss further throughout this tutorial. The health metric we use in this context is quality-adjusted life expectancy (QALE) at birth, although other suitable health metrics could also be used—such as disability-adjusted life expectancy at birth or age-specific QALE—as long as they are measured on an interpersonally comparable ratio scale suitable for use within a CEA.

The population characteristics of interest in this case study—those by which a substantial variation in uptake of the BCSP was observed—are sex, area-level deprivation, and area-level ethnic diversity. The first step in estimating our population QALE distribution is to estimate life expectancy (LE), according to each of these characteristics. Area-level deprivation in the BCSP evaluation studies was measured based on index of multiple deprivation (IMD 2004) quintile groups, and area-level ethnic diversity was based on the percentage of people in the area originating from the Indian Subcontinent, again split into quintile groups.[3] National statistics data are

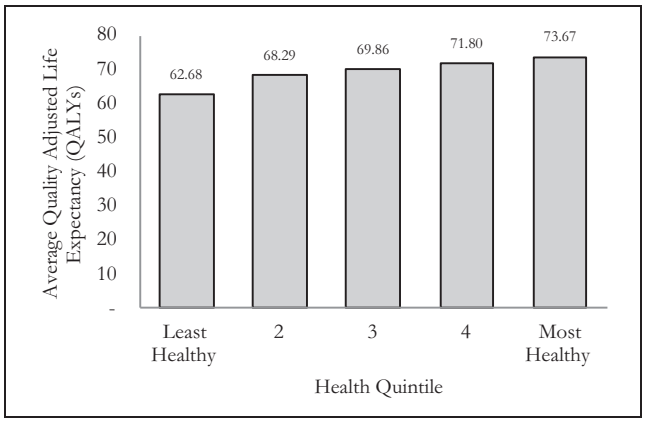

Figure 1 Baseline health distribution.

available by sex and deprivation level/social class, but are not available by our particular measure of ethnic diversity. We therefore did not include correlations with ethnic diversity in our estimation of the baseline health distribution and instead, for the purposes of the analysis, assumed its distribution is independent of deprivation and sex.

A full description of how the baseline health distribution was calculated can be found in the appendix. A summary of this QALE distribution by health quintile is shown in Figure 1. This forms the baseline health distribution that we will use in our analysis.

Estimating the distribution of health changes due to the interventions

To evaluate changes in the baseline health distribution that could be attributed to the use of alternative interventions, it is necessary to know how the costs and effects of the intervention differ between the relevant subgroups, and how the opportunity costs of any change in resource use differ by those same subgroups.

Having estimated a baseline health distribution, we next turn to modeling how this health distribution is affected by the BCSP and alternative ways of promoting increased uptake of the BCSP. We do this by using an existing cost-effectiveness model of the BCSP that simulates the natural history of CRC and the impact of screening and treatment on this natural history.[4,5] We adapt the model to look at the distributional health impacts of 4 different screening strategies:

1. *No screening*: the baseline social distribution of health
2. *Standard screening*: as implemented in the BCSP
3. *Targeted reminder*: screening plus a targeted enhanced reminder letter (personal general practitioner [GP] signed letter and tailored information package) sent only to those living in the most income-deprived small areas (IMD4 and IMD5) as well as to those living in areas with the highest proportion of inhabitants from the Indian Subcontinent (IS5)
4. *Universal reminder*: screening plus a universal basic reminder letter (sending a GP-endorsed reminder letter to all eligible patients)

Impacts are first estimated by subgroup and then combined to evaluate the impact of the screening strategies on the overall social distribution of health.

There are a number of parameters in the model that can vary by subgroup, including:

1. *Disease prevalence, severity, mortality rate, and natural history*: We assume in our case study that bowel cancer–specific parameters are constant across our population subgroups. The evidence available[6] broadly supports this assumption, although more detailed data at the subgroup level would be required to validate this assumption.
2. *Uptake of the intervention*: The impact of gFOBT uptake by subgroup is the key difference between the various implementations of the screening program. We discuss in detail in this article how this parameter is estimated for each subgroup. We also estimate the uptake of follow-up colonoscopy by subgroup for those people who are invited back for further investigation after being screened.
3. *Direct costs associated with the intervention*: We assume the direct costs related to treating a given stage of bowel cancer do not vary by subgroup (although the chance of incurring these costs and the screening-related costs by subgroup may vary under the different implementations of the screening program). This seems to be a plausible assumption in the absence of more detailed cost data at the subgroup level.
4. *Opportunity costs from displaced activities*: Opportunity costs are in the base case analysis assumed to be shared equally among all population subgroups; this assumption is explored in sensitivity analyses discussed later in this tutorial.
5. *Other-cause mortality*: We use the mortality rates by subgroup in the same way as discussed when deriving the baseline health distribution. In calculating these rates, we remove bowel cancer–specific mortality (assuming this is constant across subgroups) and apply this separately in the model.

