Measuring and explaining variation in quality across English GP practices

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Abstract

This thesis contributes to the policy debate on quality variation in English general practices. The first chapter uses spatial mapping methods to describe the considerable geographical variation across practices and shows that its pattern is quite stable over the past 10 years. We find that there are spatial clusters of practices with persistently poor quality.

In the second chapter, we analyse the determinants of practice quality as proxied by Ambulatory Care Sensitive Conditions (ACSCs) emergency admissions. We find that practices which improve their clinical quality and the availability of urgent and advance appointment reduce their ACSCs emergency admissions.

To understand the impact of relationships between practices, we present in the third chapter an application of the peer effect model to GP practices. We find that after allowing for observable factors and local contextual effects, the quality of a practice varies positively with the quality of a peer group of practices within the same Primary Care Trust.

We explore in the fourth chapter if practice quality varies with competition. We find modest effects of competition on clinical quality and patient-reported quality, with larger effects on practices that are producing lower quality.

Practices will compete on quality only if patients are responsive to practice quality when they choose a GP practice. In chapter five, we test for this patient responsiveness using data on the number of patients who change practice without a change of address and who are arguably therefore more informed about the quality of local practices. Results suggest that changes in practice quality have a significant impact on the number of patients who decide to join or leave a practice without changing their address.

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Preface

Variation is a salient feature of healthcare systems. Its causes and consequences have been analysed from a clinical perspective (e.g., the NEJM paper on intensity of services by Song et al., 2010) and from an efficiency and productivity perspective (e.g. Bojke, Castelli, Street, Ward, & Laudicella, 2012; Chandra & Staiger, 2007). Variation in healthcare that is not related to patient needs can imply both inefficiency and inequity. The efficiency losses from variations in the US have been estimated at 15-25% of total healthcare expenditure (Skinner, 2011).

A significant proportion of the literature focuses on secondary care and there is relatively little research on variation at primary care level. In England, there are large variations across GP doctors' general practices regarding quality as well as practice characteristics, including general practitioners (GPs), population and practice location characteristics. In this thesis, we contribute to the variations literature in several ways by: examining variation in an understudied sector of healthcare; using rich data on patient and practice characteristics; applying panel data econometric models, including spatial methods (which take account of unobserved practice level heterogeneity), and addressing some of the mechanisms (peer effects and competition) which may explain variation.

The overall aim of this thesis is to understand if variation in healthcare quality followed a spatial pattern and if so, what factors and mechanisms explained this phenomenon. We therefore start the analysis by exploring the spatial patterns of primary care quality stability over time in Chapter 1. The relationship between quality and patient and GP characteristics is then examined in Chapter 2. In addition to these factors, there might be market mechanisms that can explain the spatial pattern, so we explore the existence and impact of mechanisms as peer effects in Chapter 3, and competition on the quality of GP practices in Chapter 4. The thesis concludes by highlighting the importance of quality for patients' GP practice choice in Chapter 5, and supports the argument that practices may compete via quality.

Quality is multi-dimensional and often difficult to measure. Donabedian (1988) proposed that quality of care has three dimensions: "structure", "process" and "outcomes". We mainly use proxies of quality from the Donabedian process dimension, i.e., from the healthcare delivery system, such as ACSCs emergency admissions, patient satisfaction with GP opening hours and Quality Outcome Framework (QOF), and a few from the outcome dimension, such as patient satisfaction with overall care.

In the first chapter we examine the dynamics of the space-time pattern of Ambulatory Care Sensitive Conditions (ACSCs) emergency admissions using spatial statistics. We analyse ACSCs emergency admissions since it is internationally recognised that emergency admissions for these conditions could be avoided or reduced by appropriate management in primary care (Purdy, Griffin, Salisbury, & Sharp, 2009); this is an important proxy of quality of the healthcare delivery system (from the Donabedian process dimension). Tian, Dixon, and Gao (2012) report that ACSCs cost the NHS £1.42 billion annually.

Although ACSCs emergency admissions have been increasing over time, this growth is not geographically homogeneous, hence examining its spatial variation over time using spatial statistical methods not previously applied to this area. We use inverse distance weighting (IDW) to construct maps of the rate of ACSCs emergency admissions at GP practice level and which are indirectly standardised by age and gender, for sensitive analysis by deprivation. The spatial analyses show that indirectly standardised rates of ACSCs admissions are heterogeneous across English general practice but the spatial patterns are not random: there are persistent clusters of practices with high indirect standardised ACSC emergency admissions rates. By doing separate analyses of ACSCs emergency admissions, both incentivised and non-incentivised by the Quality Outcome Framework (QOF), we found that areas with a high incentivised ACSCs emergency admissions indirect standardised rate improved more between 2004 and 2013 than areas with high non-incentivised ACSCs emergency admissions.

There are links between ACSCs emergency admissions and either primary care management or financial incentives (e.g. Dusheiko, Doran, Gravelle, Fullwood, & Roland, 2011; Harrison et al., 2014). In chapter two, we expand on previous studies by using a richer set of practice and patient characteristics, taken from Donabedian structural dimensions, to examine what can explain the variation in ACSCs emergency admissions across practices and over time. Using a Poisson panel model with fixed effects to control for practice, population, location and time-invariant practice characteristics, we show that an increase in practice clinical quality and availability of urgent and advance appointments leads to reduction in ACSCs emergency admissions. The reduction is generally higher for incentivised ACSCs emergency admissions, although patient satisfaction with their ability to book urgent appointments also reduces non-incentivised ACSCs admissions. We also find that that the impact of practice quality on ACSCs emergency admissions is greater for practices in more deprived areas.

Chapter three examines whether the quality of a GP practice is influenced by the behaviour of other practices, as well as by its own characteristics. We make use of the fact that general practices were grouped administratively into Primary Care Trusts (PCTs). PCTs act as forums for local GPs to meet and compare their activity and quality as required for setting local clinical standards and monitoring GP practices' performance. Applying spatial econometric methods, we estimate a peer effect model for GP practices by making use of the reorganisation of PCTs in 2006. During this re-organisation GP practices could not choose which PCT they would be in and so we argue that PCTs constitute exogenously determined peer groups, thereby aiding identification of any peer group effects. Because practices may have different influences in their peer group, we use the practice size (number of GPs, patients and surgeries) to weight this influence. Since quality in healthcare is multi-dimensional, we applied the peer effect model for five measures of quality from the Donabedian process dimension (ACSCs emergency admissions, QOF total points, QOF population achievement, patient satisfaction with the ability to book urgent and advance appointments). Using a fixed effect spatial panel Durbin model (SDM), we found that there are positive peer effects. We also computed the effect of an exogenous increase in the quality of the largest practice in a PCT but found that though positive, it only leads to a small increase in the quality of its peers.

In chapter four, we examine another possible explanation for the spatial pattern of practice quality, namely: competition. Practice revenue increases with the number of patients in a practice and practices may seek to attract additional patients by improving their quality. Their incentive to raise quality to attract additional patients will vary with their exposure to competition from other nearby practices. Using practice fixed effect models of quality with eight measures of quality from Donabedian's process and outcome dimensions, We find that quality is higher in practices which have a larger number of GPs in rival practices within 1km. Whilst the impact is greater for practices in the lowest quartile of quality, practices in different quartiles of competitive areas do not show a different impact. We also exploit a policy (Equitable Access to Primary Medical Care) which provides financial incentives to encourage the entry of new practices in a subset of PCTs, and found that quality increased in these PCTs relative to other PCTs. However, the overall impact of competition on quality appears to be modest, though positive.

In chapter five, we complement the direct analysis of the effect of competition on quality by examining whether quality affects patient choice of practice. If there is no effect then practices have no incentive to raise quality in order to attract patients. There are previous studies of the effect of quality on choice of practice (e.g. Santos, Gravelle, & Propper, 2017) which we have expanded on by applying new data to the number of patients joining or leaving a practice without changing their address. These patients are likely to be well informed about the quality of their local practices' healthcare delivery process whereas most patients who change practices only do so when they move residence. If non-movers do not respond to quality then it is unlikely that quality will affect practice choice by the majority of these patients who only change practice when they move house. Using a Poisson panel model with fixed effects on a number of patients that leave and join a practice without changing address we found that these patients do indeed respond to quality. Practices with higher quality and more GPs per patient will attract more non-movers patients. The proportional effect of quality on the number of patients leaving a practice without change of address is considerable.

These five chapters contribute to the health economics and health geography literature by showing the factors underlying the spatial pattern of primary care quality. The thesis assesses quality of care drawing mainly on two of the three dimensions of the Donabedian Model. Our definition of quality, using proxies such as, e.g., ACSCs emergency admissions, QOF and patient satisfaction are examples of Donabedian process quality. Most of the explanatory factors we apply to variations in healthcare, such as FTE GPs, and the healthcare market mechanisms discussed in chapters 3 and 4, namely peer effects and competition, are aspects of the Donabedian structural dimension. We partially capture Donabedian's third dimension, outcomes, in chapter 4 using patient satisfaction with overall care.

To summarise, this thesis shows there is a stable spatial pattern with some practices in spatial clusters of high indirect standardised ACSCs emergency admissions for more than five years. Quality of care and FTE GPs are important explanatory factors of the spatial pattern (in Chapter 2) and influential factors on patient choice for practices (in Chapter 5). Moreover, Chapters 3 and 4 indicate that practices with stronger peers and in more competitive environments are of higher quality.

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Declaration

I declare that this thesis is a presentation of original work and I am the main author. I am the sole author of Chapter 1 “Spatial patterns and persistence in general practice Ambulatory Care Sensitive Conditions emergency admissions” and Chapter 3 “Quality in primary care are there peer effects among English GP practices?”. Chapter 2 “Variation in Ambulatory Care Sensitive Conditions emergency admissions, GPs and practice quality” is co-authored with Hugh Gravelle and Stephen Martin, chapter 4 “Spatial competition and quality: Evidence from the English family doctor market” is co-authored with Dan Liu, Hugh Gravelle and Carol Propper and chapter 5 “Does quality affect choice of family physician? Evidence from patients changing general practice without changing their address” is co-authored with Giovanni Van Empel and Hugh Gravelle.

I was the principal author of chapter 2 and 5. I have conducted most of the empirical analysis, in addition to contributing to the research question, developing original aspects of the identification strategy and the empirical methods. I have contributed extensively to the research question and empirical analysis of chapter 4 but I was not the main author. My co-authors advised on refinement of the research question, the empirical strategy, and made comments on drafts of the chapters.

This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References.

1. Spatial patterns and persistence in general practice Ambulatory Care Sensitive Conditions emergency admissions rates.

1.1.Introduction

Preventable emergency admissions are increasing every year. However, this growth is not geographically homogeneous. These types of emergency admissions are being studied around the world but a bigger focus on their spatial pattern is needed to fully understand their implication for inequity of access to healthcare.

We investigate the English spatial pattern of Ambulatory Care Sensitive Conditions (ACSCs) between 2004 and 2013 at a GP practice level. We identify the spatial pattern and it's stability over time, identifying the geographical areas with the highest and lowest rates of indirect standardised ACSCs emergency admissions for the last 10 years, as well as the areas that have experienced the highest growth rates of ACSCs.

We analyse ACSCs emergency admissions since it is internationally recognised that emergency admissions for those conditions could be avoided or reduced by appropriate management in primary care (Purdy et al., 2009).

Studies from the US, England, Scotland, Canada, Australia, Italy, Spain, Brazil, Portugal, Denmark, Germany, Singapore, Mexico, Lithuania and France report that there is geographical variation of preventable emergency admissions across regions, hospitals and GP practices[1].

In England several studies focus on variation in preventable emergency admissions Busby, Purdy, and Hollingworth (2016) explore the English interpractice variation in admission rates in 2011. Using data for 28 emergency ACSCs admissions the authors found that high-utilisation GP practices had admission rates that were 55% higher than low-utilisation GP practices, after adjusting for patients' age and gender and practice deprivation, distance to closest AED and Primary Care Trust. The three ACSCs disease groups with the highest interpractice variation - diabetes complications, alcohol-related diseases and schizophrenia - affect more deprived patients disproportionately. For these disease groups the high-utilisation GP practices had admission rates that were more than 230% higher than low-utilisation practices. The interpractice variation for diabetes complication emergency admission shows an age gradient, with a wider variation within younger groups (5 to 19 years and 20 to 39 years).

O'Cathain et al. (2013) analysed the variation on ACSCs (more specifically on 14 conditions rich in avoidable emergency admissions) between 129 hospitals in England for 2008–2011. They found that 22% of emergency admissions were classed as potentially avoidable, with threefold variation in the age-sex standardised avoidable admission rates between hospitals. The authors report that 53% of the variation between hospitals could be explained by high demand for emergency departments, numbers of acute beds per 1000 catchment population and conversion rates from emergency department attendance to admission and population deprivation.

O'Cathain et al. (2014) analyse the variation on avoidable emergency admissions between Primary Care Trusts (PCTs) in 2008-11. 22% of all emergency admissions were classified as ACSCs in 2008-11 and that 3 years age-sex direct standardised emergency admission high rates at PCT level clustered in the north of England (namely on the North East and North West) and east London. They found that population factors that had most explanatory power were deprivation (the proportion of working-age population seeking employment) and urbanicity, while the service

[1] An international literature review can be found in the Appendix 1.1

factors with highest explanatory power were attendance rates at ED, conversion of ED attendances to admissions, proportions of very short stays, ambulance calls transported to hospital and patient satisfaction with access to general practice. The authors also did a qualitative study in 6 PCTs with the highest unwarranted variation. They found three factors for which there is no routine data: Trust admissions ED schemes since Trusts with more proactive admission avoidance schemes were more successful at avoiding ACSCs admissions; integration between services, especially between health and social care; availability of out of hours services (OOH).

Other studies focus on the trend of ACSCs emergency admissions in England, Bardsley, Blunt, Davies, and Dixon (2013) analysed the trend of the number of admissions for ACSCs conditions between 2001 and 2011. The authors found a 45% increase in the number of ACSCs emergency admissions and a 25% increase on the age-standardised ACSCs emergency admissions rate with notable variations by age group and by disease groups. They report that children under 1 and adults over 70 were twice as likely to have an ACSCs emergency admission than the general population. The greatest increases in ACSCs emergency admissions were for urinary tract infection, pyelonephritis, pneumonia, gastroenteritis and chronic obstructive pulmonary disease.

Blunt (2013) examined the pattern of ACSCs emergency admissions across England from 2001 to 2013. The author reports that one in every five emergency admissions is an ACSCs emergency admission. These types of admissions increased 48% between 2001 and 2013, while the other emergency admissions increased by 34%. The geographical pattern of age, sex and deprivation standardised rates highlight areas (Healthcare authorities - Primary Care Trusts) in the North East and in the North West with the highest rates. He found significant increases in the standardised rate for areas that had rates below the national average and only one area with a significant decrease.

In a cross-sectional study Tian et al. (2012) explore how much NHS could save with ACSCs emergency admissions reduction. The authors report that the rate of emergency admissions for ACSCs varies from 9 to 22 per 1,000 populations in 2009/10 across the 326 local authorities (LAs), with the highest rates among the most deprived English LAs. They estimate that if all LAs performed at the level of the best performing quintile of LAs, ACSCs emergency admissions could be reduced by 18% and save the NHS £238 million.

Most of the studies that report geographical variation do so at a regional level (e.g. heath authorities) using several different methods to quantify variation, different ACSCs definitions and simple statistical methods.

This chapter addresses the spatial (or geographical) variation of preventable emergency admissions, proxied by ACSCs, across England from 2004/5 to 2013/14. We make a number of contributions. Since ACSCs emergency admissions have been linked to primary care management and quality, we analyse the spatial pattern of ACSCs at GP practice level. At this scale it is possible to observe the heterogeneity of ACSCs emergency admission rates within health authorities (Primary Care Trusts).

We present two alternative techniques to observe the space-time dynamics of ACSCs emergency admissions. The first is the Inverse Distance Weight map of the difference between the spatial pattern in 2013 and 2004, which highlights the areas that had a higher growth of the indirect standardised ACSCs emergency admissions rate. The second is the use of Moran's I Local Indicator of Spatial Association to examine whether there are spatial clusters of practices with similar ACSC emergency admissions rates and whether they are stable over time.

This chapter examines whether the spatial pattern of ACSCs emergency admissions conditional on the demographic characteristics of the practice list, is random or not, i.e., if there are spatial clusters of ACSCs emergency admissions. Comparisons of spatial clusters from 2004 to 2013 reveal areas of GP practices that have high indirect standardised ACSCs emergency rates for several years. These are likely to be areas that need a specific local health plan to address their primary care service features and detail the integration/relationship between primary and secondary care.

The next Section provides a brief explanation of the institutional framework for English general practices. Section 1.3 describes the data and Section 1.4 the indirect standardisation method, the measures of variation and the spatial statistics to identify and analyse the spatial pattern of ACSCs emergency admissions. Results are in Section 1.5 and Section 1.6 concludes with a discussion of the policy implications of our analysis, and our strategies for further analysis.

1.2.Institutional background

The English National Health Service (NHS) is a tax-financed system and free at point of use (apart from a small charge for dispensed medicines, which is applied to around 10% of prescriptions). NHS primary care is provided by family doctors, known as General Practitioners (GPs), organised in small surgeries known as general practices. All residents in England are entitled to register with a general practice, and have incentives to do so, as the practices provide primary care and act as the gatekeeper for elective (non-emergency) hospital care.

Most general practices are partnerships owned by GPs and have on average 5 GPs (4 Full Time Equivalent –FTE GPs). They employ other medical staff, including nurses (on average 3 Head Count – HC and 2 FTE), direct patient care staff (on average 2HC and 1.3 FTE) and administrative staff (on average 12 HC and 8 FTE), and have around 7,500 patients (NHS Digital, 2016). The NHS contracts, more specifically the Primary Care Trusts (PCTs), are with the practice rather than the individual GPs. Practices are paid by a mix of lump sum payments, capitation, quality incentive payments, and items of service payments. Quality incentives from the Pay for performance scheme, Quality and Outcomes Framework (QOF) generate a further 15% of practice revenue (Roland 2004). Practices are reimbursed for the costs of their premises but have to fund all other expenses, such as hiring nurses and clerical staff, from their revenue. PCTs were the legal entities and free-standing NHS bodies from 2001 to 2013 responsible for commissioning primary, community and secondary health services from providers. PCTs held budgets and set priorities, within the overriding priorities and budgets set by the SHA and the Department of Health. On the 1st April 2013, following the Health and Social Care Act (2012), Clinical Commissioning Groups (CCGs) replaced the PCTs. Although the CCGs are clinically-led statutory NHS bodies responsible for the planning and commissioning of health care services for their local area, they do not directly commission primary care. NHS England is responsible for the direct commissioning of services outside the remit of clinical commissioning groups, namely primary care, public health, offender health, military and veteran health and specialised services[2].

[2] Detailed information on NHS commissioning is available via https://www.england.nhs.uk/commissioning/primary-care-comm/

1.3. Data

The disease groups and more specifically the ICD10 codes[3] used to define ACSCs have been widely discussed. The Institute for Innovation and Improvement suggested a definition based on 19 disease groups (Tian et al., 2012). After a literature review Purdy et al. (2009) found 17 more disease groups, that were defined as ACSCs in the literature, but also more ICD10 codes for the 19 disease groups. From the 1,900,409 emergency admissions in 2005/6, which would be classified as a ACSCs admission by the full set of 36 conditions, only 35% were in the 19 ACSCs set used by NHS England Institute.

Sundmacher et al. (2015) use group consensus method to evaluate the degree of preventability of ACSCs and suggest a subset of 22 out of 40 ACSC diagnosis groups, covering conditions with a higher than 85% estimated degree of preventability in Germany, while Coleman and Nicholl (2010) using Delphi exercise with 48 senior clinicians suggest two sets of ACSCs for England. A set of 16 disease groups to measure the ability of systems to manage conditions to avoid serious emergencies and a set of 10 disease groups to measure the ability of the systems to control urgent conditions exacerbations that could be managed outside a hospital inpatient setting[4]. Purdy, Griffin, Salisbury, and Sharp (2010) also used a Dephi exercise to understand the prioritisation of disease groups within a core of 12 ACSCs. Dementia, COPD and kidney and urinary tract infections were the three top priority disease groups. The authors highlighted that in 2005/6 dementia was not a national priority. Consequently, dementia was introduced in the Quality Outcome Framework (QOF) in 2006/7 and GP practices started recording the number of patients diagnosed with dementia and reviewing the care of dementia patients yearly.