Quality adjustment of health gains to reflect morbidity: We apply the subgroup-specific adjustments to

Table 1 Regression Results of gFOBT Uptake from Evaluation of BCSP Pilot

		Adjusted OR (95% CI)
Age (years)	57–59	1
	60–64	1.13 (1.11–1.16)
	65–69	1.25 (1.22–1.28)
Sex	Male	1
	Female	1.38 (1.35–1.40)
Pilot round	1	1
	2	0.77 (0.76–0.80)
	3	0.82 (0.81–0.84)
Deprivation category (IMD)	Q1 (Least deprived)	1
	Q2	0.84 (0.81–0.87)
	Q3	0.70 (0.68–0.72)
	Q4	0.55 (0.54–0.57)
	Q5 (Most deprived)	0.37 (0.35–0.38)
% Indian Subcontinent	Q1–4	1
	Q5 (Highest %)	0.86 (0.84–0.89)

BCSP, National Health Service (NHS) Bowel Cancer Screening Programme; CI, confidence interval; gFOBT, guaiac fecal occult blood test; IMD, index of multiple deprivation; OR, odds ratio.

quality-adjust health gains resulting from the screening program in a similar manner to that applied to estimate the baseline health distribution. The population QALE distribution under no screening corresponds to our baseline health distribution as calculated in the previous section. In our analysis of the BCSP, we include an additional variable—area-level proportion of population from the Indian Subcontinent (IS)—which we were unable to incorporate into our estimation of the baseline health distribution. We assume that this IS variable is distributed independently of IMD and sex, and that it has no independent effect on baseline QALE (i.e., subgroups are adjusted for other-cause mortality and quality adjusted only according to their IMD and sex, and these adjustments are not affected by their IS status). We next adjust the BCSP uptake parameters by subgroup. Table 1 shows logistic regression results looking at gFOBT uptake in the 3 rounds of the BCSP pilot.[3] We use these data in combination with the proportion of invitees in each category by variable, also reported in the pilot evaluation, to get weighted average odds ratios (ORs) for uptake that can be applied in the model.

These ORs are applied to a baseline rate of uptake reported in the third-round pilot, in which males in the youngest age group, living in the most deprived areas and with the highest proportion of people from the Indian Subcontinent, had an uptake probability of 34%. For example, to calculate the uptake probability for a woman of any age across all rounds of the pilot, living in the least deprived areas and with the least numbers of people from the Indian Subcontinent, we can use the following calculation:

$$OR = 0.34/(1-0.34) * (1.38/0.82) * 1.13 * 0.86 * (1/0.37) * (1/0.86) = 2.71$$

$$P = OR/(1+OR) = 0.73$$

A similar regression analysis was reported analyzing the effect of these same variables on the uptake of follow-up colonoscopy. Data were also published in the pilot study evaluation regarding the numbers of people in each category for each variable in the study. However, cross-tabulations or correlations between the variables were not available, and we therefore assumed that each variable was independently distributed to calculate the proportion of the population in each subgroup. Table 2 shows our calculated gFOBT uptake, the follow-up colonoscopy uptake, and the proportion of the population by each subgroup.

Using these parameters in the model provides the total costs and health gains due to the BCSP under the standard screening approach.

We next turn to modeling the remaining 2 implementations of the screening program. Both implementations augment the standard screening program with additional reminders. We derive the indicative estimates of costs and impacts on screening uptake of these reminder strategies from similar interventions studied in the screening literature,[7,8] applying plausible exchange rates and inflation rates to the figures to get costs, and assuming all subgroups receiving the interventions have equal additive increases in uptake. The values used in the model for costs and impacts on gFOBT uptake for each of the strategies are given in Table 3.

To estimate total costs and health effects, the model is evaluated for a representative cohort of the population—in our case, a cohort of 1 million 30

Table 2 gFOBT Uptake, Follow-Up Colonoscopy Uptake, and Proportion of Population by Subgroup

Sex	% Indian Subcontinent	Deprivation (IMD quintile)	gFOBT Uptake (%)	Colonoscopy Uptake (%)	Population Proportion (%)
Male	Q1–4	Q1 (Least deprived)	66	86	6
		Q2	62	84	9
		Q3	58	80	10
		Q4	52	79	8
		Q5 (Most deprived)	42	77	6
	Q5 (Highest)	Q1 (Least deprived)	63	87	1
		Q2	59	85	2
		Q3	54	81	3
		Q4	48	79	2
		Q5 (Most deprived)	38	75	2
Female	Q1–4	Q1 (Least deprived)	73	85	6
		Q2	70	83	9
		Q3	66	79	10
		Q4	60	77	8
		Q5 (Most deprived)	50	76	6
	Q5 (Highest)	Q1 (Least deprived)	70	86	1
		Q2	66	83	2
		Q3	62	79	3
		Q4	56	78	2
		Q5 (Most deprived)	46	76	2

gFOBT, guaiac fecal occult blood test; IMD, index of multiple deprivation.

Table 3 Costs and Impact on gFOBT Uptake of Reminder Strategies

Strategy	Cost per Recipient	Increase in gFOBT Uptake per Recipient
Universal reminder	£3.50	6%
Targeted reminder	£7.00	12%

gFOBT, guaiac fecal occult blood test.

year olds, as was used in the original analysis of the BCSP in the model we inherited. The size of each subgroup is given by the population proportions calculated in Table 2. We sum the costs across all subgroups, and convert these to health opportunity costs using a threshold value of £20,000 per quality-adjusted life year (QALY). These health opportunity costs are then apportioned equally to each individual in the population, allowing the model to characterize net health gains in each subgroup. For example, the total costs for the standard screening program during the lifetime of the cohort of 1 million patients came to £72 million. Converting this to health opportunity costs at the rate of £20,000 per QALY gives us 3600 QALYs of health opportunity costs. Women who live in areas with a low percentage of the population from the Indian Subcontinent (IS Q1–4), and who also fall within deprivation quintile IMD Q3, make up 10% of the population. So we allocate 10% of this total health opportunity cost to them (i.e., 360 QALYs). This is then subtracted from the total health gains due to the BCSP in this subgroup to give the net health effect of the BCSP on this subgroup.

The assumption of equally distributed opportunity costs is convenient but not evidence based. So we explore alternative assumptions in sensitivity analysis, focusing on 2 extreme cases in which all opportunity costs are allocated to the least healthy and the healthiest subgroups, respectively.

The additional parameters that we have added to the model are assigned standard distributions by variable type, and their mean and standard error values are used to generate suitable random draws for these variables in the probabilistic sensitivity analysis (PSA). Details of how these additional variables are dealt with in the PSA are given in Table 4. All the results presented are produced by running the model probabilistically and averaging more than 1000 iterations of the model.

The resulting health distributions estimated for each screening implementation are described in Figures 2 and 3 and Table 5. Figure 2A shows the gFOBT uptake by health quintile for each strategy, and Figure 2B shows the colonoscopy uptake by health quintile.

Table 4 Distributions and Parameter Values Used in PSA for Additional Parameters Added to the Model

Parameter	Explanation
gFOBT and colonoscopy uptake	Uncertainty on these calculated in PSA assuming ln(OR) distributed normally. The variance covariance matrices for the uptake regressions were not available to us, so we drew each coefficient independently and combined to create uptake probabilities.
Mortality rates	Adjusted for uncertainty by the underlying model.
Quality adjustment	Used β distribution with the mean and standard error values as reported in the UK EQ-5D norms.
Cost of reminders	As no data were given on the uncertainty, we assume a 10% standard error and used this to draw values from the appropriate γ distributions.
Impact of reminders on uptake	Reported mean and standard error values used to draw from the appropriate β distributions.

gFOBT, guaiac fecal occult blood test; OR, odds ratio; PSA, probabilistic sensitivity analysis.

Table 5 QALE Distribution by Subgroup Under Each Strategy

			QALE			
Sex	% Indian Subcontinent	Deprivation (IMD quintile)	Baseline	Standard	Targeted	Universal
Male	Q1–4	Q1 (Least deprived)	72.16	72.21	72.20	72.21
		Q2	70.48	70.52	70.52	70.52
		Q3	69.09	69.12	69.12	69.13
		Q4	66.61	66.63	66.63	66.63
		Q5 (Most deprived)	60.22	60.24	60.24	60.24
	Q5 (Highest)	Q1 (Least deprived)	72.16	72.20	72.21	72.21
		Q2	70.48	70.52	70.52	70.52
		Q3	69.09	69.12	69.13	69.12
		Q4	66.61	66.63	66.63	66.63
		Q5 (Most deprived)	60.22	60.23	60.24	60.23
Female	Q1–4	Q1 (Least deprived)	74.84	74.91	74.91	74.92
		Q2	73.10	73.16	73.16	73.17
		Q3	71.77	71.82	71.81	71.82
		Q4	69.19	69.23	69.24	69.23
		Q5 (Most deprived)	63.17	63.20	63.20	63.20
	Q5 (Highest)	Q1 (Least deprived)	74.84	74.91	74.92	74.91
		Q2	73.10	73.16	73.17	73.16
		Q3	71.77	71.81	71.82	71.82
		Q4	69.19	69.23	69.24	69.23
		Q5 (Most deprived)	63.17	63.20	63.20	63.20
Overall average			69.260	69.300	69.301	69.302

IMD, index of multiple deprivation; QALE, quality-adjusted life expectancy.

QALE for each subgroup calculated from our adjusted model is given in Table 5, and these are presented for our cohort by health quintile in Figure 3A and Figure 3B, allowing us to better appreciate the relative impacts of the strategies.

Adjusting for social value judgments about fair and unfair sources of inequality

The distributions of health estimated thus far represent all variation in health in the population. However, some variation in health may be deemed ''fair,'' or at least ''not unfair,'' perhaps because it is due to individual choice or unavoidable bad luck. In such cases, the health distributions should first be adjusted to only include health variation deemed ''unfair'' before measuring the level of inequality. Social value judgments need to be made about whether health variation associated with each of the population characteristics is deemed fair. In our example, we have 3 variables to consider: sex, IMD,

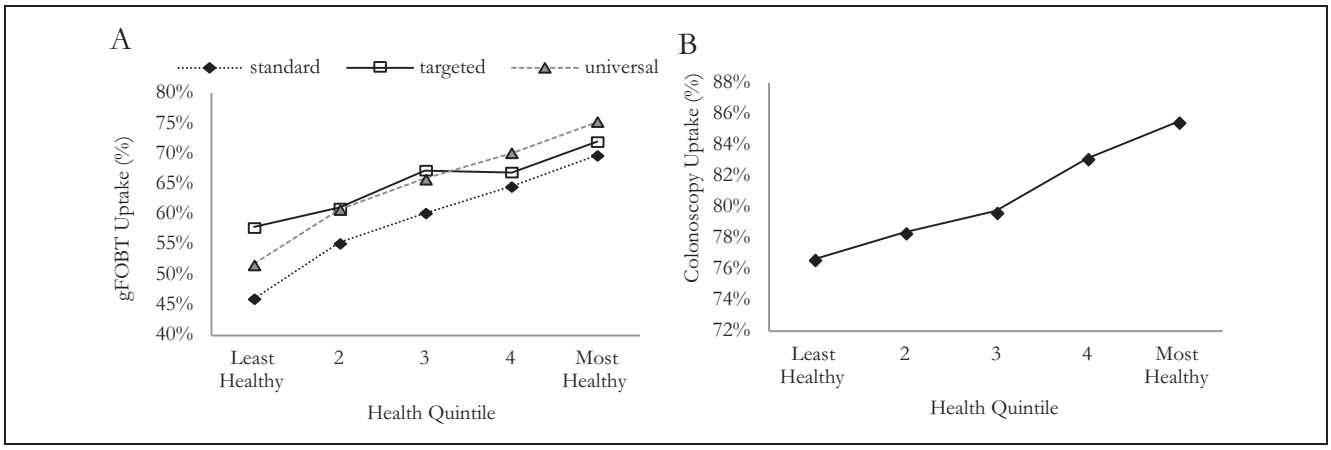

Figure 2 (A) Guaiac fecal occult blood test (gFOBT) uptake distribution by strategy; and (B) colonoscopy uptake distribution.