Some authors have grouped ACSCs in more homogenous categories. For example the NHS Outcome Framework (NHSOF) (Department of Health, 2013) distinguishes ACSCs in chronic and acute unplanned/emergency admissions to evaluate the effectiveness of primary and community care[5]. While the chronic ACSCs is an indicator for how successfully the NHS manages chronic conditions that can be managed in the community, the acute ACSCs age-sex standardised rate is an indicator for conditions that should usually be managed without the patient having to be admitted to hospital. This categorization has been used in several studies (Bardsley et al., 2013; Blunt, Bardsley, & Dixon, 2004; Busby et al., 2016) since it separates two dimensions of primary care: the management of long-term conditions and the response to urgent conditions exacerbations.

In light of the introduction of the Quality and Outcomes Framework (QOF)[6] in England, Harrison et al. (2014) classified ACSCs as incentivised and non-incentivised. The authors included in the incentivised ACSCs group disease groups that were continually incentivised under the QOF and as

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[3] International Statistical Classification of Diseases and Related Health Problems is a clinical cataloguing system proposed and updated by the World Health Organisation (WHO). It contains codes for diseases, signs and symptoms, abnormal findings, complaints, social circumstances, and external causes of injury or diseases. The list of ICD 10 codes can be found at: http://apps.who.int/classifications/icd10/browse/2010/en

[4] O'Cathain et al. (2014) used Coleman and Nicholl (2010) list of 14 health conditions to define ACSCs emergency admissions.

[5] https://www.england.nhs.uk/wp-content/uploads/2014/03/red-acsc-em-admissions-2.pdf (consulted August 2018)

[6] Quality Outcome Framework (QOF) is the pay for performance scheme for English, Welsh and Scottish GP practices. The pay for performance indicators changed along the years. Initially, in 2004/5, there were four domains: clinical, organisational, patient experience, and additional services, with the clinical domain comprehending 76 indicators in 11 disease areas. In 2015/16 there are three domains: clinical, public health and public health additional services with the clinical domain comprehending 65 indicators in 19 disease areas. NHS England reviews the set of indicators and its corresponding value in points each year. In 2015/16 the practices were rewarded with £160.15 per point on average.

non-incentivised ACSCs disease groups that were not targeted under the QOF at any time between 2004/5 and 2010/11.

ACSCs are conditions for which better management in primary care can reduce emergency admissions. The QOF incentivises some activities in primary care (record keeping and managing bio markers such as blood pressure) which were chosen because it was believed they would improve the health of patients with a range of chronic conditions (asthma, diabetes, etc.).

Our primary data source was the Hospital Episode Statistics (HES)[7] from 2004/5 to 2013/14. HES data is collected during a patient's stay at hospital and this data is submitted to allow hospitals to be paid for the care they deliver. An episode is created each time a patient is seen by a different Consultant. For each episode of care HES records information on the patient clinical care (e.g. diagnosis, procedures), the hospital spell of care (e.g. admissions and discharge dates and types), the patient characteristics (e.g. age, gender, ethnicity, LSOA, CCG) and the patient's GP practice code. The hospital stay of the patient is usually measured by the spell of care, which is the combination of all the finished consultant episodes that the patient experiences during her stay. We analysed data on all emergency admissions, excluding admissions that were transfers between hospitals. Emergency admissions were defined as the first episode in a spell of care, coded as an emergency, and admitted from a source other than another hospital ward or outpatient clinic. Using the primary diagnosis code in HES we classify the admissions as ACSCs or non-ACSCs. We use the patients' GP practice code recorded on the HES episode to attribute to each GP practice the number of ACSCs emergency admissions per age and gender band.

We use a comprehensive definition of ACSCs that include all the conditions (ICD 10 codes) defined by Harrison et al (2014) as incentivised and non-incentivised and by the Department of Health (2013) as chronic or acute.

The location of GP Practices was collected from NHS choices and Connecting for Health (archive and current data files). The location data includes the location of all surgeries which is over 10,000 for the over 8,000 practices. This is important since we will use all the locations to calculate the minimum distance between GP practice surgeries.

We obtained practice lists with the number of patients per age and gender bands from GPs workforce data (NHS Digital[8]) and income deprivation from Neighbourhood statistics (Office for National Statistics[9]). Income deprivation was obtained at Lower Super Output Area (LSOA) level and attributed to practices using the Attribution Data Set (NHS Digital[10]), which provides information on the share of patients residing in LSOA *a* that are registered with practice *j* for each year *t*.

We only include GP practices with more than 1000 patients in year *t*, *t-1* and *t+1* and that have more patients than emergency admissions per age and gender band.

[7] Hospital Episode Statistics are Copyright 2015 and re-used with the permission of NHS Digital.
[8] NHS Digital workforce data is available at http://content.digital.nhs.uk/workforce
[9] ONS neighborhood statistics is available at http://www.neighbourhood.statistics.gov.uk/dissemination/

[10] ADS data set available at http://content.digital.nhs.uk/

1.4. Methods

1.4.1. Indirect standardisation

To explore the spatial pattern of ACSCs emergency admissions rates across the more than 8,000 English GP practices and to examine the unexplained variation, we need to make the GP practice rates comparable. Given that disease and risk factors within a particular population will depend strongly on its age and gender structure but also by deprivation in some analyses.

Indirect standardisation is preferable when there are small numbers of admissions in particular groups. In our case, we have small numbers of admissions per GP practice once we count them by age and gender group. If we used direct standardisation the estimated rates would be subject to substantial sampling variation.

It is common on official statistics to allow for exogenous factors such as age and gender when comparing hospital admissions areas. We therefore use age and gender standardisation to examine the spatial patterns and their stability over time. We also standardised by deprivation to initially examine whether deprivation partially explains those patterns. Latter in other chapters, we take other factors into account (e.g. morbidity, practice characteristics) using regression methods.

The expected number of admissions per practice when adjusting by age and gender is:

$$ExpAdm_i = \sum_{j=1}^{J} \frac{ADM_{std_j}}{Pop_{std_j}} Pop_{ij} \qquad (1)$$

where Pop_{ij} is the number of GP practice *i* patients in age and gender group *j* and $\frac{ADM_{std_j}}{POP_{std_j}}$ the age and gender specific admission rate from the standard population[11].

The expected number of admissions per practice when adjusting for age, gender and deprivation is:

$$ExpAdm_i = \sum_{g=1}^{5} \sum_{j=1}^{J} \frac{ADM_{std_{jg}}}{Pop_{std_{jg}}} Pop_{ijg} \qquad (2)$$

where Pop_{ijg} is the number of GP practice *i* patients in age, gender group *j* and deprivation quintile *g* and $\frac{ADM_{std_{jg}}}{POP_{std_{jg}}}$ the age, gender and deprivation quintile specific admission rate from the standard population.

The standardised admission rate is the ratio between the observed and the expected:

[11] The standard population was the total practice list by age and gender at national level.

$$ACSCs_{STD_i} = \frac{ADM_i}{ExpAdm_i} \times 100 \qquad (3)$$

1.4.2. Spatial pattern analyses

Since "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970) it is important to use spatial statistics to understand if the spatial pattern presents statistical significant clustering or not.

1.4.2.1 Heat Maps using the Inverse Distance Weighting technique

GP practice location is spatial point data. To visualise the spatial pattern of standardised ACSCs emergency admission rates at GP practice level we used Inverse Distance Weighting (IDW). IDW is a deterministic, nonlinear interpolation technique that aims to create surface layers from data points. The surface is created by connecting a series of sample points with recorded sampled values, by predicting the value in the non-sampled space between them. The non-sampled locations are estimated taking into account a weighted average of the nearby sample locations/points. This method was also used by Lovett et al. (2014) to examine COPD admission at Lower Super Output Area (LSOA) level.

1.4.2.2 Spatial Statistics

To understand if the spatial pattern for the GP practice ACSCs emergency admissions standardised rate across England is or is not random, we test for global and local spatial correlation using Moran's *I* statistics. Since spatial correlation is a measure of the relation between values in nearby spatial units, we first need to define what we mean by "nearby". In spatial statistics, the "nearby", or more exactly the relationship between GP practices, will be expressed by a non-negative matrix, known as spatial weight matrix.

Weight Matrix Specification

The specification of the spatial weight matrix is important since it captures how the GP practices influence each other.

In our case, we have the location of all the GP practice branches. A GP practice has on average 1.2 branches and we define the strength of the relationship with other GP practices using the minimum distance between the branches of GP practice i and j. In the example in Figure 1, GP practice A has 2 branches, A1 and A2, and different sets of GP practice neighbours within a given radius of each of its branches. The spatial proximity between, for example, practices A and E will be captured by one unique measure w_{AE} in the W matrix. We will set w_{AE} to be a function of the minimum distance between practice A and E GP practice branches, i.e,
$w_{AE} = F\left(\min\left\{d_{A_1E_1}, d_{A_1E_2}, d_{A_2E_1}, d_{A_2E_2}\right\}\right) = F(d_{A1E2})$.

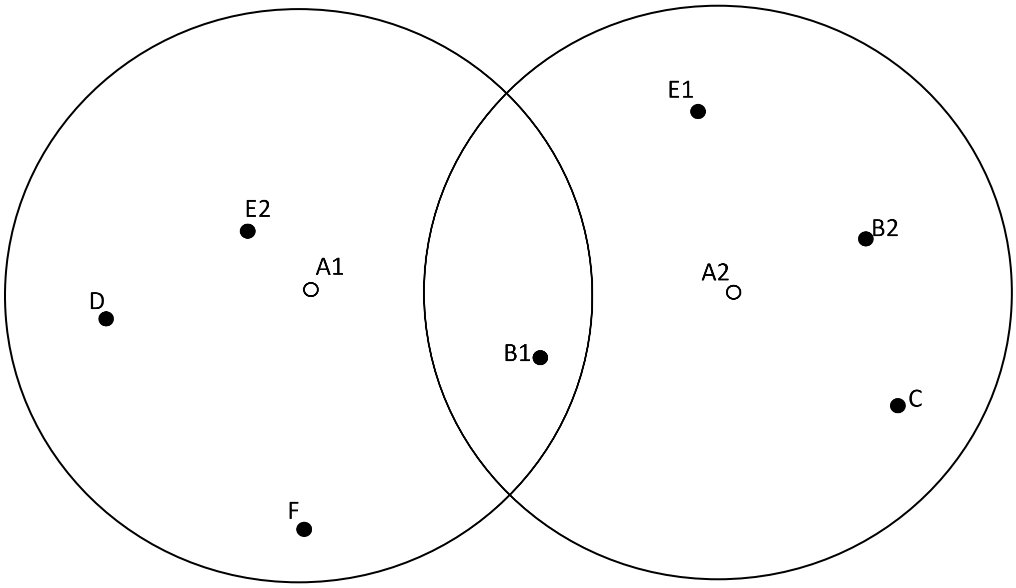


Figure 1 - GP practices branches location

We specified three W matrixes that are based on distance. These are describe below:

a) The first W matrix specification, the within 5km radii W matrix, sets w_{ij} is 1 if the GP practice surgeries/branches are less than 5km apart and 0 otherwise (as in equation(4)). This specification, assumes that the strength of the relationship between practices within the radii is the same.

$$\begin{cases} w_{ij} = 1 \quad if \quad d_{ij} \leq 5km \\ w_{ij} = 0 \quad if \quad d_{ij} > 5km \\ w_{ii} = 0 \end{cases} \tag{4}$$

where d_{ij} is the distance between GP practice i and j.

b) Secondly we defined w_{ij} as:

$$w_{ij} = 1/d_{ij} \quad if \quad d_{ij} < 5km \quad and \quad i \neq j \tag{5}$$

In this specification GP practices' relationships have a different strength according to the distance between branches within the 5km radius. The critical cut-off distance beyond which we disregard GP practices' relationships is important for computational issues.

c) Thirdly we defined w_{ij} as 1 if a GP practice is within the 5 nearest GP practices, as defined in the following equation:

$$\begin{cases} w_{ii} = 0 \\ w_{ij} = 1 \quad if \quad d_{ij} \leq d_i(k) \\ w_{ij} = 0 \quad if \quad d_{ij} > d_i(k) \end{cases} \tag{6}$$

where $d_i(k)$ is the minimum distance to the 5th nearest neighbour of GP practices i.

This specification allows all GP practices to have relationships of the same strength with 5 GP practices, ignoring if the practice is in a more urban or rural setting.

To normalise the influence of all other GP practices j over each practice i, the spatial weight matrices are row-standardised so that the elements w_{ij} in each row sum to 1.

$$w_{ij}^{*} = \frac{w_{ij}}{\sum_i w_{ij}} \qquad (7)$$

The expectation is that the correlation between the GP practice *i* and its neighbours to decrease with the increase of the neighbours. So we would expect higher correlations when using a within 5 radii W matrix then when using a within the same local authority W matrix. The expectation regarding the nearest neighbour W matrix is less straight forward since it will decrease the number of GP practices within a neighbourhood of an urban GP practice and increase the number of GP practice neighbours of a rural GP practice. We also specify a W matrix which attributes different weights to neighbouring GP practices within a 5km radii in (5) according to the inverse distance they are from GP practice *i*. We expect that the correlation between GP practice *j* and its neighbours will be higher with this matrix since the nearest GP practices will have a higher weight.

Moran's I global and local statistics

Moran (1950) proposed the first general measure for spatial correlation and Cliff and Ord (1972) suggested it as a statistical test naming, it "Moran's I test". The test was originally developed to test the spatial correlation among regression residuals but it has also been used to test the randomness of the spatial pattern of variables (e.g. Le Gallo & Ertur, 2003).

The Moran's *I* statistics:

$$I_t = \frac{n}{S_0} \frac{\sum_i \sum_j w_{ij}(x_{i,t} - \mu_t)(x_{j,t} - \mu_t)}{\sum_i (x_{i,t} - \mu_t)^2} \qquad (8)$$

where $S_0 = \sum_i \sum_j w_{ij}$

$x_{i,t}$ is the indirect standardised rate of ACSCs emergency admissions in GP practice *i* on year t ; μ_t is the mean indirect standardised rate of ACSCs emergency admissions in year t; n is the number of GP practices and w_{ij} is an element of the spatial weight matrix W that measures the relationship between GP practice i and j. The elements on the diagonal of the W matrix are set to zero ($w_{ii} = 0$).

Usually the strength of the relationship between i and j is based on the spatial proximity of the observations. Spatial proximity, when using location data, is defined using the distance, i.e., the closer two observations are, the stronger their relationship is, as mentioned above. To normalise the influence of all other GP practices j over each practice i, the spatial weight matrix is usually row-standardised such that the elements w_{ij} in each row sum to 1. In this case equation (8) simplifies since for row-standardised weights $S_0 = n$ and Moran's I statistics is:

$$I_t = \frac{\sum_i \sum_j w_{ij}(x_{i,t} - \mu_t)(x_{j,t} - \mu_t)}{\sum_i (x_{i,t} - \mu_t)^2} \quad (9)$$

Using a row-standardised weight matrix is also more intuitive since the Moran's I statistics can be interpreted as the correlation between GP practice *i* indirect standardised rate of ACSCs emergency admissions and the weighted average of nearby GP practices indirect standardised rate of ACSCs emergency admissions.

Moran's I takes the form of a correlation between the deviation from the mean of $x_{i,t}$, $(x_{i,t} - \mu_t)$, and their spatially lagged values $w_{ij}(x_{j,t} - \mu_t)$.

To use Moran's I statistics as a test, Cliff and Ord (1973 and 1981) developed Moran's I statistics moments (mean and variance) under which observations are drawn from a normal distribution or from random permutations distribution.

The mean of Moran's I under the null of no correlation is :

$$E(I) = -\frac{1}{n-1} \quad (10)$$

The Moran's I test is a global spatial statistics, i.e., it tests if the spatial pattern is random or spatially clustered, but doesn't identify the local spatial clusters. Anselin (1995) proposed a Moran's I Local Indicator of Spatial Association (LISA). The author defined as LISA any statistics that satisfied the following two conditions: (a) the LISA for each observation gives an indication of the extent of significant spatial clustering of similar values around that observation; (b) the sum of LISAs for all observations is proportional to a global indicator of spatial association.

$$I_{i,t} = \frac{(x_{i,t} - \mu_t)}{m_0} \sum_j w_{ij} (x_{j,t} - \mu_t) \text{ with } m_0 = \sum_i (x_{i,t} - \mu_t)^2 \Big/ n$$

(11)

as before $x_{i,t}$ is the indirect standardised rate of ACSCs emergency admissions in GP practice i in year t; μ_t is the mean indirect standardised rate of ACSCs emergency admissions in year t, n is the number of GP practices and w_{ij} is an element of the spatial weight matrix W that measures the relationship between GP practice i and j. The summation over j will only include GP practices for which w_{ij} is different from 0, i.e., when there is a relationship between GP i and j.

When using a row-standardised weight matrix W, the mean of Moran's I LISA equals the global Moran's I statistics.

The mean for Local Moran's I is:

$$E(I_i) = -w_i / (n-1) \tag{12}$$

with w_i as the sum of the row elements, i.e., $w_i = \sum_j w_{ij}$. When we use a row-standardised weight matrix the mean for Local Moran's I is reduced to $-1/(n-1)$.

1.5. Results

The number of Ambulatory Care Sensitive Conditions (ACSCs) emergency admissions has increased over time as shown in Table 1-1. The ACSCs emergency admissions increased 24.3% between 2004 and 2013, and after a considerable decrease in ACSCs emergency admissions in 2007, the highest annual growth rate was in 2008[12].

1.5.1. Time trend

Table 1-1: Total ACSCs emergency admissions

	All	Annual growth rate
2004	852,562	
2005	871,307	2.20%
2006	879,517	0.94%
2007	842,715	-4.18%
2008	913,404	8.39%
2009	940,672	2.99%
2010	982,689	4.47%
2011	991,772	0.92%
2012	1,050,509	5.92%
2013	1,059,687	0.87%

Table 1-2 has trends for incentivised, non-incentivised, chronic and acute ACSCs.
The discrepancy between the total number of ACSCs in Table 1-1 and the sum of Chronic and Acute ACSCs in Table 1-2 is due to the inclusion of incentivised and non-incentivised conditions included in Harrison et al. (2014) but not incorporated in Department of Health (2013). While Chronic ACSCs and Incentivised ACSCs decreased by -3.54% and -1.23% between 2004 and 2013, the Acute and Non-Incentivised ACSCs have increased by 28.4% and 36.15%, respectively.