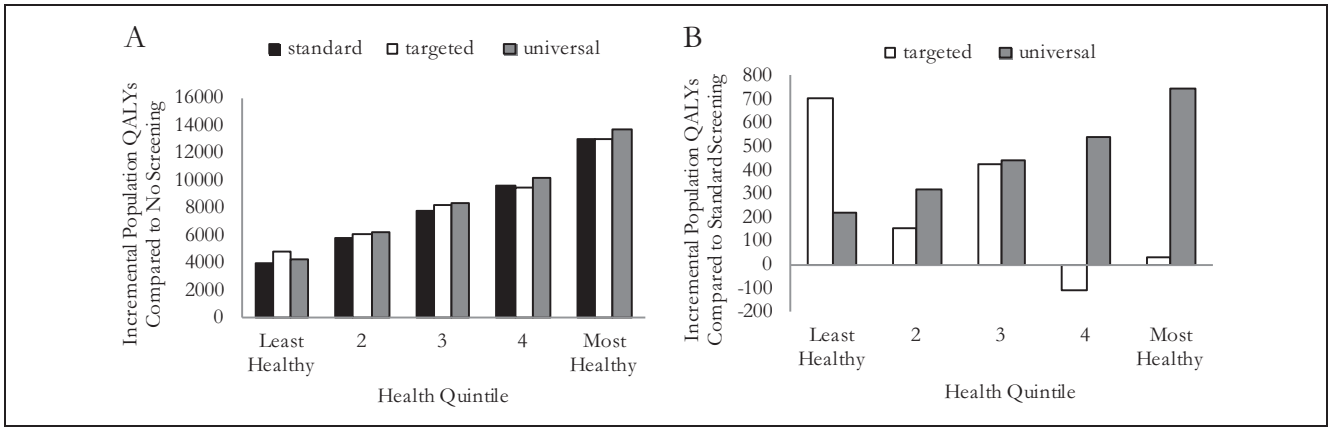

Figure 3 (A) Health compared to no screening (per million of population invited for screening); and (B) health compared to standard screening (per million of population invited for screening).

and ethnicity. We might make the value judgment that differences in health due to sex are fair, whereas differences in health due to IMD and ethnicity are unfair—this is 1 of 8 possible value judgments that we can make on fairness in this example. One way of adjusting our modeled health distributions for this value judgment is by using direct standardization.[9] To do this, we run a regression on our QALE distribution weighting the subgroups by the proportion of the population they represent to find the association between each variable and QALE. An example of such a regression is given in Table 6. We then use reference values for those variables deemed fair (i.e., sex in this case) while leaving the other variables to take the values they have in the relevant subgroups and predict out an adjusted QALE distribution. In this example, we use male as the reference value for sex and predict out the QALE distribution as shown in Table 7. This distribution represents only the variation in health deemed unfair by the social value judgment made. Reference values used in the adjustment process are typically population averages for continuous variables, whereas for categorical variables the most commonly occurring category is typically used with sensitivity analysis performed on the impact of alternative choices of reference category.

Stage B: Evaluating Social Distributions of Health

Comparing interventions in terms of total health and unfair health inequality

Once we have estimated the appropriate health distributions, we can then go on to characterize the distributions in terms of the twin policy goals of

Table 6 Fairness Adjustment Regression

	Coefficient (SE)
Constant	74.92 (4.37E-05)
IS Q1–4	−0.004 (2.56E-05)
Male	−2.708 (5.47E-05)
IMD Q2	−1.75 (4.91E-05)
IMD Q3	−3.097 (4.84E-05)
IMD Q4	−5.675 (5.02E-05)
IMD Q5	−11.71 (5.33E-05)
Male*IMD Q2	0.065 (6.95E-05)
Male*IMD Q3	0.015 (6.84E-05)
Male*IMD Q4	0.104 (7.10E-05)
Male*IMD Q5	−0.259 (7.532E-05)

IMD, index of multiple deprivation; IS, Indian Subcontinent; SE, standard error.

improving total health and reducing health inequality. One useful piece of information for decision makers produced at this step of the analysis is the size of the health opportunity cost of choosing an intervention that reduces health inequality—this is simply the difference in total health between the intervention and a comparator. However, this step of the analysis can also go further than that by providing information about the size of the reduction in health inequality, in terms of the difference in 1 or more suitable inequality indices between the intervention and a comparator. The selection of appropriate inequality indices requires further value judgments about the nature of the inequality concern. There are a number of commonly used indices to measure inequality that can be broadly grouped into those measuring relative inequality (scale-invariant indices), those measuring absolute inequality (translation invariant), and those measuring health poverty or shortfall from a reference value. If there is no clear choice of inequality measure, it may be preferable to calculate a range of alternative measures.