[12] The negative annual growth rate in 2007 (financial year 2007/8) is also reported in Blunt (2013) and Bardsley et al. (2013)

Table 1-2: ACSCs emergency admissions: the four different definitions

	Incentivised	Annual growth rate	Non-Incentivised	Annual growth rate	Acute	Annual growth rate	Chronic	Annual growth rate
2004	485,474		170,178		284,998		379,618	
2005	479,987	-1.1%	179,064	5.2%	309,756	8.7%	375,988	-1.0%
2006	472,637	-1.5%	185,009	3.3%	323,962	4.6%	374,251	-0.5%
2007	439,070	-7.1%	182,228	-1.5%	318,433	-1.7%	344,515	-7.9%
2008	469,367	6.9%	195,298	7.2%	355,248	11.6%	370,477	7.5%
2009	462,971	-1.4%	206,406	5.7%	382,935	7.8%	361,158	-2.5%
2010	472,868	2.1%	212,969	3.2%	417,324	9.0%	367,812	1.8%
2011	470,497	-0.5%	216,602	1.7%	430,096	3.1%	361,990	-1.6%
2012	484,944	3.1%	227,092	4.8%	374,050	-13.0%	374,050	3.3%
2013	479,507	-1.1%	231,695	2.0%	366,182	-2.1%	366,182	-2.1%
2004 to 2013:		**-1.23%**		**36.15%**		**28.49%**		**-3.54%**

1.5.2. Spatial pattern of indirect standardised ACSCs rate

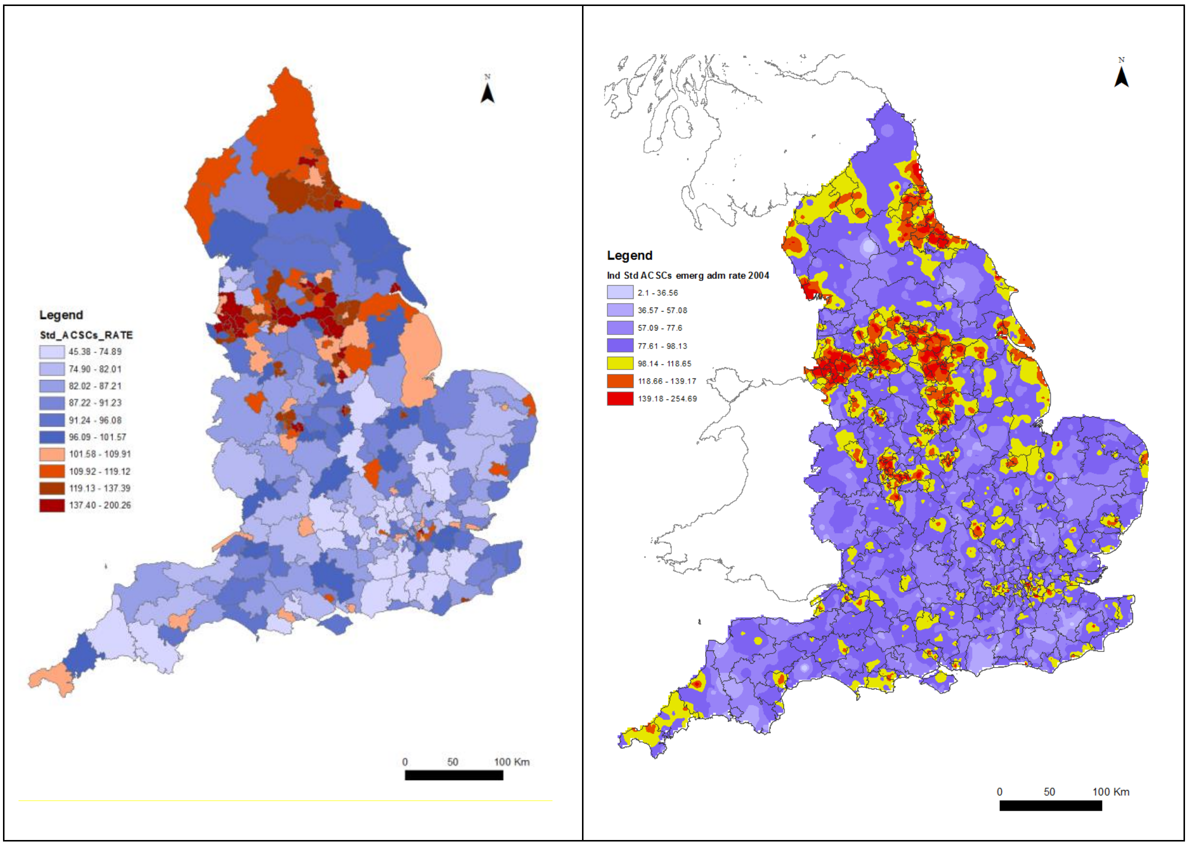
The spatial pattern of ACSCs has been reported in Atlases ACSCs (NHS Right Care, 2011 and 2015[13]) at Primary Care Trust (PCTs) and Clinical Commission Groups (CCGs) level. The map on the left of Figure 2 shows the spatial pattern of 2004 indirect standardised rate of ACSCs for the 303 Primary Care Trusts[14], while the map on the right shows the spatial pattern at GP practice level[15]. Each map displays a colour per unit of analysis (a PCT or a raster pixel) according to the interval produced by the standard deviation of the distribution. The areas with lower than the mean ACSCs emergency admissions indirect STD rate are in blue. While the areas at the mean indirect standardised ACSCs emergency admissions rate (more precisely within one Standard deviation of the mean) are in yellow and the areas with higher indirect standardised ACSCs emergency admissions rate, i.e., one and two SDs from the mean indirect standardised ACSCs emergency admission rate are in orange and red.

[13] Both atlases were consulted at https://fingertips.phe.org.uk/profile/atlas-of-variation (6th August 2018).

[14] In 2006 the 303 Primary Care Trusts were reduced to 152. The new geographical borders are shown in maps.

[15] We used the Indirect Weight Distance interpolation tool to create the map at GP practice level.

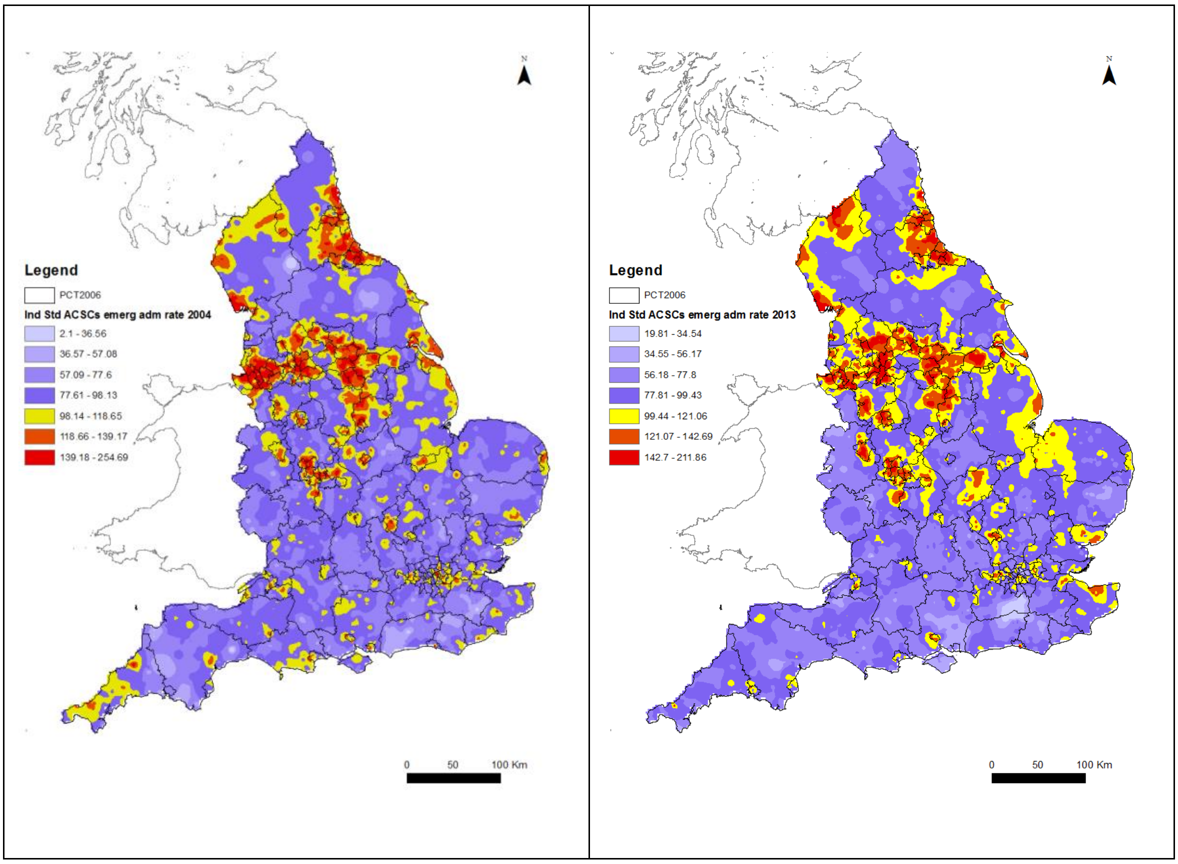
Figure 2 – Comparison of spatial scales: PCT versus practice level ACSCs rates in 2004



The maps show similar spatial patterns, but the practice level map allows us to visualise the variation within a PCT and the spillovers across PCT borders. The analysis at GP practice level allows a better understanding of the spatial concentration of high and low rates of indirect standardised ACSCs. For example, the Northumberland 2004 PCT, on the top right of the map, is highlighted in an orange colour in the map at PCT level, while the GP practice level map shows that the high ACSCs indirect standardised rates are concentrated on the border with North Tyneside 2004 PCT around the city of Ashington and that the PCT actually has low ACSCs indirect standardised rates in the northern areas. The fact that most cities with high population density and/or high levels of deprivation are highlighted in the GP practice level map with high ACSCs indirect standardised rates will be discussed later on.

We report in Figure 3 the spatial pattern of Indirect Standardised ACSCs rate for 2004 and 2013. Comparing the spatial pattern of Indirect Standardised ACSCs rate for 2004 and 2013 we see that the ACSCs rate has increased.

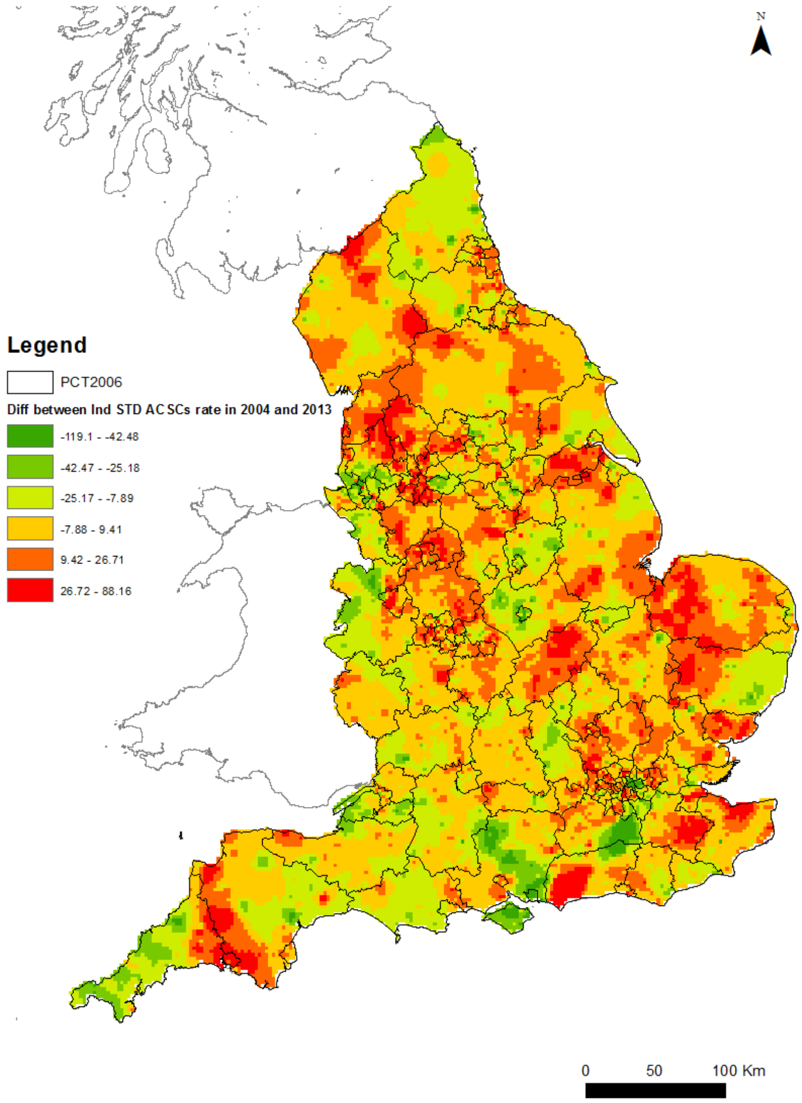
Figure 3 - Spatial pattern of Indirect Standardised ACSCs emergency admissions in 2004 and in 2013



The areas with high ACSCs emergency admissions indirect standardised rates are larger in 2013 (although the SD being very similar for the two years, 20.52 and 21.63 for 2004 and 2013 respectively), indicating that more areas have higher ACSCs indirect STD rates. Highlighted in red is the M62 motorway corridor between Liverpool and Hull and the cross-country train line corridor between Leeds and Birmingham, although this last one with more areas without high ACSCs emergency admissions indirect STD rates. The 2006 PCTS of Lincolnshire and Norfolk had an increase of areas with within 1SD of the mean ACSCs emergency admissions indirect STD rate. While, Northamptonshire 2006 PCT had a spread of higher ACSCs emergency admissions indirect STD rates, with an increase of areas that are one to two SD over the mean ACSCs emergency admissions indirect STD rate in 2013. The areas that suffer those increases are actually Northampton city and the surrounding areas of Corby.

The difference in the ACSCs indirect standardised rate between 2013 and 2004 is highlighted in Figure 4. While the red areas are those that suffered an increase of GP practices indirect STD ACSCs emergency admissions rate between 2013 and 2004, the green areas highlight areas where GP practices indirect STD ACSCs emergency admissions rate decreased within the same period. Some areas with a persistently high ACSCs rate improved, for example the Liverpool and Hull areas while others have not, for example the Newcastle and Greater Manchester areas. On the other hand, areas with a low ACSCs rate, e.g. Plymouth and York, worsen between 2004 and 2013.

Figure 4 - Difference between 2013 and 2004 ACSCs indirect standardised rates (per 1000 patients)



Given that the Quality Outcome Framework (QOF) was introduced in 2004 and it incentivised directly some Chronic and Acute conditions, we show in Figure 5 the incentivised ACSCs emergency admissions indirect STD rate, in 2004 and 2013. The M62 motorway corridor between Liverpool and Hull is once again highlight in red, however, in 2013 it seems that the corridor is less densely red, with more areas having a lower than the mean indirect STD rate in Liverpool and Lancashire. The North Lincolnshire 2006 PCT, around the city of Scunthorpe had an increase on the ACSCs incentivised emergency admissions indirect STD rate, with a two to three times higher than the mean ACSCs incentivised emergency admissions indirect STD rate in 2013. On the other hand, Cornwall and Isles of Scilly 2006 PCT areas improved, and in 2013, the PCT only had areas in one SD over or below the mean of ACSCs incentivised emergency admissions indirect STD rate.

Figure 5 - Indirect Standardised Incentivised ACSCs emergency admissions in 2004 and 2013

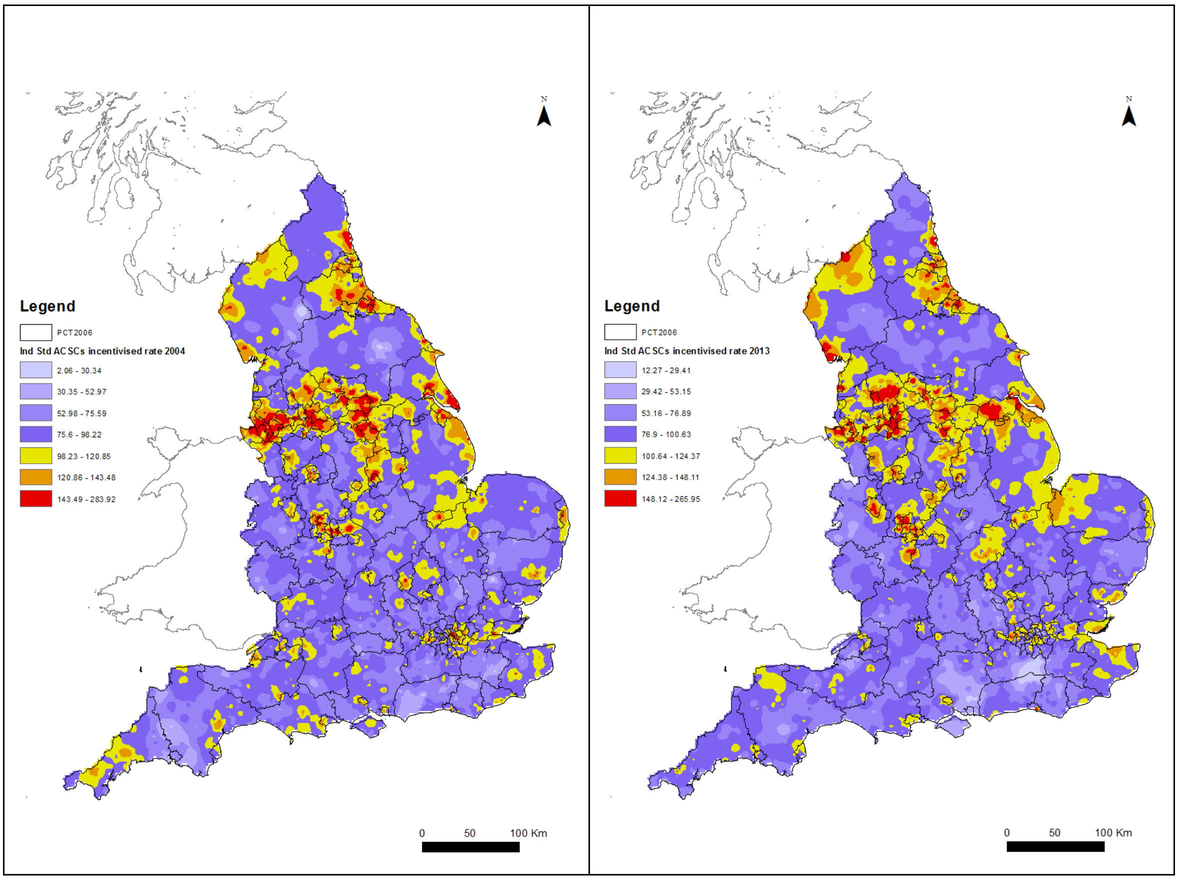
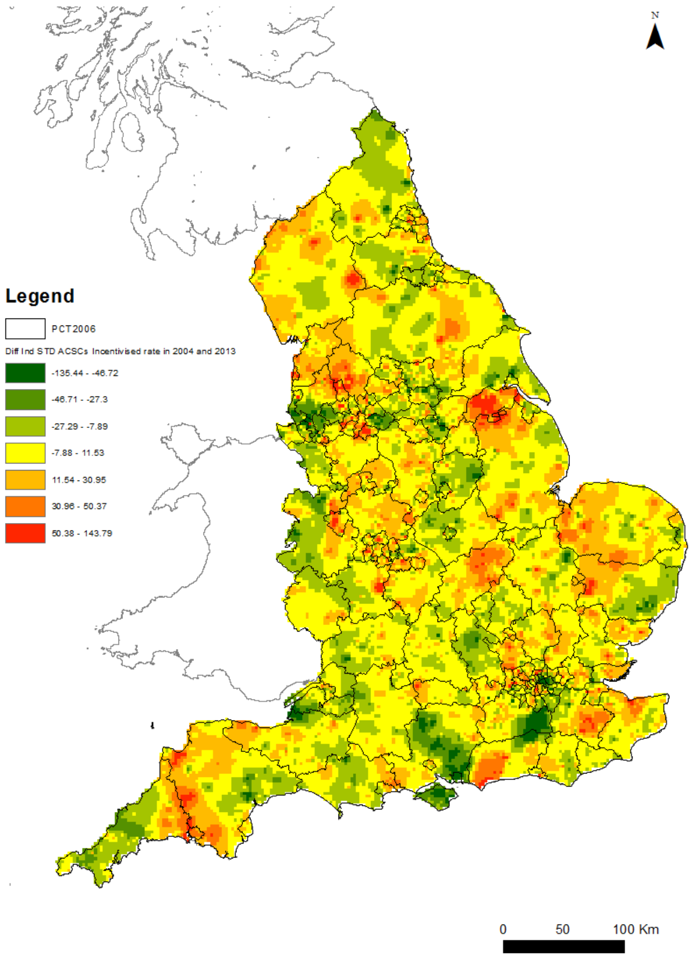