Table 8 shows the results of calculating a range of relative and absolute inequality measures for the QALE distributions associated with our 4 screening strategies. A higher value for each measure indicates

Table 7 Fairness Adjusted Health Distribution Reference Sex = Male

			QALE	
Sex	% Indian Subcontinent	Deprivation (IMD quintile)	Targeted	Targeted Adjusted
Male	Q1–4	Q1 (Least deprived)	72.20	72.20
		Q2	70.52	70.52
		Q3	69.12	69.12
		Q4	66.63	66.63
		Q5 (Most deprived)	60.24	60.24
	Q5 (Highest)	Q1 (Least deprived)	72.21	72.21
		Q2	70.52	70.52
		Q3	69.13	69.13
		Q4	66.63	66.63
		Q5 (Most deprived)	60.24	60.24
Female	Q1–4	Q1 (Least deprived)	74.91	72.20
		Q2	73.16	70.52
		Q3	71.81	69.12
		Q4	69.24	66.63
		Q5 (Most deprived)	63.20	60.24
	Q5 (Highest)	Q1 (Least deprived)	74.92	72.21
		Q2	73.17	70.52
		Q3	71.82	69.13
		Q4	69.24	66.63
		Q5 (Most deprived)	63.20	60.24

IMD, index of multiple deprivation; QALE, quality-adjusted life expectancy.

Table 8 Inequality Measures Calculated for 4 Screening Strategies

Relative Inequality Indices	No Screening	Standard	Targeted Reminder	Universal Reminder
Relative gap index (ratio)	0.17527*	0.17592	0.17586	0.17596
Relative index of inequality	0.18607*	0.18674	0.18668	0.18678
Gini index	0.03101*	0.03112	0.03111	0.03113
Atkinson index ($\varepsilon = 1$)	0.00171*	0.00172	0.00172	0.00172
Atkinson index ($\varepsilon = 7$)	0.01330*	0.01337	0.01337	0.01338
Atkinson index ($\varepsilon = 30$)	0.06253*	0.06281	0.06279	0.06283
Absolute Inequality Indices	**No Screening**	**Standard**	**Targeted Reminder**	**Universal Reminder**
Absolute gap index (range)	10.98604*	11.03064	11.02726	11.03325
Slope index of inequality	12.88747*	12.94123	12.93691	12.94438
Kolm index ($\alpha = 0.025$)	0.20281*	0.20430	0.20416	0.20439
Kolm index ($\alpha = 0.1$)	0.87801*	0.88429	0.88371	0.88467
Kolm index ($\alpha = 0.5$)	4.56391*	4.58739	4.58587	4.58883

$\alpha = 0.025$, low absolute inequality aversion; $\alpha = 0.5$, high absolute inequality aversion; $\varepsilon = 1$, low relative inequality aversion; $\varepsilon = 30$, high relative inequality aversion.
*The most equal strategy.

a higher level of inequality between the healthiest and the least healthy.

Ranking interventions using dominance rules

The first step in comparing distributions is looking to commonly used distributional dominance rules, because these allow strategies to be ranked with minimal restriction to the form of the underlying social welfare function. In terms of standard economic dominance rules, we can note from Table 5 that no screening and standard screening are strictly dominated in the space of QALE by the universal reminder strategy—that is, the no sex-IMD-ethnicity subgroup is less healthy, and at least 1 subgroup is healthier. However, this rule does not account for the level of inequality. When ranking distributions based on mean health and the level of health inequality, it is possible to use alternative economic dominance rules provided by Atkinson[10] and Shorrocks.[11] These dominance rules apply when mean health is higher and inequality is lower for almost any measure of inequality. Both rules are based around the Lorenz curve,[12] a tool to analyze relative inequality constructed for health distributions by ordering the population from least healthy to most healthy and plotting the cumulative proportion of population health against the cumulative proportion of the population. Regarding Atkinson's theorem tests for Lorenz dominance between distributions, this means that the Lorenz curves for the distributions do not cross, and the more equal distribution has at least as much mean health as the less equal distribution. In other words, a distribution is dominated if it has higher inequality and the same or lower amount of mean health. On these criteria, the standard screening strategy is dominated by the targeted reminder. Shorrocks' theorem tests for generalized Lorenz dominance, wherein the Lorenz curve is multiplied by the mean health. A distribution is dominated if the generalized Lorenz curve lies wholly below that of an alternative intervention. Under this criterion, both the targeted and universal reminder strategies dominate the no-screening option. This leaves us to compare the universal-reminder and targeted-reminder strategies. Although the universal reminder produces a higher average QALE overall and benefits the less deprived quintile groups more, the targeted reminder is the more equal strategy on every measure listed in Table 8 and benefits the most deprived quintile groups more. In our example, the generalized Lorenz curves for these 2 distributions cross, and hence we cannot use Shorrocks' theorem to rank the distributions.