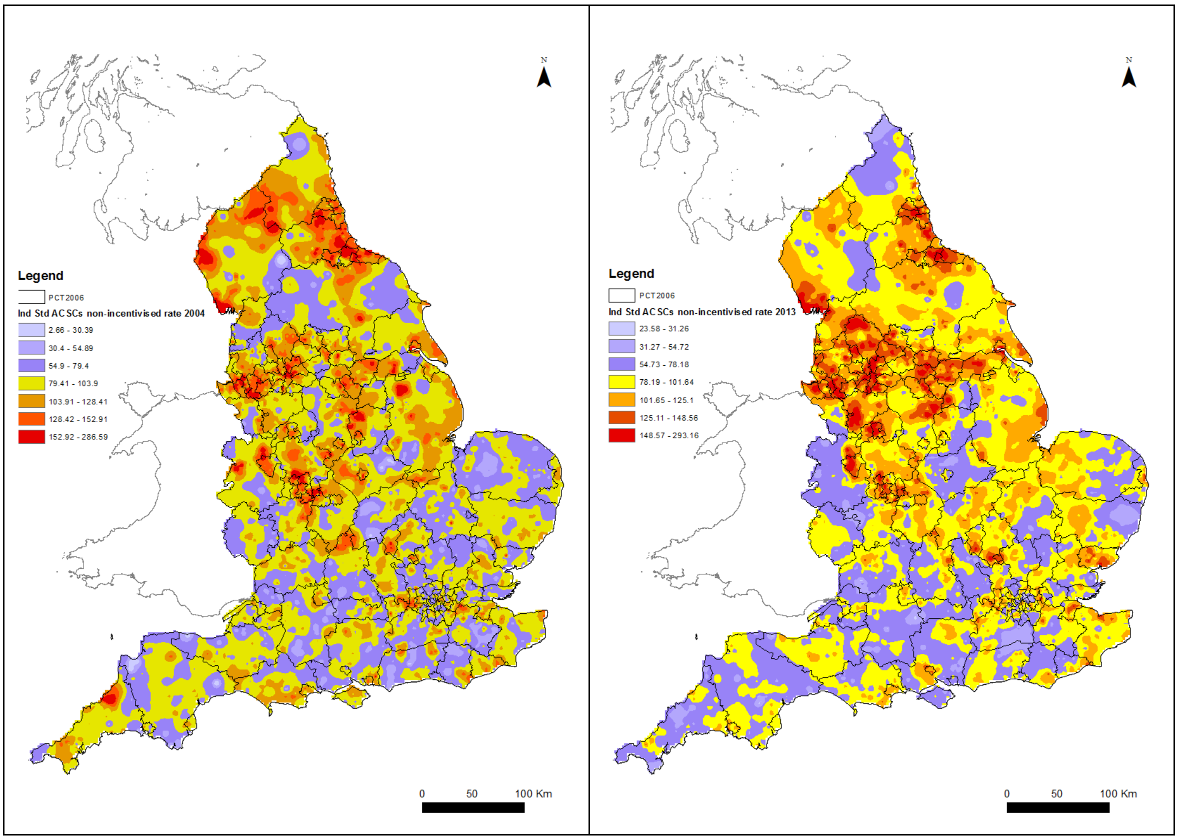
Figure 6 shows in dark green the improvement of areas, such as Liverpool, Lancashire and Hampshire of ACSCs emergency admissions indirect STD rate for conditions incentivised by the QOF. There are still some areas that got worse such as the North Lincolnshire 2006 PCT, specially the areas surrounding Scunthorpe city, and the area around Penrith in Cumbria 2006 PCT. The area on the border between Cornwall and Isles of Scilly 2006 PCT and Devon 2006 PCT is also highlighted in red. These areas have lower than the mean ACSCs incentivised emergency admissions indirect STD rate in 2004 and 2013, but nevertheless, it seems that they suffered an increase.

Figure 6- Difference in Indirect STD ACSCS incentivised rate in 2004 and 2013



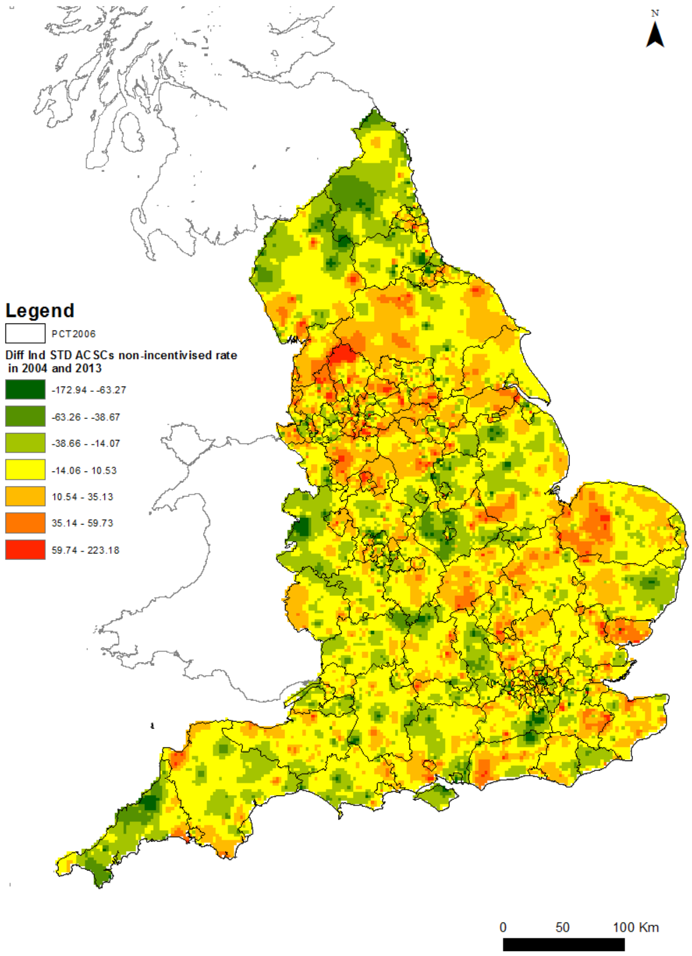
The two maps presented in Figure 7 for ACSCs Non-incentivised emergency admissions indirect STD rate for 2004 and 2013, show a spread of the areas of high indirect STD rate in 2013 compared to 2004. Some areas had an increase of with high indirect STD rate between 2004 and 2013. In 2004, the North of England, namely the counties of Northumberland, Cumbria, Durham and Yorkshire, had more areas with high ACSCs Non-incentivised emergency admissions indirect STD rates. While in 2013, the red areas spread around the M62 motorway corridor between Liverpool and Hull, Lancashire and Stoke-on-Trent 2006 PCT and Telford and Wrekin 2006 PCT, to name the larger areas.

Figure 7 - Indirect Standardised Non-Incentivised ACSCs in 2004 and 2013



The difference between the ACSCs Non-incentivised emergency admissions indirect STD rate in 2013 and in 2004, reported in Figure 8, shows that the areas that improved more are in the North (Cumbria and Northumberland), on the border with Wales (namely in Shropshire) and in the South of England in the Cornwall and Isles of Scilly 2006 PCT between Camelford and Bolventor. The green areas within the red M62 motorway corridor from Liverpool to Hull are mostly concentrated in 2006 PCTs of Liverpool, Knowsley, Warrigton and Hull. The bigger areas demarked by an increase in the ACSCs Non-incentivised emergency admissions indirect STD rate are mainly in the north of the East Lancashire 2006 PCT and in the west of Norfolk 2006 PCT[16].

Figure 8- Difference in Indirect STD ACSCS Non-Incentivised rate in 2004 and 2013

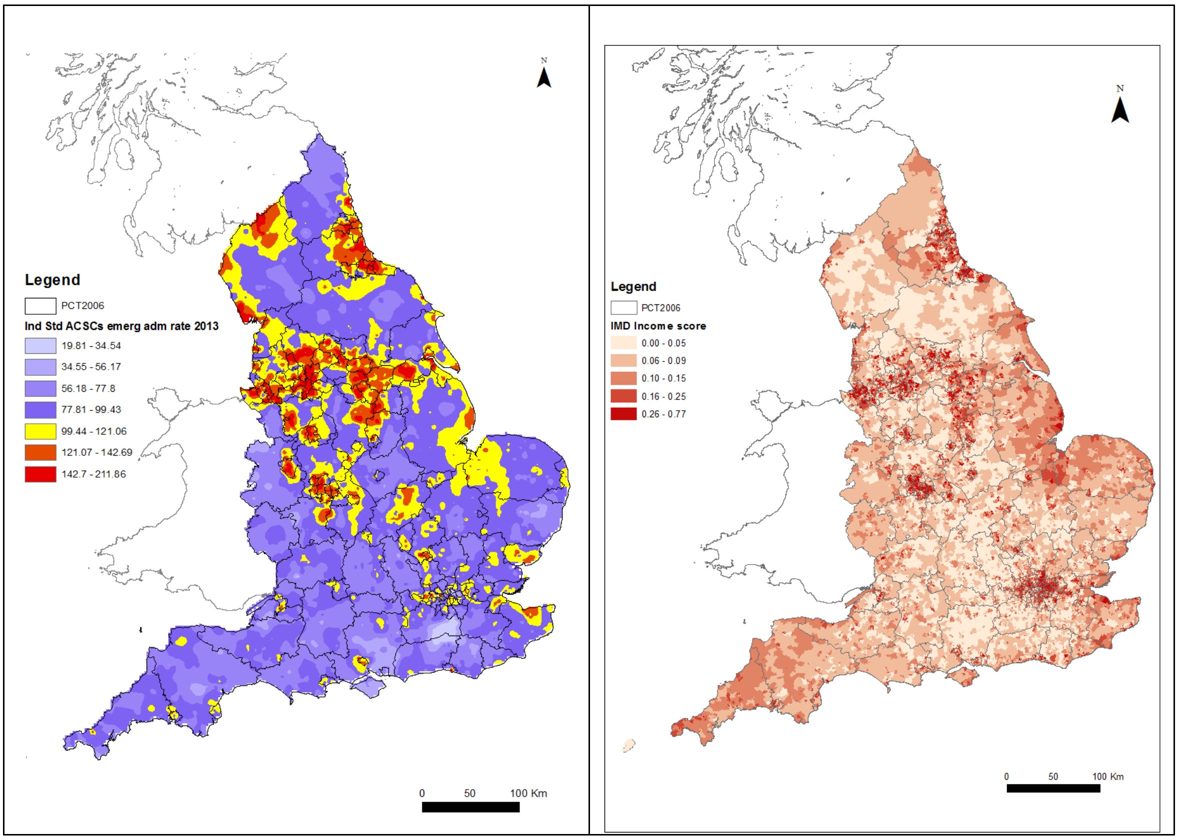


The literature suggests that a major contributor to the spatial pattern of indirect standardised ACSCs emergency admissions rate is deprivation. Figure 9 allows a crude comparison of the indirect standardised ACSCs rate and income deprivation spatial patterns.

[16] The spatial pattern for chronic and acute ACSCs emergency admissions indirect standardised rate in 2004, 2013 and the difference between them can be found in Appendix 1.3.

There are similarities, with both maps highlighting in red the southern part of the North East, the M62 motorway corridor from Liverpool to Hull and the core of the Midlands. On the contrary, Cumbria, in the north west of England, shows high ACSCs rate and low-income deprivation levels.

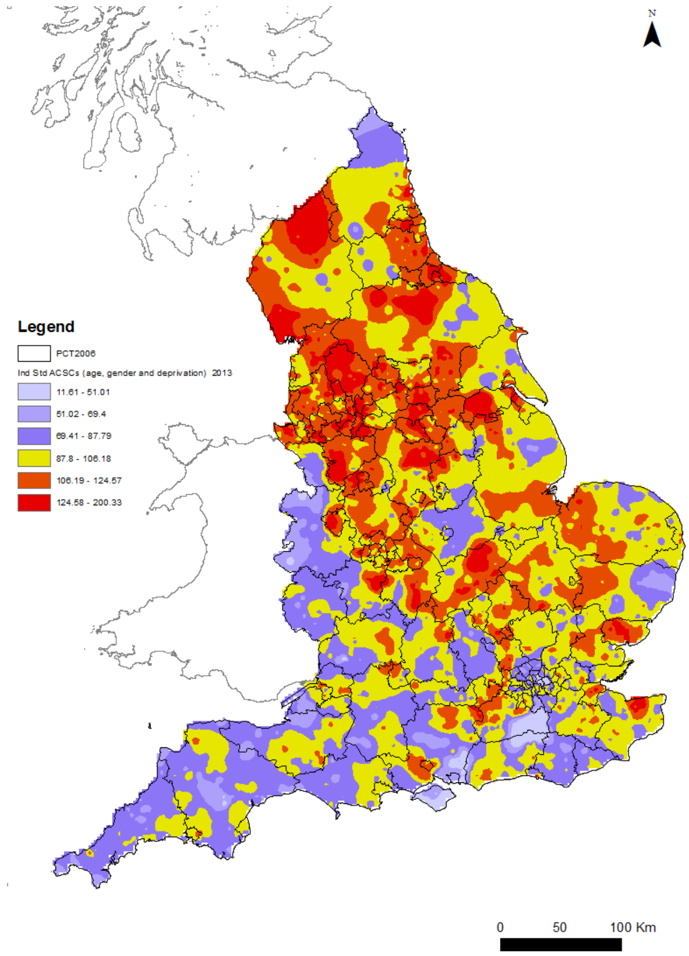
Figure 9 - Indirect Standardised ACSCs emergency admission rate in 2013 and Income Deprivation in 2010



Once we standardised by age, gender and deprivation quintile the spatial pattern changes as shown in Figure 10. The red areas are where GP practices had more emergency ACSCs admissions than expected, given their practice list age, gender and neighbourhood income deprivation level. Figure 10 shows a high number of where the indirect standardised rate of ACSCs emergency admissions once deprivation is included, but also a high number of areas for which ACSCs emergency admissions are higher than expected, even after standardising for GP practices patient list age, gender and deprivation[17].

[17] The spatial pattern for the indirect standardized rate by age, gender and deprivation for incentivised and non-incentivised ACSCs emergency admissions can be found in Appendix 1.4.

Figure 10 - Indirect Standardised ACSCs emergency admission rate by age, gender and deprivation in 2013



The results have shown so far that the ACSCs emergency admission rate has increased over time, driven by the increase in acute and non-incentivised ACSCs emergency admissions. The spatial patterns of the indirect standardised ACSCs emergency admissions rate for 2004, 2013 and for the difference between the indirect standardised ACSCs rate are reported on the maps (Figure 2 to Figure 8 and Figure A. 1 to Figure A. 6). The maps mainly show that although the spatial patterns for 2004 and 2013 are fairly similar, some areas, such as Hull, showed a decrease in acute ACSCs and an increase in chronic ACSCs. However, if the deprivation of the area is taken into account, the GP practices in that area have almost the expected number of ACSCs admissions. The inclusion of deprivation in the standardisation implied that more GP practices had the expected ACSCs emergency admissions given their practice list age, gender and deprivation. However, the areas with the highest ACSCs emergency admissions indirect STD rates were almost the same[18].

[18] The difference between indirect standardised ACSCs emergency admissions with and without deprivation can be found in Appendix 1.4.

1.5.3 Spatial Correlations

In the previous Section 1.5.2. we described how the spatial pattern of ACSCs emergency admissions indirect standardised rate changed over time and which areas were affected by higher and lower rates. In this Section we test for the randomness of spatial patterns of ACSCs emergency admissions standardised rate and describe how some areas with high (or low) ACSCs emergency admissions indirect standardised rate cluster significantly in space.

1.5.3.1. Global spatial autocorrelation

To analyse the randomness of the spatial pattern of ACSCs emergency admissions standardised rate across England per GP practice we start by testing the global spatial correlation using Moran's I statistics.

The significant values of Moran's I statistics for all, acute, chronic, incentivised and non-incentivised ACSCs using a 5 nearest neighbours weight matrix[19] are reported in Table 1-3[20]. Under the null of no spatial correlation the expected value of global Moran's I statistics is -1/(N-1) which, around 8,000 practices is very close to zero. The fact that there is a significant positive global spatial autocorrelation over the analysis period shows that the spatial pattern of the indirect standardised ACSCs emergency admissions rates is not random, i.e., that there are clusters of similar values in nearby locations, known as spatial clusters.

Table 1-3: Global Moran's I Statistics for the ACSCs indirect standardised admissions

	All ACSCs	Acute ACSCs	Chronic ACSCs	Incentivised ACSCs	Non-Incentivised ACSCs
2004	0.459	0.362	0.430	0.426	0.286
2005	0.481	0.348	0.441	0.449	0.329
2006	0.515	0.407	0.447	0.458	0.362
2007	0.569	0.488	0.474	0.490	0.410
2008	0.602	0.502	0.537	0.543	0.441
2009	0.590	0.488	0.515	0.525	0.436
2010	0.615	0.540	0.540	0.546	0.452
2011	0.594	0.525	0.505	0.513	0.425
2012	0.580	0.492	0.492	0.497	0.435
2013	0.579	0.483	0.483	0.501	0.441

All the Global Moran's I statistics test are significant with a p-value<=0.0001

[19] Please see section 1.4.2.2. for weight matrix specifications.

[20] We obtained similar Moran's I global and local spatial correlations results for the other weight matrices.

1.5.3.2. Local spatial autocorrelation

The Anselin (1995) Local Indicator for Spatial Association (LISA) for Moran's I will allow the detection of spatial clusters of high and low values of indirect standardised ACSCs rates across England. The spatial clusters of high values (usually named high-high – HH) indicate high indirect STD rates of ACSCs emergency admissions in several GP practices that are geographically close, while spatial clusters of low values indicate low indirect STD rates of ACSCs emergency admissions among GP practices that are geographically close (usually named low-low – LL)[21].

Table 1-4 reports the number of GP practices in each spatial clusters and the ACSCs indirect standardised rate range for each type of cluster. There are 749 GP practices in a spatial cluster of high ACSCs rates and 347 in a spatial cluster of low ACSCs rates in 2004 and 722 and 535 in 2013, respectively. The variation on ACSCs indirect standardised rate is wider among the GP practices in the spatial cluster of high values (with a SD higher than 30) than among those in the spatial cluster of low values (with a SD lower than 15), probably because practices in the LL clusters have a ACSCs emergency admission rate bounded to zero.

Table 1-4: Moran's I LISA 2004 - 2013 for all ACSCs emergency admissions indirect standardised rate

Year	Spatial clusters				All ACSCs emergency admissions Indirect STD		
		Frequency	Percentage	Mean	min	max	SD
2004	HH	749	9.09%	176.82	119.40	579.67	36.24
2004	LL	347	4.21%	50.46	0	76.60	12.60
2004	not significant	7140	86.69%	99.13	0	386.07	29.07
2005	HH	730	8.93%	177.41	122.04	880.29	42.26
2005	LL	370	4.52%	46.35	0	72.68	13.67
2005	not significant	7077	86.55%	99.67	0	320.32	27.80
2006	HH	753	9.24%	178.95	125.09	731.07	39.43
2006	LL	395	4.84%	46.82	0	71.79	12.80
2006	not significant	7005	85.92%	99.31	3.46	255.36	27.85
2007	HH	770	9.50%	178.63	123.99	442.42	35.74
2007	LL	595	7.34%	46.96	11.69	75.65	11.57
2007	not significant	6739	83.16%	100.94	0	293.27	28.59
2008	HH	814	10.10%	178.39	124.50	491.52	34.10
2008	LL	606	7.52%	40.27	4.94	75.91	12.95
2008	not significant	6636	82.37%	100.68	2.79	283.00	27.95
2009	HH	784	9.82%	177.10	122.92	557.91	36.06
2009	LL	611	7.65%	40.00	7.92	72.38	13.75
2009	not significant	6588	82.53%	101.44	3.30	246.38	26.92
2010	HH	807	10.23%	175.83	128.87	436.52	31.95
2010	LL	633	8.03%	43.81	7.73	74.18	14.04
2010	not significant	6447	81.74%	101.10	13.07	288.19	27.27
2011	HH	790	10.09%	173.38	121.87	437.07	31.08
2011	LL	571	7.29%	46.52	8.44	75.02	13.07
2011	not significant	6468	82.62%	100.52	19.33	271.99	26.41
2012	HH	764	9.75%	172.91	125.51	415.23	31.18

21 We will describe the results referring to the significant spatial cluster as spatial clusters since we only describe those.