Analyzing tradeoffs between total health and health inequality using social welfare indices

Having used distributional dominance to eliminate no screening and standard screening, to rank the remaining 2 strategies it is necessary to specify more fully an underlying social welfare function. A number of alternative social welfare indices have been proposed that could be used to characterize the dual objectives of increasing total health and reducing health inequality. A common feature of such functions is the need to specify the nature of

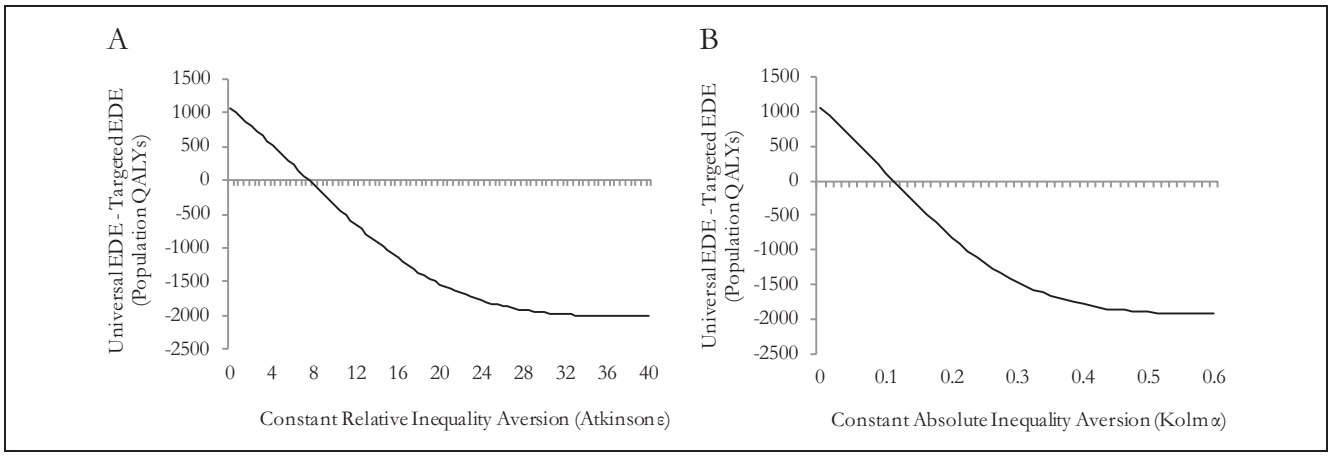

Figure 4 (A) Sensitivity to level of relative inequality aversion; and (B) sensitivity to level of absolute inequality aversion.

and level (or value) of inequality aversion. The inequality aversion parameters in these functions describe the tradeoff between total health and the level of health inequality (i.e., the amount of total health that a decision maker would be willing to sacrifice to achieve a more equal distribution). These inequality aversion parameters are difficult to interpret on a raw scale. A more intuitive scale can be provided by combining a specific value of the parameter with a specific health distribution to derive the *equally distributed equivalent* (EDE) level of health. The difference between the mean level of health in that distribution and the EDE level of health then represents the average amount of health per person that one would be willing to sacrifice to achieve full equality in health, given that specific value of inequality aversion.

In this example, we will use 2 social welfare indices closely linked to the dominance rules applied above: the Atkinson index[10] to evaluate the distributions in terms of relative inequality, and the Kolm index[13] to evaluate the distributions in terms of absolute inequality. The EDE for these social welfare indices can be calculated as follows using the inequality aversion parameters ε and α, respectively:
Atkinson social welfare index:

$$h_{ede} = \left[\frac{1}{n}\sum_{i=1}^{n}[h_i]^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}$$

Kolm social welfare index:

$$h_{ede} = -\left(\frac{1}{\alpha}\right)log\left(\frac{1}{n}\sum_{i=1}^{n}e^{-\alpha h_i}\right)$$

Figure 4A and Figure 4B show the difference in EDE health between the 2 strategies across different levels of inequality aversion for the relative and absolute social welfare indices, respectively. With zero inequality aversion, the EDE represents the mean health, and we see that the universal strategy offers 1000 more population QALYs compared to the targeted strategy. For inequality aversion levels greater than $\varepsilon = 8$ and $\alpha = 0.12$, the targeted strategy would be preferred, implying that the decision maker would be willing to sacrifice those 1000 population QALYs to achieve the lower level of inequality.

Recent work on eliciting these inequality aversion parameters from members of the general public in England[14] estimates an Atkinson ε parameter of about 10.95 (95% confidence interval [CI]: 9.23–13.54) and a Kolm α parameter of about 0.15 (95% CI: 0.13–0.19).

Sensitivity Analysis

There are a number of sensitivity analyses we can run to explore the impact of making alternative assumptions in our modeling on our choice of preferred strategy. Tables 9 and 10 present the results, respectively, of exploring 1) the impacts of alternative assumptions around the distribution of opportunity costs, and 2) the impacts of alternative social value judgments about which inequalities are considered unfair.

We could also perform additional sensitivity analyses, including exploring alternative ways that the reminder strategies might affect the different population subgroups (e.g., having constant proportional effects rather than constant absolute effects) and

Table 9 Sensitivity to Alternative Opportunity Cost Distributions

	All Opportunity Cost Borne by Least Healthy Subgroup				All Opportunity Cost Borne by Healthiest Subgroup	
Social Welfare Indices	**No Screening**	**Standard**	**Targeted Reminder**	**Universal Reminder**	**Targeted Reminder**	**Universal Reminder**
Mean health	69.25969	69.30006	69.30127	69.30233*	69.30127	69.30233*
Atkinson EDE ($\varepsilon = 1$)	69.14152	69.18056	69.18147	69.18252*	69.18286	69.18373*
Atkinson EDE ($\varepsilon = 7$)	68.33888	68.36800*	68.36610	68.36734	68.37799*	68.37769
Atkinson EDE ($\varepsilon = 30$)	64.92865*	64.91468	64.89302	64.89892	64.95627*	64.95350
Kolm EDE ($\alpha = 0.025$)	69.05688	69.09486	69.09556	69.09660*	69.09793	69.09866*
Kolm EDE ($\alpha = 0.1$)	68.38168	68.41112*	68.40958	68.41074	68.42046*	68.42020
Kolm EDE ($\alpha = 0.5$)	64.69578*	64.68086	64.65951	64.66532	64.72148*	64.71879

EDE, equally distributed equivalent.
*The strategy yielding the highest social welfare.