2012	LL	568	7.25%	46.61	7.28	75.51	12.86
2012	not significant	6504	83.00%	101.38	20.59	316.28	26.96
2013	HH	722	9.28%	172.68	118.21	421.59	31.63
2013	LL	535	6.88%	46.54	6.14	76.11	13.97
2013	not significant	6524	83.85%	101.43	22.17	296.14	26.96

The 71% of GP practices that were in a significant spatial cluster of high values in 2004 were also in a HH cluster in 2013, while the 70% of GP practices that were in a significant spatial cluster of low values in 2004 were also in a LL cluster in 2013. These transition probabilities reinforce the stability of the spatial pattern highlighted when comparing the maps of Figure 3 in Section 1.5.2, especially the areas that had high or low ACSCs emergency admissions indirect STD rates in 2004 and 2013.

Table 1-5: transition probabilities (%) across significant spatial cluster between 2004 and 2013

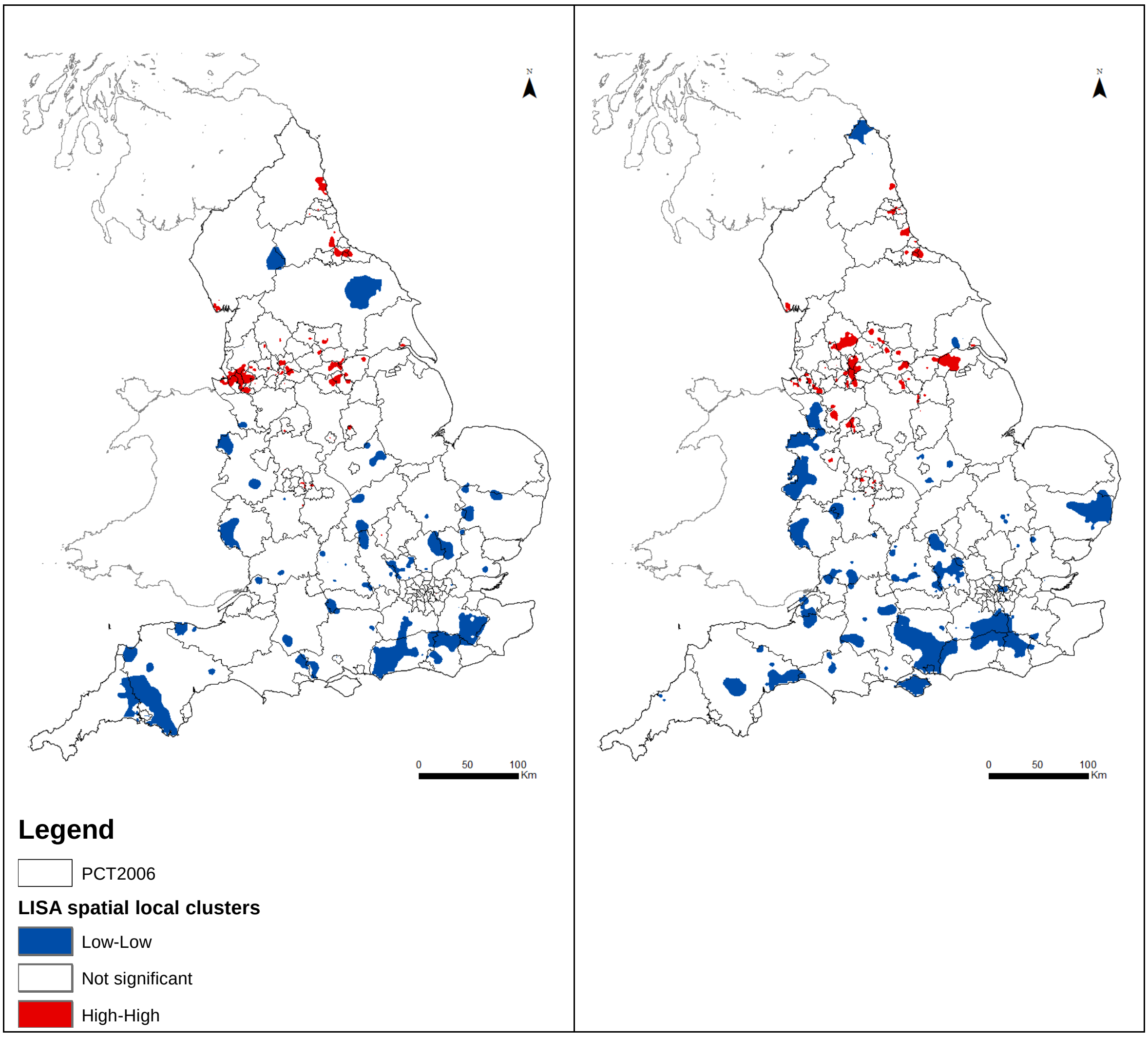
	LL	not significant	HH	Total
LL	71.22	28.78	0	100
not significant	2.61	94	3.39	100
HH	0.06	29.69	70.25	100
Total	6.82	83.61	9.57	100

We used the Inverse Distance Weighting technique to understand the areas that had significant spatial clusters. Given that the Moran's I LISA was calculated using a five nearest neighbours' weight matrix (as explained in Section 1.4.2.2), we allowed for an interpolation within 12 km radii from each GP practice. The stability of the spatial pattern reported in Table 1-5 and the growth in the number of GP practices that belong in each significant spatial cluster (reported in Table 1-4) are reflected in the two

Figure 11 maps.

The spatial clusters of high values are larger around Liverpool, Greater Manchester, Rotherham, Barrow-in-Furness and Ashington in 2004. While in 2013 it is the area around Scunthorpe (in the North Lincolnshire 2006 PCT) and a wider area in Greater Manchester and in the surrounding areas of Blackburn that spreads to East Lancashire 2006 PCT Burnley town. The 2004 low ACSCs emergency admissions indirect STD rate spatial clusters of North Yorkshire, Cornwall and Devon disappeared by 2013, while the ones located in Hampshire, Sussex and Shropshire spread and a new large spatial cluster appeared on the Suffolk coast.

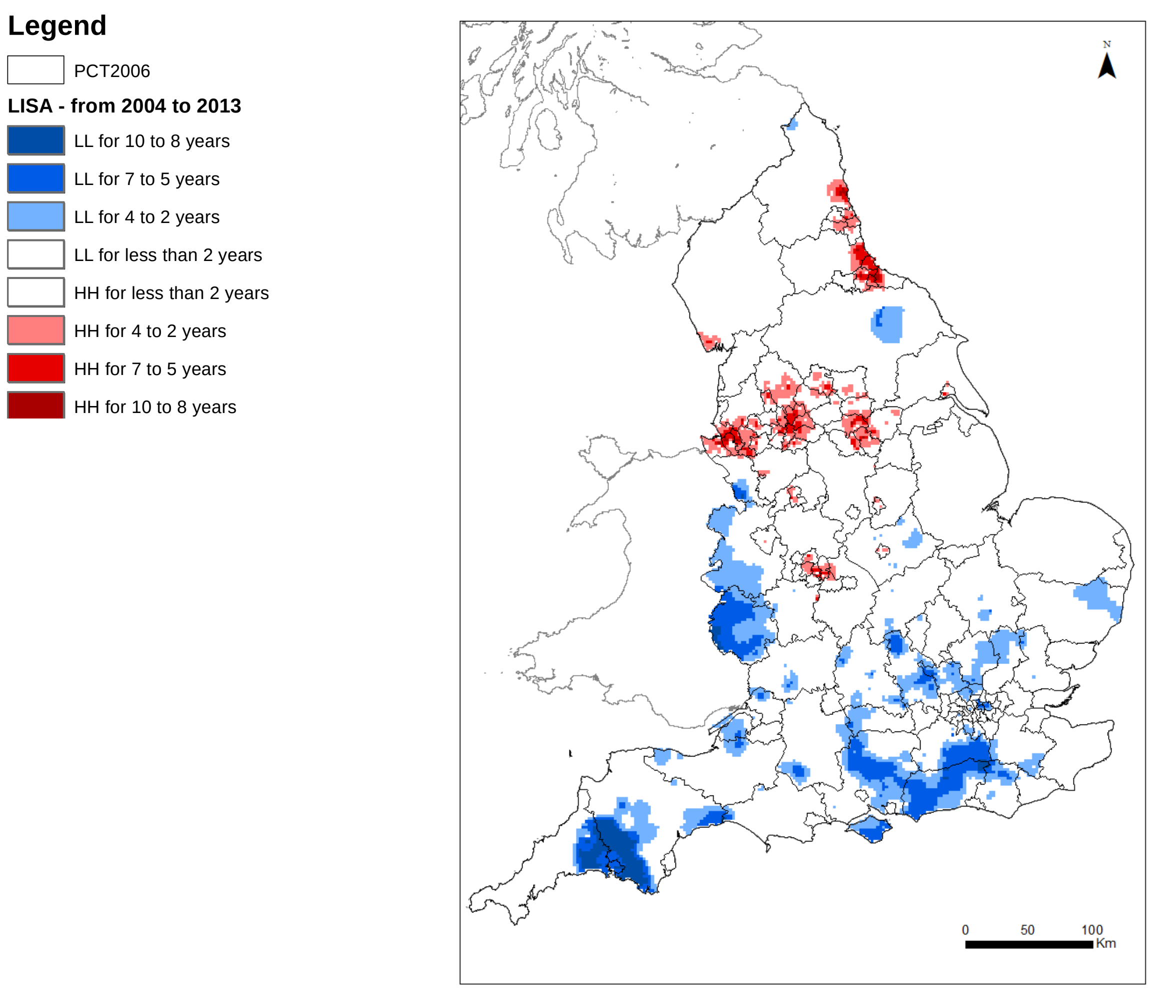
Figure 11: Moran's I LISA significant spatial clusters for ACSCs indirect STD rate for 2004 and 2013



To summarise the stability over time of the significant spatial clusters, we overlay the significant spatial cluster over the 10 years (2004 to 2013). The darker areas in Figure 12 demark the areas that were is a spatial cluster, of high or low values, in at least 8 of the 10 years of analysis. The darker blue areas are found in the South of England. The spatial cluster of low values that was present for at least 8 years and that has the widest area spreads from Cornwall to Plymouth and the South West, and disappeared in 2013. The other two spatial clusters that comprise vast areas are located in Hampshire and Sussex and on the border of the West Midlands and Wales. These two spatial clusters have areas that have been in a spatial cluster for 7 to 5 years and other areas that have been in a spatial cluster for 4 to 2 years. The high values spatial clusters are mainly for areas within a spatial cluster for at least 5 years. The North East coast, Barrow-in-Furness, Liverpool, Greater Manchester, the South Yorkshire area and the West Midlands area (specifically the areas surrounding Birmingham) dominate the high value spatial cluster areas. Comparing to high values spatial clusters of 2013 in

Figure 11, it is noticeable that Scunthorpe (in the North Lincolnshire 2006 PCT) does not appear since this high value spatial cluster of Scunthorpe is only significant in 2013.

Figure 12- Overlay of significant spatial cluster for ACSCs emergency admissions indirect STD rate from 2004 to 2013



The dynamics for acute, chronic, incentivised and non-incentivised ACSCs emergency admissions indirect standardised rate[22] varied between 51% and 68%. The non-incentivised ACSCs emergency admissions had the smaller value of stability for GP practices within the HH spatial cluster and incentivised ACSCs emergency admissions the larger value of stability for the GP practices within the LL spatial cluster.

The overlay of significant cluster for acute and chronic ACSCs emergency admissions indirect standardised rate from 2004 to 2013 was similar to the one presented above but with fewer areas covered by the LL spatial cluster. On the other hand, the overlay of significant cluster for incentivised and non-incentivised ACSCs emergency admissions indirect standardised rate from 2004 to 2013 is more localised, reflecting the wider dynamics between the significant spatial clusters.

[22] Results of the global and local spatial statistics for acute, chronic, incentivised and non-incentivised ACSCs emergency admissions indirect standardised rate can be seen at Appendix 1.5.

1.6. Discussion

The time dynamics of the spatial pattern show that some areas have been affected by high and low ACSCs emergency admissions rates for 10 years. The fact that we do the analysis at GP practice level allows us to understand how heterogeneous the spatial pattern within the Primary Care Trusts is.

Acute and Non-Incentivised ACSCs emergency admissions increased between 2004 and 2013, nevertheless, the increase was not homogenous across England nor within PCTs. After adjusting for the age and gender structure of the GP practice list, the unexplained variation of Acute and Non-incentivised ACSCs emergency admissions shows local clusters of high and low emergency admissions rates. For example, the 2013 Acute ACSCs emergency admissions spatial pattern shows wider variation and more areas with high indirect STD rates, especially in the M63 motorway corridor between Liverpool and Hull. When we take the difference between the 2013 and 2004 spatial pattern, the areas of Greater Manchester and Hull are especially highlighted by the increase in Acute ACSCs emergency admission indirect STD rate. The space-time dynamics map shows that Liverpool, Greater Manchester and the South of Yorkshire have GP practices in the spatial cluster of high Acute ACSCs emergency admissions indirect STD rate for at least five years.

Understanding the space-time dynamics of these particular areas is important since it raises questions about the quality, equity, and efficiency of resource allocation and use. Since we have shown that standardisation by age, gender and deprivation does not elevate variation this raises the question of whether it is due to other factors affecting morbidity or to variations in practices resources, clinical quality or accessibility. This is the question we address in subsequent chapter.

2. Variation in Ambulatory Care Sensitive Conditions emergency admissions, GPs and practice quality.

2.1. Introduction

Ambulatory Care Sensitive Conditions (ACSCs) are conditions which should not result in emergency admissions if managed appropriately in primary care (Purdy et al., 2009). Depending on the conditions included, ACSCs admissions accounted for between 14% and 41% of emergency admissions in 2005/6 (Purdy et al., 2009) and cost the NHS £1.42 billion annually (Tian et al., 2012). ACSC emergency admissions are a signal of inefficient resource use and the considerable variation in rates of practice level ACSC emergency hospital admissions, even after controlling for deprivation, age and gender, may also be an indication of inequity.

We investigate whether there are practice level determinants of ACSC emergency admissions, such as practice staffing, and general practitioners (GP) decisions affecting access, consultation styles, and quality of care. These determinants are amenable to central and local policy, ranging from the level and form of practice resourcing, financial incentives, regulation, targets, and guidelines.

As reported in earlier chapter, some studies reported the increasing trend of ACSCs emergency admissions in England.

The introduction of the Quality and Outcomes Framework (QOF) in 2004 was intended to raise clinical quality, particularly in the prevention of chronic condition and their complications (Roland 2004). Harrison et al. (2014) analysed the time trends, between 2004 and 2011, of ACSC emergency admissions, to understand the impact of the QOF on hospital emergency admissions. The authors analysed the ACSC emergency admissions that were incentivised[23] by the QOF and those that were not and report a clear increase in non-incentivised ACSC emergency admissions (and non- ACSC emergency admissions), and a contrasting decrease in incentivised ACSC emergency admissions. Analysis of the period extending from 5 years before the introduction of the QOF scheme to 7 years after revealed that the emergency admissions rates for all conditions increased by 34% between 1998/99 and 2010/11, while non-incentivised ACSC emergency admissions increased by 39% and non-ACSC emergency admissions rose by 41%. In contrast, incentivised ACSCs decreased by 10%. This decrease is even more impressive given that the rate of emergency admissions for incentivised ACSCS had been increasing by 1.7% per year before the introduction of the QOF scheme. The fact that the trends in incentivised ACSCs fell by 2.7–8% compared with non-incentivised ACSCs, and by 2.8–10.9% compared with non-ACSCs, between the first year of the QOF (2004/5) and 2010/11, suggests that targeting chronic disease groups in primary care can reduce the emergency admission burden on resources and health care costs.

We reported the literature on determinants of ACSCs in earlier chapter (Section 1.1, page 19). However, we will add here a review of the studies that focus on the effects of primary care quality on ACSCs.

Kasteridis et al. (2016) and Goddard, Kasteridis, Jacobs, Santos, and Mason (2016) examined the impact of the introduction of the 2006 QOF indicator for dementia on discharge destination and length of stay for patients admitted for dementia, and on ACSC emergency admissions from 2006/7 to 2010/11, respectively. More precisely, Kasteridis et al. (2016) analysed if patients

[23] Harrison et al. (2014) included in the incentivised ACSCs group disease groups that had clearly been continuously incentivised under the QOF since the introduction of the scheme in 2004, and, as non-incentivised ACSCs, the remaining disease groups that were not targeted under the QOF at any time between 2004/5 and 2010/11.

registered with GP practices that have better QOF indicator scores for the annual dementia review have a smaller likelihood of a care home placement following an acute hospital emergency admission. The major predisposing factors for institutionalisation in a care home were older age, female gender and the need factors of incontinence, fall, hip fracture, cerebrovascular disease, senility and total number of additional comorbidities. Over and above those factors, the dementia QOF review had no significant impact on the likelihood of care home placement for patients whose emergency admission primary diagnosis was dementia, but there was a small negative effect if the emergency admission was for an ACSC, with an odds ratio of 0.998. On the other hand, Goddard et al. (2016) found a significant and negative effect of the Dementia QOF indicator on length of stay among urgent admissions for dementia. Patients discharged to the community had significantly shorter hospital stays if they were cared for by practices that reviewed a higher percentage of their patients with dementia. However, this effect is not significant for patients discharged to care homes or who died in hospital. The authors also report that longer length of stay is associated with a range of comorbidities, markers of low availability of social care and intensive provision of informal care. Dusheiko et al. (2011) explored the association between general practices' quality of diabetic management, given by QOF indicators, and emergency admissions for short-term complications of diabetes between 2004/5 and 2006/07. They reported that practices with better quality of diabetes care had fewer emergency admissions for short-term complications of diabetes. However, they did not find an association with hypoglycaemic admissions. Some studies have also used cross-sectional analysis to assess the impact of the QOF indicators in specific ACSCs. For example, Calderón-Larrañaga et al. (2011) analysed the association between the specific QOF Chronic Obstructive Pulmonary Disease (COPD) indicators and COPD hospital admissions in 2008/9 (the year before the influenza pandemic). The authors reported that smoking prevalence and deprivation were risk factors for admission, while better performance on the QOF indicator for patients with COPD who had received an influenza immunisation, patient satisfaction with ability to book a GP appointment within 2 days and the number of GPs per 1000 patients in the practice were protective factors for COPD admissions. Purdy, Griffin, Salisbury, and Sharp (2011) analysed the early impact of the QOF on angina and myocardial infarction 2006/7 hospital, reporting that although a higher overall clinical QOF score was associated with lower rates of admissions for angina and myocardial infarction, these admissions rates were not associated with the four specific coronary heart disease QOF indicators. The specific QOF indicator is also not significant for heart failure admissions, as reported by Brettell et al. (2013) . The authors use Hospital admissions between 2004/5 and 2011/12 at GP practice level and find that the heart failure are higher for GP practice with higher heart failure and chronic heart disease (CHD) prevalence, more deprived patients and lower for practices with more GP supply and better access (measured by the GP patient survey).

Besides the quality of GP practices there has been a concern with the continuity of care that practices offer to their patients. Barker, Steventon, and Deeny (2017) use the Clinical Practice Research Datalink (CPRD) to analyse the impact of continuity of care on ACSCs admissions for patient between 62 and 82 years from 200 GP practices that had at least 2 GP visits during the study period (2001/12-2012/13). The continuity of care index measures how many times a patient was able to see the same GP, while the number of contacts with a GP was entered separately. The authors report a negative and significant effect of continuity of care and a positive and effect of number of contacts. The effects were larger for the group of patients with more contacts over the two years. Vuik, Fontana, Mayer, and Darzi (2017) also show that patients with chronic ACSCs emergency admissions also had significantly more general practice contacts than patients with a chronic ACSCs disease but without a chronic ACSCs emergency admission.

Given that QOF created incentives for some chronic disease groups, we use Harrison et al. (2014) definition of incentivised and non- incentivised ACSCs admissions to study the factors that explain the variation of ACSCs emergency admissions at GP practice level from 2006/7 to 2011/12.

This chapter makes a contribution to the literature by analysing at GP practice level the determinants of ACSCs emergency admissions, as GP practice characteristics (including number of GPs), clinical quality and patient access. We use a GLM framework to select the best fitting model. The next Section provides a brief description of the methods, while Section 2.3. describes the data, Section 2.4. the results and Section 2.5. concludes.

2.2. Methods

The distribution of the number of ACSCs emergency admissions distribution/functional form is not known a priori, so we used a Generalised Linear Models (GLM) framework to select the distribution and consequently the model which has the best fit.

GLM model specify two components, namely, the distribution of the ACSCs emergency admissions (within the exponential family of distributions) and the link function, which relates the conditional mean of the depend variable (the ACSCs emergency admissions) to a linear function of the explanatory variables, i.e:

$$g\left(E\left(y\,|\,x\right)\right)=g\left(\mu\right)=X\beta \tag{13}$$

ACSCs emergency admission (represented by *y*) follows an exponential family distribution and have mean μ, its expected value is represented by *E(y)*, g is the link function and Xβ is the linear predictor. Equivalently $\mu=E\left(y\,|\,x\right)=g^{-1}\left(X\beta\right)$. We use a log link function when we estimate the GLM model using Poisson, negative binomial or Gamma distribution for ACSCs emergency admissions, and identity link function when using a Gaussian (normal) distribution.

The log link function implies that $\ln\mu=X\beta$ or $\mu=e^{X\beta}$ while the identity link function simplifies to $\mu=X\beta$.

The variance is assumed to be a function of the mean:

$$Var\left(y\right)=E\left(y\right)^{\lambda} \tag{14}$$

where the values of λ (from 0 to 3) specify different distributions, namely when λ=0, it specifies a constant variance, which is the Gaussian distribution. If we specify a Gaussian distribution and an identity link the results should be consistent with the Ordinary Least Squares (OLS), or more precisely with the Maximum Likelihood (ML) estimation of the linear model. If λ=1 the variance is proportional to the mean, which is the Poisson distribution. When we specify a Poisson distribution with a log link, the estimates should be consistent with the ML Poisson model. While if λ=2, the variance is proportional to the square of the mean, which is the Gamma distribution, and if λ=3, the variance is proportional to the cube of the mean, which is the Inverse Gaussian distribution.

We use the Pregibon (1980) link test to examine if the link function was properly specified. The link test is based on the idea that if a model is properly specified, any additional explanatory variables should not be significant. Thus we regress *y* on the prediction from the model and the squared prediction and test if the coefficient of the squared prediction is significantly different from zero.

To test if the distribution function is appropriate, Manning and Mullahy (2001) suggest the modified Park (1966) test, running the regression function that explains the log of the squared residuals as a function of the log predictions, i.e., $\ln\left(y-\hat{\mu}\right)^2=\theta_1+\theta_2\ln\hat{\mu}+error$, where $\hat{\mu}$ are the predictions. If θ_2 is close to zero this suggests use of the normal distribution, θ_2 close to 1 suggests the Poisson, close to 2 the Gamma and to 3 the inverse Gamma.

After comparing alternative GLM specifications (Table 2-3), our preferred model is a Poisson model with fixed effects and an exposure term[24]. This model takes the following form:

$$Ey_{jt}=\exp\left(\beta_0+\sum_t D_{t'}\beta_{t'}+\beta_g g_{jt}+\beta_L L_{jt}+q_{jt}\beta_q+m_{jt}\beta_m+d_{jt}\beta_d+x_{jt}\beta_x+\alpha_j+\varepsilon_{jt}+\ln L_{jt}\right) \quad (15)$$

D_t are the year dummies allowing for unexplained temporal changes, g_{jt} are the practice characteristics including the FTE and type of GPs, L_{jt} is the total number of patients in the practice, q_{jt} are the quality measures of the practice; m_{jt} patient morbidity and need, d_{jt} demographic variables (total list, age and gender groups), x_{jt} other variables, such as distance to A&E departments, α_j is the unobserved practice factors and ε_{jt} unobserved time varying practice factors. The $\ln L_{jt}$ is the logarithm of practice list *j* at time *t*, which coefficient is set to equal 1 so that the model includes an exposure term. α_j is the natural logarithm of an unobserved practice factor (γ_j) which shifts the mean number of admissions multiplicatively.

The marginal effect of an increase in a quality variable q_{ij} on the expected number of ACSCs emergency admissions is

$$\frac{\partial Ey_{jt}}{\partial q_{jt}}=\beta_q\left(\beta_0+\sum_t D_{t'}\beta_{t'}+\beta_g g_{jt}+\beta_L L_{jt}+q_{jt}\beta_q+m_{jt}\beta_m+d_{jt}\beta_d+x_{jt}\beta_x+\alpha_j+\varepsilon_{jt}+\ln L_{jt}\right) \quad (16)$$
$$=\beta_q Ey_{jt}$$

so that the coefficient β_q reported in most of our result tables is the proportionate change in the expected number of ACSCs emergency admissions from a one unit increase in the quality measure.

We also report the average marginal effect of a standard deviation increase, which is:

$$\frac{\partial Ey_{jt}}{\partial q_{jt}}=SD(q)=\beta_q EySD(q)$$

where *Ey* is the mean Ey_{jt} over all practice years observations.

[24] We have also included unconditional GP practice FE in all the GLM models.

2.3. Data

ACSCs emergency admissions. We use the admission method and diagnostic fields in Hospital Episode Statistics (HES) to count the number of emergency ACSCs admissions for each practice (by using the patients' GP practice code as recorded on the HES episodes) in each financial year from 2006/7 to 2011/12, so for example, the 2006 ACSCs emergency admissions are collected from 1st April 2006 to 31st March 2007. Disease management of some ACSCs is incentivised by the Quality and Outcomes Framework (QOF). Examples include diabetes, COPD, asthma, epilepsy, hypertension, CHD, stroke, and mental health. Other ACSCs are not included in the QOF. Examples include anaemia, cellulitis and perforated ulcer. It is plausible that practice decisions have more effect on incentivised ACSCs. First, GPs may respond to the incentives by putting more effort into managing them. Second, the choice of QOF indicators was based on evidence of the extent to which the incentivised indicators could affect ACSC admissions. We therefore distinguish between incentivised and unincentivised ACSCs.[25] We also use separate counts of admissions for some specific large conditions (asthma, congestive heart failure, coronary heart disease (CHD), chronic obstructive pulmonary disease (COPD), epilepsy, and stroke).

GPs. We focus on the effect of the number of full time equivalent (FTE) GPs in a practice.[26] We also control for other GP characteristics. The proportions of GPs trained outside the UK in Europe or outside Europe may affect care for ACSCs, possibly because of language and cultural differences. Since there are gender differences in GP consultation styles, preventive behaviour, and referrals (Jefferson, Bloor, Birks, Hewitt, & Bland, 2013) we include the proportion of female GPs in a practice. The age of the GP is a proxy for experience and investment in keeping their knowledge and skills up to date and we include the average age of GPs in the practice. There has been a recent rise in the proportion of GPs who are salaried. They are paid considerably less than GPs who are partners in their practices and may have different motivation and their efforts in improving patient care and reducing ACSCs may also differ. We therefore include the proportion of salaried GPs. Data on GPs characteristics at GP practice level were collected from the General Medical Services[27] which is based on an annual census collected on 30th September of each year (HSCIC, 2014). We have attributed the data from, for example, 30th September 2006 to the financial year of 2006/7 since the date of the snapshot is exactly in the middle of the financial year.

Clinical quality. We measure the clinical quality of care in the practice with data from the QOF. Since many of the indicators in the QOF are intended to measures activities which should reduce unnecessary hospitalisations, we expect these quality measures to be predictive of ACSC admissions from the practice. Practices receive points according to their performance on QOF indicators, with each point carrying a reward of around £125 for the average practice. But points

[25] Details are in Harrison et al (2014) and in the previous chapter (the list of used ICD10 codes can be found in Appendix 1.2).

[26] It made little difference whether we used the headcount or fte number of GPs since they are highly correlated (0.97 in 2011/12). It also made little difference if we omitted GP registrars (trainee GPs) and GP retainers (GPs who provide service sessions in general practice and are employed by the partnership to undertake set sessions, being allowed to work a maximum of four sessions per week). There is no data on numbers of nurses and other practice staff at practice level for the period we study (2006/7 to 2011/12).

[27] More recently this dataset is known as Workforce minimum dataset

earned are not a good measure of quality of care for ACSCs. First, some of the organisational indicators relate to care for the whole practice list. Second, even when the indicator is for an ACSC, the number of points awarded does not increase once performance is beyond an upper threshold. Third, it has been suggested that some practices game their scores by exception reporting patients for whom it would be difficult to achieve a clinical indicator (Doran , Fullwood , Reeves , Gravelle , & Roland 2008; Gravelle, Sutton, & Ma, 2010). We therefore measure performance on an indicator as the percentage of patients with the relevant condition for whom the indicator has been achieved. The population achievement, the clinical quality indicator, for each condition, is the average of the percentage scores on indicators for that condition, weighted by the maximum points achievable for each indicator. We measure overall clinical quality as a maximum points weighted average of the condition clinical scores (for more information see Appendix 2.1.). In 2006/7 the number of conditions where there were financial incentives for care (rather than just having a register) increased from 11 to 15, and there were changes to thresholds and points. The structure of the QOF was reasonably stable thereafter, apart from the abolition of the square root adjustment in the practice disease prevalence factor in 2009/10. After 2009/10 the payment increases linearly until the indicator threshold, after which the practice earns the total payment. QOF data is collected by NHS digital for each financial year, so for example for 2006/7, the data is collected between 1st April 2006 and 31st March 2007.

Patient reported access. We use responses to the General Practice Patient Survey (GPPS) to construct patient reported quality measures. The first (*urgent appointments*) is the proportion of patients answering yes to “Were you able to see a doctor on same day or in the next two days the GP surgery or health centre was open?”. The second (*advance appointments*) is the proportion answering yes to “Last time you tried to, were you able to get an appointment with a doctor more than 2 full days in advance?". We interpret these as measures of access to primary care. We use responses to the General Practice Patient Survey (GPPS)[28] to construct patient reported quality measures. We used the dates of the fieldwork, i.e., the time frame in which the survey was collected, to attribute the survey results to that financial year (please see Appendix 2.2 for more details). Whilst the fieldwork is almost continuous along the financial years from 2009 onwards, for 2006, 2007 and 2008 the fieldwork was only taken from January to March. Since those are winter months, known for an increased demand for primary and secondary care, we anticipate that patients will be less satisfied with their ability to book appointments. However, the same could be said for the summer months when most people take holiday breaks and the hot weather might have an impact on chronic diseases such as, for example, asthma and COPD. Therefore, we expect that a bias on the reported satisfaction with the ability to book advance and urgent appointments is small or non-existent.

The year dummies included in models will also pick up some of the effects of changes in the timing of the GPPS.*Needs variables*.

Education, skills and training deprivation score from the index of multiple deprivation (IMD)[29], measures the lack of attainment and skills in the local population. The indicators fall into two sub-

[28] We used the weighted GPPS responses available at https://gp-patient.co.uk/.

[29] More information on the index of multiple deprivation can be found at

https://www.gov.uk/government/collections/english-indices-of-deprivation and domains designed to reflect the 'flow' and 'stock' of educational disadvantage within an area respectively. While one is related to children and young people the other is related to adult skills. We attribute this to the practice as weighted average of the proportions in the LSOAs of the practice list, where the weights are the share of the list residing in each LSOA available in the Attribution Data Set (ADS). IMD was published on 30th September 2004, 2007 and 2010, mainly using data from 2001, 2005 and 2008 respectively. On the other hand, ADS is collected every year in April. Therefore, for example, I attribute the 2004 IMD using 2006 ADS to have a GP practice IMD 2006 based on its patient list for education, skills and training deprivation (for more information see Appendix 2.3).

Incapacity benefits, also known as Disability Living Allowance (DLA), are measured using data provided by the ONS on the proportion of LSOA populations who are receiving incapacity benefit in each year. We use the same attribution strategy as above, attributing to the practice a weighted average of the proportions in the LSOAs of the practice list, where the weights are the share of the practice list resident in each LSOA. A quarterly snapshot of the DLA data is collected in the end of February, May, August and November. Since we wanted to attribute the data to the financial year, we used the August snapshot of each year, for example we attribute the data from August 2006 to the financial year of 2006/7.

Nursing home residents per GP practice are available from NHS Digital. We use the number of practice patients who are in a nursing home since they may be sicker than patients living in their own home. The data for the list of patients registered in nursing homes is extracted yearly on 30th September, so we have attributed the data from, for example, 30th September 2006 to the financial year of 2006/7 since the date of the snapshot is exactly in the middle of the financial year.

Morbidity. We measure morbidity using QOF data on condition prevalence, which is the number of practice patients with each of 17 chronic health conditions. These 17 chronic health conditions have been included and maintained in the QOF at least from 2006/7 to 2011/12. Not all the categories are for patients with ACSCs (eg patients who are obese, and patients receiving palliative care) but most are. Practices with a higher register of, for example, hypertension, might have a higher rate of ACSCs emergency admissions since higher proportion of the practice list is at risk one, or might have a smaller rate of ACSCs emergency admissions because they are specialised on the management of the population with that health conditions.

Geographical factors. We use dummy variables for the ONS urban/rurality classification. These will pick up both unobserved need and prevalence if they differs systematically with rurality and may measure, albeit crudely differences in distance to practices and to hospitals. We also constructed measures of the straight line distance between the centroids of patients' LSOAs of residence and their practice. It is plausible that patients will visit their GP more frequently, and hence receive better care, if they live nearer to their practice. The GP practice surgeries locations were collected from NHS choices, QOF and NHS Technology Reference data Update Distribution (TRUD). We also use the distance from the practice to the nearest A&E which may influence the probability that the patient will use an A&E rather than their practice when seeking attention for

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http://webarchive.nationalarchives.gov.uk/20100411141238/http://www.communities.gov.uk/communities/neighbourhoodrenewal/deprivation/deprivation07/

minor conditions. Since ACSC conditions are better cared for in general practice rather than A&E such patients will receive poorer care for ACSCs and so run a higher risk of a future hospital admissions for complications. However, the distance between GP practices and hospitals does not vary over time, while the weighted distance between GP practices and centroids of patients' LSOAs will vary since there are annual changes to the proportion of patients living in the different LSOAs within GP practice catchment area.

We constructed a panel data from 2006/7 to 2011/12 for 7982 English GP practices, after dropping small GP practices (with less than 1000 patients) and GP practices that have a variation of more than two standard deviations on the FTE GPs since these GP practices might have a structural change, which is exogenous to what we want to analyse.

2.4. Results

Table 2-1 reports the descriptive statistics for the 7982 GP practices over the six years period, 2006 to 2011, of analysis[30]. A GP practice has on average 83 ACSCs emergency admission per year, of those 58 are for QOF incentivised conditions and 25 for non-incentivised conditions. From the six specific incentivised conditions we explore, the disease group with more emergency admissions per practice is Chronic Obstructive Pulmonary Disease (COPD), while Diabetes has the smallest number of emergency admissions. A GP practice has on average 4 FTE GPs and 39% of its GP workforce is female. The average GP age is 49 and 31% qualified outside the UK. The quality indicators have high means, with an average clinical quality of 79 (out of 100) and the proportion of patients satisfied with the ability to book urgent and advance appointments is 0.83 and 0.74, respectively.

[30] From the 65564 observations, for over 13000 different GP practice identifiers, we have dropped observations due to lack of information on quality or GP practice characteristics (16652 observations), small GP practices with less than 1000 patients (76 observations) and GP practices with a variation of of more than two standard deviations on the FTE GPs (797 observations).

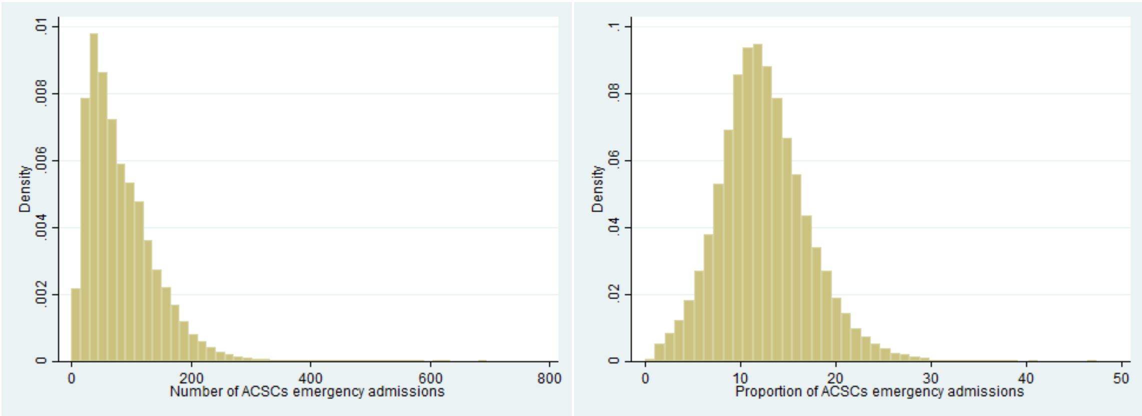
Table 2-1: Descriptive statistics

Variables	Average	Median	Standard Deviation	2006	2011	Growth rate
ACSCs emergency admissions (number)						
All ACSCs	83.555	70	57.535	88.734	101.139	13.98%
Incentivised ACSCs	58.445	49	41.322	59.075	59.824	1.27%
Non Incentivised ACSCs	25.109	21	17.810	23.104	27.456	18.83%
Specific ACSCs disease groups						
Chronic Obstructive Pulmonary Disease (COPD)	12.495	9	11.526	12.351	12.902	4.46%
Asthma	7.133	6	6.233	7.799	6.417	-17.72%
Stroke	8.169	6	6.777	7.768	9.008	15.96%
Diabetes	2.810	2	2.985	2.816	2.774	-1.52%
Diabetes hyperglycaemic	1.489	1	2.071	1.691	1.322	-21.81%
Diabetes hypoglycaemic	1.321	1	1.641	1.126	1.452	28.97%
Epilepsy	4.247	3	4.282	4.139	4.388	6.02%
Cardiovascular	7.990	6	6.662	7.819	8.540	9.22%
GP practice workforce factors						
FTE GPs	4.243	3.63	2.939	4.136	4.388	6.11%
Proportion of female GPs	0.386	0.4	0.266	0.362	0.413	14.26%
Average GP age	48.669	47.167	7.179	48.557	48.626	0.14%
Proportion of GPs qualified in the UK	0.687	0.833	0.376	0.687	0.689	0.20%
Proportion of GPs qualified in the EU	0.048	0	0.134	0.048	0.048	0.28%
Proportion of GPs qualified outside the EU	0.265	0	0.370	0.265	0.263	-0.58%
Proportion of salaried GPs	0.168	0	0.225	0.125	0.193	54.37%
GP practice quality indicators						
Patient reported access:						
urgent appointments	0.835	0.855	0.108	0.853	0.850	-0.42%
advance appointments	0.743	0.765	0.158	0.747	0.759	1.68%
Clinical quality:						
Population achievement	0.797	0.808	0.063	0.804	0.797	-0.85%
Disease specific population achievement:						
Chronic Heart Disease (CHD)	0.819	0.824	0.049	0.818	0.781	-0.046
Chronic Obstructive Pulmonary Disease (COPD)	0.801	0.814	0.093	0.820	0.790	-0.037
Asthma	0.789	0.794	0.084	0.755	0.798	0.056
Stroke	0.815	0.820	0.058	0.799	0.814	0.019
Epilepsy	0.779	0.794	0.101	0.789	0.708	-0.102
Diabetes	0.771	0.775	0.051	0.779	0.765	-0.018
Atrial Fibrillation	0.889	0.904	0.083	0.840	0.911	0.085
Hypertension – Blood pressure	0.796	0.798	0.057	0.788	0.799	0.014
Smoking	0.935	0.940	0.036	0.935	0.936	0.002
Heart Failure	0.793	0.796	0.114	0.806	0.768	-0.048
Mental Health	0.788	0.804	0.114	0.759	0.775	0.021

Note: Descriptive statistics for GP practice urbanicity, QOF disease registers, demographic, geographic and socioeconomic factors are in Appendix 2in Table A.11. The unbalanced panel includes 7982 GP practices and 46314 observations.