Table 10 Sensitivity to Alternative Social Value Judgments

Social Value Judgment			**Preferred Strategy Based on Social Welfare Index**					
IMD	**Ethnic Diversity**	**Sex**	**Atkinson EDE ($\varepsilon = 1$)**	**Atkinson EDE ($\varepsilon = 7$)**	**Atkinson EDE ($\varepsilon = 30$)**	**Kolm EDE ($\alpha = 0.025$)**	**Kolm EDE ($\alpha = 0.1$)**	**Kolm EDE ($\alpha = 0.5$)**
Fair	Fair	Fair	U	U	U	U	U	U
Fair	Unfair	Fair	U	U	U	U	U	U
Fair	Fair	Unfair	U	U	U	U	U	U
Fair	Unfair	Unfair	U	U	U	U	U	U
Unfair	Fair	Fair	U	U	T	U	U	T
Unfair	Unfair	Fair	U	U	T	U	U	T
Unfair	Fair	Unfair	U	U	T	U	U	T
Unfair	Unfair	Unfair	U	U	T	U	U	T

EDE, equally distributed equivalent; IMD, index of multiple deprivation; T, targeted reminder; U, universal reminder.

testing for alternative underlying distributions of CRC mortality, incidence, and severity.

DISCUSSION

DCEA is a framework for incorporating health inequality concerns into the cost-effectiveness analysis of health care interventions. It aims to help cost-effectiveness analysts provide decision makers with useful quantitative information about the health inequality impacts of health care interventions, and the nature and size of tradeoffs between the dual objectives of improving total health and reducing health inequality. It also aims to help cost-effectiveness analysts accommodate different value judgments about health inequality made by different decision makers and stakeholders.

Social value judgments about health inequality are complex, context dependent, and contestable. For this reason, DCEA does not prescribe in advance any particular set of social value judgments about health inequality. A number of social value judgments need to be made when implementing the DCEA framework, in particular regarding which dimensions of inequality are deemed unfair and the nature and strength of inequality aversion. The framework makes these social value judgments explicit and transparent, and lends itself well to checking the sensitivity of conclusions based on alternative plausible social value judgments. DCEA thus aims to provide decision makers with useful quantitative information about health inequality effects that can help to inform a deliberative decision-making process, by showing how different social value judgments might lead to different conclusions. Empirical work to estimate the nature and level of societal inequality aversion implicit in current health care allocation decisions would be useful in validating and complementing estimates of the inequality aversion levels emerging from value

elicitation exercises conducted on members of the general public in England.[14] This work would be analogous to the recent work that has been done to generate empirical estimates of the cost-effectiveness threshold.[15]

DCEA is intended to be a general and flexible analytical framework that allows a diverse range of specific methods and techniques to be applied at different stages of the analysis. In particular, the evaluation stage can in principle use any kind of equity weighting and/or multicriteria decision analysis to analyze tradeoffs between improving total health and reducing health inequality, and it is not restricted to application of the specific Atkinson and Kolm social welfare functions described in this tutorial.

We have seen in this tutorial that DCEA is demanding in terms of data, but feasible to implement in a real-world context through creative application of the standard tools of economic analysis. The data and methods we have used are inevitably partial and crude in many respects, and it is our hope that the underpinning data and technical methods will be improved and refined throughout the years. Although the framework and methods involved may seem complex, in our opinion this complexity is well within the capabilities of analysts currently conducting standard CEA. The key to expanding the use of DCEA will be the development of better methods for assisting decision makers to clarify and quantify the nature of their inequality concerns, and better ways of communicating findings to nonspecialist audiences.

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APPENDIX

Estimating the baseline health distribution

Data on LE by IMD quintile and sex is published directly by the Office of National Statistics (16). However, for the purposes of our analysis we also require the underlying mortality rates used to estimate these figures in order to incorporate them in the decision analytical model where all-cause mortality is separated from colorectal cancer specific mortality. Unfortunately, these underlying mortality rates are not available by IMD quintile groups. So to ensure we remain consistent between our baseline QALE distribution and QALE distributions associated with the various implementations of the BCSP produced by our model, we use ONS mortality rates by social class (17) to proxy those by IMD, and apply the mapping between social classes and IMD quintile groups given in Table A.I.

Table AI Mapping between IMD Quintile Groups and Social Class

Deprivation (IMD Quintile)	Social Class
Q1 (Least Deprived)	I&II (Professional occupations & Managerial and technical occupations)
Q2	I&II (Professional occupations & Managerial and technical occupations)
Q3	IIIN (Skilled non-manual occupations)
Q4	IIIM (Skilled manual occupations)
Q5 (Most Deprived)	IV&V (Partly-skilled occupations & Unskilled Occupations)

We then use these mapped mortality rates to calculate the LE at birth by IMD quintile groups (2002-05) using the standard ONS methodology (18). Table A.II compares life expectancies estimated indirectly using the mapping process described above with published direct estimates of life expectancy by IMD quintile for the same period (2002-05). We see from the comparison that while the mapped values are on the whole reasonably close to the published values, they begin to diverge for the more deprived areas.

Table AII Comparison between Mapped and Published LE by IMD Quintile Group

Sex	Deprivation (IMD Quintile)	LE by Mapped IMD Quintiles (years)	LE Published IMD Quintiles (years)	Difference (Mapped – Published)
Male	Q1 (Least Deprived)	80.4	80.0	0.4
	Q2	80.4	78.6	1.8
	Q3	79.2	77.3	1.9
	Q4	77.7	75.4	2.3
	Q5 (Most Deprived)	76.2	72.2	4.0
Female	Q1 (Least Deprived)	83.7	83.2	0.5
	Q2	83.7	82.3	1.4
	Q3	82.6	81.5	1.1
	Q4	81.1	80.1	1.0
	Q5 (Most Deprived)	80.3	77.9	2.4

We next adjust these life expectancies for morbidity. To do this we adjust for age and sex by applying the relevant weights from the published EQ-5D Norms (19) for each age range (reproduced in Table A.III) and aggregate to give and age and sex adjusted QALE. Taking the example of a male in the least deprived IMD quintile group (Q1) we can read from Table A.II that their estimated life expectancy is 80.4 years. Using the weights in Table A.III we estimate the QALE for individuals in this subgroup as:

*24*0.94 + (35-25)*0.93 + (45-35)*0.91 + (55-45)*0.84 + (65-55)*0.78 + (75-65)* 0.78 + (80.5-75)*0.75 = 69.8 QALYs*

Table AIII QALY Weights by Age and Sex Based on EQ-5D Norms

Age	Male	Female
0-25	0.94	0.94
25-34	0.93	0.93
35-44	0.91	0.91
45-54	0.84	0.85
55-64	0.78	0.81
65-74	0.78	0.78
75+	0.75	0.71

In addition to quality adjusting LE for age and sex, we also would like to adjust for variation in quality of life by area level deprivation. In order to do this we turn to the ONS data for LE and disability free life expectancy (DFLE) by IMD quintile (16). We assume that the average quality adjustment we have applied by using the age and sex weights captures the adjustment for the middle IMD quintile group (Q3)for each sex, and calculate relative adjustment factors for the other IMD quintile groups by further assuming the ratio of DFLE to LE is the same as the ratio of QALE to LE. We use this data to calculate the adjustment factors shown in Table A.IV.

Table AIV Using LE and DFLE to Calculate QALE Adjustment Factors by IMD

Sex	Deprivation (IMD Quintile)	LE	DFLE	Ratio DFLE/LE	QALE Adjustment Factor
Male	Q1 (Least Deprived)	80.0	67.3	0.84	1.03
	Q2	78.6	64.3	0.82	1.00
	Q3	77.3	63.4	0.82	1.00
	Q4	75.4	59.7	0.79	0.96
	Q5 (Most Deprived)	72.2	54.2	0.75	0.91
Female	Q1 (Least Deprived)	83.2	67.8	0.81	1.02
	Q2	82.3	65.7	0.80	1.00
	Q3	81.5	64.9	0.80	1.00
	Q4	80.1	61.8	0.77	0.97
	Q5 (Most Deprived)	77.9	57.2	0.73	0.92

Applying the adjustment factor to our QALE estimate for our male from IMD Q1 gives a refined QALE estimate taking into account area level deprivation of:

*69.8 * 1.03 = 72 QALYs*

Similar calculations for the other subgroups yield the QALE estimates in Table A.V.

Table AV QALE by Sex and Deprivation

Sex	Deprivation (IMD Quintile)	QALE
Male	Q1 (Least Deprived)	72.2
	Q2	70.5
	Q3	69.1
	Q4	66.6
	Q5 (Most Deprived)	60.2
Female	Q1 (Least Deprived)	74.8
	Q2	73.1
	Q3	71.8
	Q4	69.2
	Q5 (Most Deprived)	63.2

Ordering the subgroups by QALE from least healthy to most healthy and adjusting for the size of each subgroup we are able to create a population distribution of QALE at birth taking into account differential mortality and morbidity by age, sex and area level deprivation.

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Glossary

BCSP	Bowel Cancer Screening Programme
BMA	British Medical Association
CBA	Cost Benefit Analysis
CCG	Clinical Commissioning Group
CEA	Cost-Effectiveness Analysis
CI	Confidence Interval
CRC	Colorectal Cancer
DCEA	Distributional Cost-Effectiveness Analysis
DH	Department of Health
DHSS	Department of Health and Social Security
EAPMC	Equitable Access to Primary Medical Care
ECEA	Extended Cost Effectiveness Analysis
EDE	Equally Distributed Equivalent
FCE	Finished Consultant Episode
FTE	Full Time Equivalent
gFOBT	Guaiac Faecal Occult Blood Test
GP	General Practitioner
GRO	General Register Office
HEC	Health Education Council
HES	Hospital Episode Statistics
HRG	Health care Resource Group
IMD	Index of Multiple Deprivation
IS	Indian Subcontinent
LE	Life Expectancy
LSOA	Lower Layer Super Output Area

NAO	National Audit Office
NHS	National Health Service
NICE	National Institute for Health and Care Excellence
ONS	Office for National Statistics
OR	Odds Ratio
PbR	Payment by Results
PCT	Primary Care Trust
PSA	Probabilistic Sensitivity Analysis
QALE	Quality Adjusted Life Expectancy
QALY	Quality Adjusted Life Year
QOF	Quality and Outcomes Framework
RAWP	Resource Allocation Working Party
RII	Relative Index of Inequality
SII	Slope Index of Inequality
SWF	Social Welfare Function
WHO	World Health Organisation

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