The ACSCs emergency admission does not follow a known distribution. Figure 13 shows that the distribution of the number of ACSCs emergency admissions and the proportion of ACSCs emergency admissions per 1000 patients are right skewed with practices with very high number or rates of ACSCs emergency admissions.

Figure 13- Distribution of proportion of ACSCs emergency admissions



To understand which model specification fitted better to the ACSCs emergency admissions, we used the link and park test. The tests rejects all the specifications, however, the Park test indicates that Poisson model is the best fit, with the log of ACSCs emergency admissions prediction coefficient near one. The normal probability plot of the deviance residuals also indicate the Poisson model is the best fit with the normal probability plot of the deviance residuals displayed in a straight line overlaying the theoretical normal distribution.

Table 2-2: GLM: Link and Park test

All ACSCs emergency admissions	Number of	Number of	Number of	Proportion	Number of
Family:	Poisson	Gamma	Negative Binomial	Gaussian	Mundlak Poisson
Link:	Log	Log	Log	Identity	Log
AIC	371309	481989	482878	202648	552578
BIC	371685	482373	483272	203024	553347
Link test:					
Hat square z-stat	292.66	290.54	290.60	1.25	164.39
	(0.00)	(0.00)	(0.00)	(0.212)	(0.00)
Park test					
Ln of ACSCs emergency admissions prediction coefficient (lnpred)	1.1678	1.274	1.271	4.573	1.723
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
test lnpred=0 - Gaussian	3949.13	13413.72	13243.35	896.87	906.14
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
test lnpred=1 - Poisson	81.54	620.67	604.62	547.52	159.60
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
test lnpred=2 - Gamma	2005.49	4354.80	4343.05	283.94	23.39
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
test lnpred=3 - Inverse Gaussian	9721.01	24616.10	24458.64	106.13	497.51
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Note: The tests refer to the models presented Table 2-3. Standard errors in parentheses. * p<0.10, **p<0.05 and *** p<0.001.

Figure 14 displays the normal probability plot of the deviance residuals. The normal probability plot is a graphical technique for assess visually if the deviance residuals are approximately normally distributed. The deviance residuals are plotted against a theoretical normal distribution in such a way that the points should form an approximate straight line.

Deviance residuals were calculated as $r_j^D = sign(y_j - \hat{\mu}_j)\sqrt{d_j^2}$ where the sign function will be positive, if the difference between the ACSCs emergency admissions of observation *j* and the predicted value of ACSCs emergency admissions of observation *j* is greater than zero and negative if it is less than zero. $\sqrt{d_j^2}$ is the squared deviance residual, which, for example, for the Poisson family is :

$$d_j^2 = \begin{cases} 2\hat{\mu}_j & if\ y_j = 0 \\ 2\{y_j \ln(y_j / \hat{\mu}_j) \text{-} (y_j \text{-} \hat{\mu}_j)\} & \text{otherwise} \end{cases}$$

This measure is recommended by McCullagh and Nelder (1989) since it has the best properties for examining the goodness of fit of a GLM. Since when the model is correct, the deviance residuals are approximately normally distributed, the best fitted model will be the one for which normal probability plot of the deviance residuals against a theoretical normal distribution is a straight line. From the five plots displayed below in Figure 14 the Poisson model shows the best fit with the normal probability plot of the deviance residuals displayed in a straight line overlaying the theoretical normal distribution.

Figure 14 - Normal plots for the five GLM models

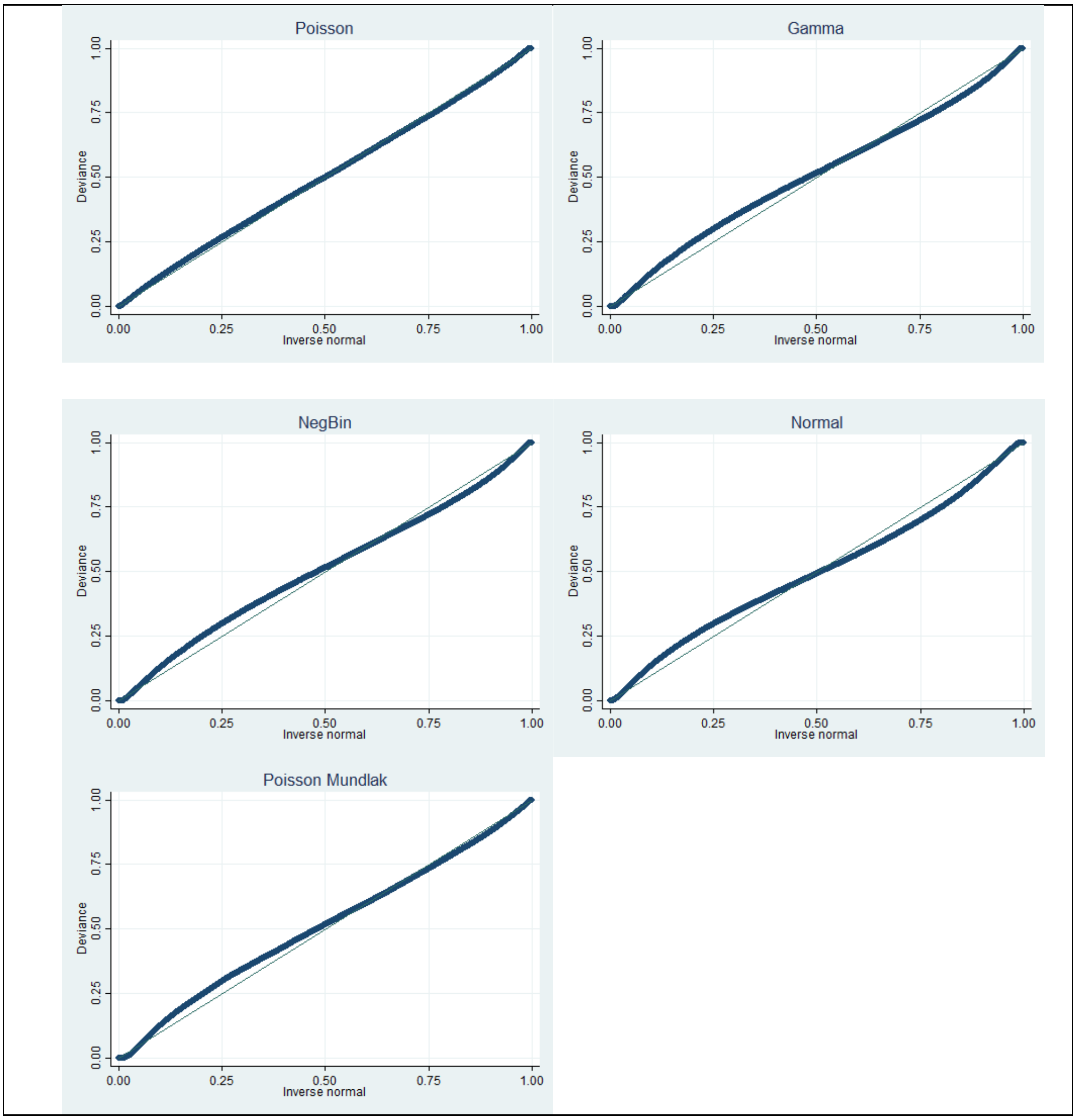


Table 2-3 summarises the results of the model described above using the GLM framework. We estimated five different models using the number and proportion of ACSCs emergency and the coefficients on FTE GPs and quality variables are similar.

We also estimated alternative methods of allowing for time invariant practice factors by models with fixed effects, random effects and the means of the varying variables (Mundlak, 1978). The results in Appendix 2 (

Table A. 14) strongly suggests that fixed effects specification is preferred to random effects (Hausman test Chi2 (28)=1010.15, p-value<0.000). The Mundlak model has very similar explanatory effects to the fixed effects model but the latest has a better fit according to the information criteria.

Table 2-3: GLM results: All ACSCs emergency admissions

All ACSCs emergency admissions	Number of	Number of	Number of	Proportion	Number of
Family:	Poisson	Gamma	Negative Binomial	Gaussian	Mundlak Poisson
Link:	Log	Log	Log	Identity	Log
Practice list exposure term	Yes	Yes	Yes	No	Yes
FTE GPs	-0.00242*	-0.00284*	-0.00284*	-0.0177	-0.00265**
	(0.00127)	(0.00156)	(0.00155)	(0.01683)	(0.00129)
Proportion of female GPs	0.00431	0.0269**	0.0263**	0.305**	0.00524
	(0.01164)	(0.01258)	(0.01250)	(0.15273)	(0.01163)
Average GP age	-0.00269	0.000204	0.000169	-0.00170	-0.00305
	(0.00316)	(0.00364)	(0.00361)	(0.04287)	(0.00316)
Proportion of EU GPs	-0.00535	-0.00217	-0.00233	-0.0331	-0.0120
	(0.02161)	(0.02340)	(0.02325)	(0.29283)	(0.02172)
Proportion of Non-EU GPs	0.0179	0.0152	0.0150	0.158	0.0183
	(0.01316)	(0.01538)	(0.01525)	(0.18674)	(0.01324)
Proportion of salaried GPs	0.00534	0.00437	0.00442	0.00972	0.00593
	(0.00976)	(0.01091)	(0.01083)	(0.13076)	(0.00978)
Population achievement	-0.0695**	-0.0800**	-0.0790**	-0.704**	-0.0697**
	(0.022)	(0.031)	(0.031)	(0.314)	(0.022)
Urgent appointments	-0.110***	-0.129***	-0.129***	-1.290***	-0.112***
	(0.01836)	(0.02301)	(0.02273)	(0.25079)	(0.01834)
Advance appointments	-0.0245*	-0.0292*	-0.0292**	-0.436**	-0.0269**
	(0.01312)	(0.01498)	(0.01486)	(0.17961)	(0.01322)
AIC	371309	481989	482878	202648	552578
BIC	371685	482373	483272	203024	553347

Note: The models also include the GP practice demographic variables, workforce factors, socioeconomic factors and disease registers, the weighted distance of patients' neighbourhood to the nearest GP practice surgery and year dummies. There were 46314 observations of the 7982 GP practices between 2006 and 2011. Standard errors in parentheses. * p<0.10, **p<0.05 and *** p<0.001.

When we estimate the Poisson panel data model with fixed effects for all, incentivised and non-incentivised ACSCs emergency admissions, the coefficient on FTE GPs and quality measures that were significant for all ACSCs emergency admissions are higher and significant for incentivised ACSCs emergency admissions (Table 2-4). The quality indicators are also significant for the non-incentivised, however, the coefficients are smaller than for all or for the incentivised ACSCs emergency admissions. The satisfaction with ability to book advance appointments is significant for all and non-incentivised ACSCs emergency admissions but not for incentivised ACSCs emergency admissions[31].

[31] *We estimated two additional models for all emergency admissions and non-ACSCs emergency admission and results are reported in in Table A.11 of Appendix 2.2. As expected, GP practices with higher quality have fewer emergency admissions and non-ACSCs emergency admissions. While the population achievement has a higher impact on all emergency admissions and non-ACSCs emergency admissions, the patient satisfaction for advance and urgent appointments has a higher impact on all ACSCs, incentivised and non-incentivised ACSCs emergency admissions.*

Table 2-4: Baseline model for all, incentivised and non-incentivised ACSCs emergency admissions

	ACSCs emergency admissions		Incentivised ACSCs emergency admissions		Non-incentivised ACSCs emergency admissions	
FTE GPs	-0.00242*	(0.0013)	-0.00324**	(0.0014)	-0.000587	(0.0017)
Proportion of female GPs	0.00431	(0.0116)	0.00514	(0.0129)	0.00307	(0.0155)
Average GP age	-0.00269	(0.0032)	-0.000856	(0.0037)	-0.00735*	(0.0043)
Proportion of EU GPs	-0.00534	(0.0216)	-0.0101	(0.0244)	0.00525	(0.0299)
Proportion of Non-EU GPs	0.0179	(0.0132)	0.0177	(0.0149)	0.0189	(0.0178)
Proportion of salaried GPs	0.00534	(0.0098)	0.00485	(0.011)	0.00520	(0.0138)
Population achievement	-0.0695**	(0.0002)	-0.0764**	(0.0003)	-0.0577*	(0.0003)
Urgent appointments	-0.110***	(0.0184)	-0.122***	(0.0208)	-0.0835***	(0.0249)
Advance appointments	-0.0245*	(0.0131)	-0.0103	(0.0147)	-0.0565**	(0.0176)
AIC	309213		287554		227477	
BIC	309589		287930		227853	

Note: The Poisson panel data models also include the GP practice demographic variables, workforce factors, socioeconomic factors and disease registers, the weighted distance of patients' neighbourhood to the nearest GP practice surgery, year dummies and practice list exposure list. There were 46314 observations of the 7982 GP practices between 2006 and 2011. Standard errors in parentheses. * p<0.10, **p<0.05 and *** p<0.001.

We present in Table 2-5 the results of our baseline model when we use eleven disease specific population achievements[32]. Diabetes and smoking population achievements are the two (out of eleven) significant and negative disease specific population achievements. The Diabetes population achievement coefficient is higher for non-incentivised ACSCs emergency admissions even that Diabetes is an incentivised ACSCs emergency admission.

[32] From the 17 specific disease groups that were included in the QOF from 2006 to 2011 we only include population achievement measures for the 11 that are likely related to the ACSCs specific disease emergency admissions. Therefore we excluded cancer, hypothyroidism, dementia and depression because there is not a direct link to the ACSCs specific disease emergency admissions and obesity and palliative care because the only clinical QOF indicator is having a register.

Table 2-5: Baseline model with disease specific population achievements

	ACSCs emergency admissions		Incentivised ACSCs emergency admissions		Non-incentivised ACSCs emergency admissions	
FTE GPs	-0.00234*	(0.0013)	-0.00315**	(0.0014)	-0.000543	(0.0017)
Proportion of female GPs	0.00425	(0.0116)	0.00517	(0.0129)	0.00280	(0.0155)
Average GP age	-0.00277	(0.00326)	-0.000923	(0.0037)	-0.00748*	(0.0043)
Proportion of EU GPs	-0.00690	(0.0217)	-0.0120	(0.0245)	0.00444	(0.0300)
Proportion of Non-EU GPs	0.0170	(0.0131)	0.0165	(0.0149)	0.0186	(0.0178)
Proportion of salaried GPs	0.00615	(0.0098)	0.00564	(0.011)	0.00607	(0.0138)
CHD PA	0.0297	(0.0434)	0.0315	(0.0506)	0.0227	(0.0582)
COPD PA	-0.0285	(0.0189)	-0.0463**	(0.0221)	0.0137	(0.0271)
Asthma PA	-0.0165	(0.0197)	-0.0141	(0.0224)	-0.0228	(0.0276)
Stroke PA	-0.0160	(0.0364)	-0.0433	(0.0417)	0.0448	(0.0499)
Epilepsy PA	-0.00922	(0.0172)	-0.00263	(0.0197)	-0.0258	(0.0239)
Diabetes PA	-0.174***	(0.0494)	-0.167**	(0.0561)	-0.185**	(0.0665)
Atrial Fibrillation PA	0.00611	(0.0176)	0.00792	(0.0202)	0.00180	(0.0255)
Hypertension – Blood pressure PA	-0.0321	(0.0386)	-0.0167	(0.0441)	-0.0680	(0.0536)
Smoking PA	-0.0700*	(0.0401)	-0.0573	(0.0466)	-0.0945*	(0.0555)
Heart Failure PA	0.0264*	(0.0143)	0.0301*	(0.0166)	0.0199	(0.0203)
Mental Health PA	0.00302	(0.0144)	0.0113	(0.0165)	-0.0153	(0.0203)
Urgent appointments	-0.108***	(0.0184)	-0.119***	(0.0207)	-0.0809**	(0.0249)
Advance appointments	-0.0237*	(0.0131)	-0.00969	(0.0147)	-0.0551**	(0.0176)
AIC	309127.395		287500.18		227453.16	
BIC	309590.785		287963.57		227916.55	

Note: The Poisson panel data models also include the GP practice demographic variables, workforce factors, socioeconomic factors and disease registers, the weighted distance of patients' neighbourhood to the nearest GP practice surgery, year dummies and practice list exposure list. There were 46314 observations of the 7982 GP practices between 2006 and 2011. Standard errors in parentheses. * p<0.10, **p<0.05 and *** p<0.001.

Table 2-6 has results for the baseline model for the number of specific disease ACSCs emergency admissions models the results are slightly different. The FTE GPs significantly decrease Stroke and Diabetes hypoglycaemic ACSCs emergency admissions, while the QOF clinical quality is negative and significantly associated with COPD, Asthma, Stroke and Epilepsy ACSCs emergency admissions. However, population achievement is positive and significantly associated with ACSCs diabetes hypoglycaemic emergency admissions. This may be because practices are incentivised to reduce blood sugar levels which means the risk of hypoglycaemia.

Table 2-6: Specific disease ACSCs emergency admissions models

	COPD	Asthma	Stroke	Diabetes	Diabetes hyperg	Diabetes hypog	Epilepsy	Cardiovascular
FTE GPs	-0.00240	-0.00195	-0.00847***	-0.00453	0.00308	-0.0120**	-0.00694*	-0.00156
	(0.00295)	(0.00310)	(0.00249)	(0.00476)	(0.00697)	(0.00586)	(0.00395)	(0.00276)
Proportion of female GPs	-0.0205	0.0170	-0.00274	-0.0219	-0.0743	0.0527	0.00367	-0.0133
	(0.02550)	(0.02868)	(0.02270)	(0.04383)	(0.06367)	(0.05438)	(0.03903)	(0.02607)
Average GP age	0.00152	-0.00767	0.00214	-0.00695	-0.0109	-0.00159	0.0204*	0.00172
	(0.00743)	(0.00820)	(0.00676)	(0.01225)	(0.01753)	(0.01553)	(0.01153)	(0.00730)
Proportion of EU GPs	0.0233	-0.0803	0.00162	-0.0945	-0.204*	0.0322	0.0489	-0.0260
	(0.04814)	(0.05634)	(0.04582)	(0.08269)	(0.11408)	(0.10640)	(0.07007)	(0.04941)
Proportion of Non-EU GPs	0.0120	-0.000350	0.0312	0.0355	-0.0638	0.145**	0.0274	0.0439
	(0.02761)	(0.03125)	(0.02633)	(0.04827)	(0.07173)	(0.05860)	(0.04376)	(0.03005)
Proportion of salaried GPs	0.0247	-0.0299	0.0348*	-0.0190	0.0410	-0.0996**	0.00610	-0.00379
	(0.02273)	(0.02520)	(0.02025)	(0.03808)	(0.05484)	(0.04781)	(0.03469)	(0.02200)
Population achievement	-0.111**	-0.113*	-0.0977**	0.0180	-0.162	0.215*	-0.143*	0.0568
	(0.05383)	(0.06127)	(0.04804)	(0.09632)	(0.15049)	(0.12015)	(0.07926)	(0.06440)
Urgent appointment	-0.169***	-0.156***	-0.0435	-0.0805	-0.236**	0.0780	-0.0523	-0.138**
	(0.04123)	(0.04727)	(0.03692)	(0.06948)	(0.10020)	(0.08921)	(0.06076)	(0.04227)
A advance appointment	0.0196	-0.0649*	0.0376	-0.0199	0.0254	-0.0796	-0.00725	-0.0309
	(0.02957)	(0.03359)	(0.02555)	(0.04960)	(0.07358)	(0.06222)	(0.04459)	(0.02866)
N practice	7965	7972	7968	7887	7577	7563	7921	7968
Observations	46237	46266	46259	45848	44170	44074	46015	46271
AIC	207958.06	173401.14	170085.91	127266.90	95898.915	88893.52	151375.73	173898.04
BIC	208333.94	173777.05	170461.81	127642.43	96272.83	89267.35	151751.41	174273.96

Note: The Poisson panel data models also include the GP practice demographic, workforce, socioeconomic and disease registers variables, the weighted distance of patients' neighbourhood to the nearest GP practice surgery, year dummies and practice list exposure list. The number of GP practices and observations vary across the models because some GP practices have zero specific ACSCs emergency admissions for all the years. SE in parentheses. * p<0.10, **p<0.05 and *** p<0.001.

Table 2-7 reports the results for the models for ACSCs specific disease conditions emergency admissions when we use the disease specific population achievement. Diabetes population achievement influences negatively and significantly Asthma, Stroke, diabetes hyperglycaemic and cardiovascular ACSCs emergency admissions, however, it also has a positive and significant influence on Diabetes hypoglycaemic ACSCs emergency admissions. Dusheiko et al. (2011) reported a negative and significant association between the QOF diabetes indicators and Acute and nonspecific hyperglycaemic emergency admissions and no significant association between the same indicators and hypoglycaemic emergency admissions.

Table 2-7: Specific ACSCs disease emergency admissions models with all the specific population achievements

	COPD	Asthma	Stroke	Diabetes	Diabetes hyperglycaemic	Diabetes hypoglycaemic	Epilepsy	Cardiovascular
FTE GPs	-0.00217	-0.00192	-0.00836***	-0.00448	0.00328	-0.0122**	-0.00669*	-0.00166
	(0.00296)	(0.00310)	(0.00249)	(0.00475)	(0.00696)	(0.00587)	(0.00394)	(0.00276)
Proportion of female GPs	-0.0203	0.0163	-0.00268	-0.0221	-0.0759	0.0527	0.00779	-0.0139
	(0.02545)	(0.02875)	(0.02269)	(0.04387)	(0.06384)	(0.05437)	(0.03890)	(0.02601)
Average GP age	0.00147	-0.00770	0.00202	-0.00700	-0.0109	-0.00148	0.0195*	0.00158
	(0.00744)	(0.00820)	(0.00676)	(0.01223)	(0.01742)	(0.01552)	(0.01153)	(0.00729)
Proportion of GPs qualified in the EU	0.0205	-0.0796	-0.000584	-0.0915	-0.204*	0.0385	0.0465	-0.0281
	(0.04816)	(0.05636)	(0.04593)	(0.08266)	(0.11405)	(0.10607)	(0.07082)	(0.04941)
Proportion of GPs qualified outside the EU	0.0113	-0.000246	0.0300	0.0378	-0.0631	0.150**	0.0255	0.0426
	(0.02763)	(0.03122)	(0.02638)	(0.04822)	(0.07167)	(0.05847)	(0.04373)	(0.03004)
Proportion of salaried GPs	0.0249	-0.0287	0.0360*	-0.0188	0.0415	-0.101**	0.00691	-0.00320
	(0.02273)	(0.02523)	(0.02026)	(0.03807)	(0.05476)	(0.04787)	(0.03473)	(0.02202)
CHD PA	-0.00180	0.135	0.0477	0.137	0.335	-0.0967	0.159	0.116
	(0.10459)	(0.11550)	(0.09813)	(0.16777)	(0.24240)	(0.23358)	(0.14997)	(0.10529)
COPD PA	-0.201***	0.0665	-0.0182	0.0788	0.00560	0.154	-0.0454	-0.0262
	(0.04661)	(0.04998)	(0.04290)	(0.07769)	(0.10976)	(0.10589)	(0.06839)	(0.04732)
Asthma PA	0.0361	-0.0638	-0.0199	-0.0817	-0.0642	-0.109	0.0828	-0.00256
	(0.04674)	(0.05164)	(0.04204)	(0.07846)	(0.11225)	(0.10228)	(0.07082)	(0.04603)
Stroke PA	-0.0945	0.00596	-0.0685	0.00147	-0.0325	0.0553	-0.156	-0.0548
	(0.08823)	(0.09168)	(0.08255)	(0.14134)	(0.19990)	(0.19119)	(0.13200)	(0.08990)

Epilepsy PA	0.00979	0.0521	0.0103	0.126*	0.233**	0.0300	-0.432***	0.0140
	(0.04090)	(0.04539)	(0.03815)	(0.07214)	(0.10530)	(0.09026)	(0.06549)	(0.04137)
Diabetes PA	0.0461	-0.316**	-0.258**	-0.208	-0.719**	0.344	0.0444	-0.238**
	(0.11578)	(0.12312)	(0.10178)	(0.19747)	(0.27861)	(0.25194)	(0.16900)	(0.11449)
Atrial Fibrillation PA	0.0390	-0.0276	0.0428	-0.0286	-0.0199	-0.0528	0.0487	-0.0297
	(0.04204)	(0.04292)	(0.04341)	(0.06858)	(0.09644)	(0.09607)	(0.06649)	(0.04604)
Hypertension – Blood pressure PA	0.0217	-0.0107	0.0184	0.174	-0.0595	0.402*	-0.0644	-0.107
	(0.08895)	(0.10222)	(0.08353)	(0.15987)	(0.23295)	(0.20627)	(0.13971)	(0.08987)
Smoking PA	-0.0886	-0.0491	-0.160*	-0.298*	-0.237	-0.389*	0.00753	-0.0137
	(0.09710)	(0.10720)	(0.09223)	(0.16062)	(0.24129)	(0.20836)	(0.14619)	(0.09629)
Heart Failure PA	-0.00631	-0.0176	0.0197	0.154**	0.204**	0.105	0.0775	0.0560
	(0.03510)	(0.03693)	(0.03229)	(0.05914)	(0.08211)	(0.08007)	(0.05266)	(0.03479)
Mental Health PA	0.0280	-0.0280	0.0292	-0.0887	-0.174**	0.00253	0.0626	-0.0132
	(0.03253)	(0.03780)	(0.02992)	(0.05598)	(0.08084)	(0.07743)	(0.05189)	(0.03372)
Urgent appointment	-0.166***	-0.156***	-0.0413	-0.0811	-0.231**	0.0747	-0.0465	-0.134**
	(0.04121)	(0.04732)	(0.03689)	(0.06939)	(0.09999)	(0.08915)	(0.06074)	(0.04222)
Advance appointment	0.0179	-0.0649*	0.0377	-0.0182	0.0316	-0.0827	-0.00666	-0.0264
	(0.02960)	(0.03361)	(0.02558)	(0.04962)	(0.07327)	(0.06228)	(0.04468)	(0.02861)
N practice	7965	7972	7968	7887	7577	7563	7921	7968
Observations	46237	46266	46259	45848	44170	44074	46015	46271
AIC	207929.41	173401.67	170088.45	127256.08	95872.67	88895.7	151294.73	173896.22
BIC	208392.71	173865.00	170551.78	127718.93	96333.55	89356.46	151757.77	174359.56

Note: The Poisson panel data models also include the GP practice demographic variables, workforce factors, socioeconomic factors and disease registers, the weighted distance of patients' neighbourhood to the nearest GP practice surgery, year dummies and practice list exposure list. The number of GP practices and observations vary across the models because some GP practices have zero specific ACSCs emergency admissions for all the years. Standard errors in parentheses. * p<0.10, **p<0.05 and *** p<0.001.

Using the coefficients of our baseline model in Table 2-4, we present in Table 2-8 the change in number of admissions (marginal effects) from a standard deviation increase in quality $\left(\beta_q EySD_q\right)$.

Table 2-8 reports that an increase of one standard deviation (0.11) in the ability of patients to book an urgent appointment would avoid, almost, one ACSCs emergency admission. To avoid one ACSCs emergency admission a GP practice would have to increase its PA by more than two SDs. While similar results are found for incentivised ACSCs emergency admissions, for non-incentivised ACSCs emergency admissions a one standard deviation increase in the ability of patients to book an urgent appointment would only avoid about 0.23 of a non-incentivised ACSCs emergency admission. However, a one standard deviation increase in the ability of patients to book an advance appointment would also avoid 0.23 of a non-incentivised ACSCs emergency admission.

Table 2-8: Effect of quality on ACSCs emergency admissions

	Effect *[βEySD]*	Standard Errors	95% Confidence Interval	
All ACSCs				
Population achievement	-0.367	0.117	-0.597	-0.138
Urgent appointment	-0.999	0.166	-1.324	-0.673
Advance appointment	-0.324	0.173	-0.664	0.016
Incentivised				
Population achievement	-0.404	0.134	-0.666	-0.142
Urgent appointment	-1.104	0.188	-1.472	-0.736
Advance appointment	-0.136	0.194	-0.517	0.245
Non-incentivised				
Population achievement	-0.0917	0.051	-0.1916	0.0083
Urgent appointment	-0.227	0.0678	-0.3598	-0.0942
Advance appointment	-0.2242	0.0699	-0.3613	-0.0872

We also examined if the effect of FTE GPs, PA, urgent and advantage appointment varied by the deprivation level of the GP practice list. Figure 2.1 to 2.4 show that the impact of quality on ACSCs emergency admissions increases with deprivation. However, for GP practices with the most deprived patient list the effect is smaller.

Figure 15 - Effects of FTE GPs and quality on ACSCs emergency admissions by deprivation deciles

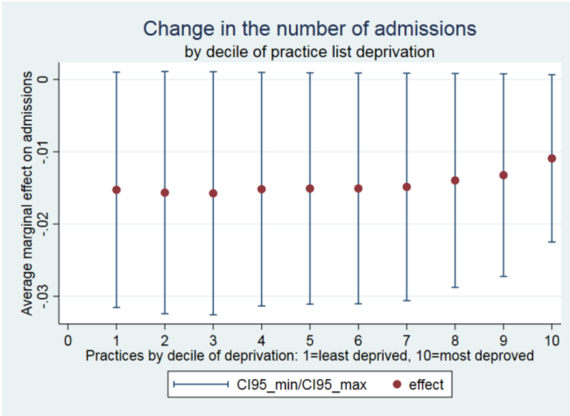


Figure 2. 1- FTE GPs

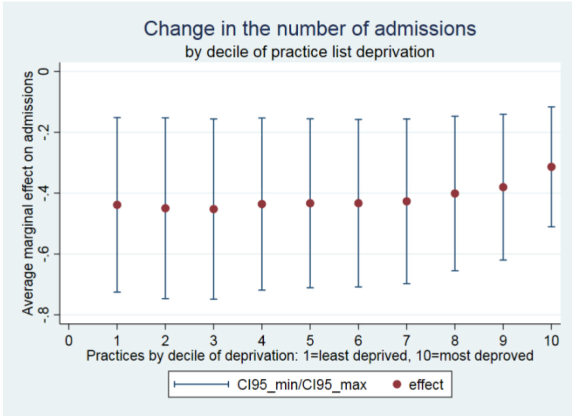


Figure 2. 2 - Population achievement

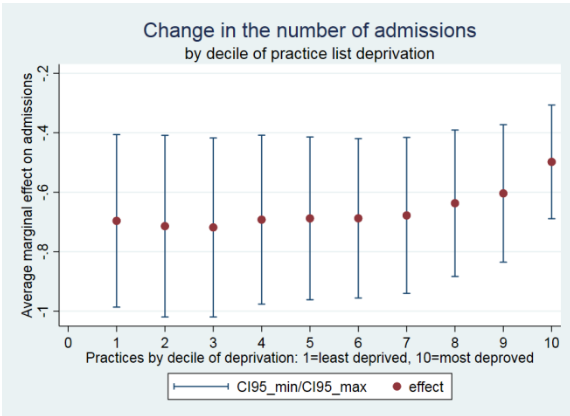


Figure 2. 3 Urgent appointments

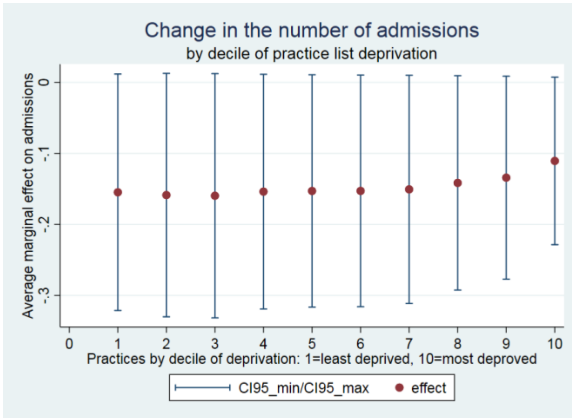


Figure 2. 4 - Advantage appointments

If we exclude quality from our baseline model (see Table 2-9) the coefficient on FTE GPs increases as expected since a higher quality is likely achievable when a GP practice has more FTE GPs[33].

[33] The correlation between FTE GPs per 1000 patients and the quality variables vary between -0.01 and 0.13.

Table 2-9: Models with and without quality variables

	With quality		Without quality	
FTE GPs	-0.00242*	(0.0013)	-0.00282**	(0.0013)
Proportion of female GPs	0.00431	(0.0116)	0.00614	(0.0117)
Average GP age	-0.00269	(0.0032)	-0.00274	(0.0032)
Proportion of GPs qualified in the European Union (and not in the UK)	-0.00535	(0.0216)	-0.00519	(0.0217)
Proportion of GPs qualified outside the European Union	0.0179	(0.0132)	0.0184	(0.0132)
Proportion of salaried GPs	0.00534	(0.0098)	0.00607	(0.0098)
Population achievement	-0.0695**	(0.0002)		
Urgent appointments	-0.110***	(0.0184)		
Advance appointments	-0.0245*	(0.0131)		
AIC	309213.423		309384.39	
BIC	309589.3		309734.12	

Note: The Poisson panel data models also include the GP practice demographic variables, workforce factors, socioeconomic factors and disease registers, the weighted distance of patients' neighbourhood and the nearest GP practice surgery, year dummies and practice list exposure list. There were 46314 observations of the 7982 GP practices between 2006 and 2011. Standard errors in parentheses. * p<0.10, **p<0.05 and *** p<0.001.

Table 2-10 reports that the number of GPs has a significant and positive impact on the patients' satisfaction with the ability to book urgent and advantage appointments. So the impact of number of GPs on ACSCs emergency admissions is direct and indirect since a higher number of GPs increases patient access.

Table 2-10: Impact of FTE GPs on practices quality

	Population achievement		Urgent appointment		Advantage appointment	
FTE GPs	-0.0476	(0.03042)	0.0040***	(0.0005)	0.00194**	(0.0007)
Proportion of female GPs	-0.287	(0.23513)	-0.0097**	(0.0036)	-0.019***	(0.005)
Average GP age	0.0000609	(0.00070)	0.000008	(0.0000)	-0.000016	(0.0000)
Proportion of EU GPs	-0.273	(0.46978)	0.00120	(0.0071)	0.00565	(0.0096)
Proportion of Non-EU GPs	0.338	(0.28159)	-0.00535	(0.0044)	0.00239	(0.0059)
Proportion of salaried GPs	-0.319	(0.21510)	-0.00272	(0.0031)	-0.00355	(0.0043)
AIC	252752.46		-143437.8		-114219.59	252752.5
BIC	253102.19		-143088.0		-113869.86	253102.2

Note: The Poisson panel data models also include the GP practice demographic variables, workforce factors, socioeconomic factors and disease registers, the weighted distance of patients' neighbourhood and the nearest GP practice surgery, year dummies and practice list exposure list. There were 46314 observations of the 7982 GP practices between 2006 and 2011. Standard errors in parentheses. * p<0.10, **p<0.05 and *** p<0.001.

2.5. Discussion

The ACSCs emergency admissions increased by 13.98 per cent between 2006/7 and 2011/12, with the increase led by the conditions that have not been incentivised by the QOF.

This chapter is the first study to examine the reasons for these trends at GP practice level, specifically the role of GP practice characteristics, such as GP supply and quality performance on the ACSCs emergency admissions.

Using models controlling for time invariant practice characteristics we show that practices which improve their clinical quality and availability of urgent and advance appointment reduce the number of ACSCs emergency admissions. The reduction is generally higher for incentivised ACSCS emergency admissions. Patients' satisfaction with the ability to book urgent appointments also has a negative effect on non-incentivised ACSCs.

The effects of a quality increase and/or number of GPs on ACSCs emergency admissions are modest overall.

The rich panel data set at GP practice level, with information on GP practice characteristics from GP supply to patient list demographics and deprivation, allowed us to explore the major drivers of ACSCs emergency admissions from GP practices. The results are robust and show that to reduce ACSCs emergency admissions, GP practices need to increase not just the number of GPs but also the quality of care and access to advance and urgent consultations.

However, ACSCs emergency admissions are also subject to the Hospital Trust admission thresholds policies and we are not able to control for this. Nevertheless, since we use GP practice fixed effects and it is likely that the GP practice patients go to the same Hospital Trust over the years, we do not think our results are biased by the Hospital Trust policy.

Future research to disentangle the substitution and complementary effects amongst different types of staff within practices and between GP practices and hospitals would allow a better understanding of the health costs that low quality practices impose on patients and the NHS as a whole. The range of skill mixes in GP practices has increased in recent years. The health professionals within a GP practice have extended from GPs and nurses to include, for example, pharmacists, physician associates and paramedics. The impact that these professionals bring to the quality of the practices and the ability of practices to avoid ACSCs emergency admissions, needs to be investigated. Unfortunately data on that set of health professionals within a GP practice is only available from 2015 (and detailed information on nurses was only available from 2013).

To understand the relationships between GP practice and Hospital Trust, we can identify the informal multispecialty physician networks using health administrative data to exploit natural linkages among patients, physicians, and hospitals based on existing patient flow. This helps understand whether networks could foster accountability for efficient, integrated care through care management tools and quality improvement. GP practices within networks might be able to provide better healthcare and avoid ACSCs emergency admissions.

3. Quality in primary care are there peer effects among English GP practices?

3.1. Introduction

Peer effects in English GP practices could be of high value in health policy aimed at improving clinical practice. Given that some GP practices might be leaders within peer groups, health authorities could target those practices to introduce innovative services and expect that these will spillover across the practice peers.

In this paper, we present a GP practice peer effects model on quality decisions, testing if there are quality peer effects among GP practices in the same health authority using a spatial Durbin model. The difficulty of identifying peer effects has been widely discussed in the literature following Manski (1993) seminal paper on endogenous effects.

Manski (1993) describes how the reflection problem arises when researchers try to identify the peer effect, i.e., the impact of the average behaviour of a group on the behaviour of individuals that comprise the group. The reflection term is used since it represents the difficultly that exists in distinguishing between the influence an individual has on her mirror reflection and how she might change her behaviour due to the observation of her reflection in the mirror. In economic (and sociological) terms this means that it is difficult to distinguish between the contextual, the correlated and the peer effect. While contextual effects are the influence of the average group characteristics, correlated effects are the average non-observable characteristics and peer effects the group behaviour on the behaviour of the individual, respectively. Manski sets-out the necessary assumptions for identification of these parameters in both linear and non-linear model specifications (we will explore those restrictions later on Section 3).

The most common approach has become reliant on having prior knowledge of the peers network together with an instrumental variable for the endogenous peer effect itself. Angrist (2014) explains how some studies have failed to establish a casual peer effect, using linear models and instrumental variables (IV) approach. He highlights how studies that have analysed peer effects using bivariate regressions and group level regressions have wrongly claimed to observe a casual peer effect. Furthermore, Angrist criticises the analyses of peer effects using individual, peer effects and contextual effects (group averages of explanatory factors) that use weak IVs, as for example a set of dummy variables (e.g. states and years) since that these will fail to satisfy the exclusion restriction required for a casual interpretation of the second stage least squares (2SLS) estimates. Nevertheless he also notes that studies whose research design allows peer characteristics to be unrelated with individual characteristics, producing an independent peer group variation, i.e. orthogonal to explanatory variables, provide evidence on the nature of the social spillover, or peer effect. This restriction is also noted by other authors as Manski (1993), Bramoullé, Djebbari, and Fortin (2009), Blume, Brock, Durlauf, and Jayaraman (2015) and Athey and Imbens (2017). These last authors in fact try to overcome the endogeneity of the peer group formation by modelling the network formation.

The literature has explored peer effects in education, workforce and health. In education, most studies rely on randomization of students to classrooms (Graham, 2008) or dorms (Carrell, Sacerdote, & West, 2013; Sacerdote, 2001). Some studies also explore double randomization of students and teachers as Graham (2008), in which students and teachers are independently randomly assigned to classrooms so that the classroom type (small or large) generates exogenous variation in the variance of peer quality across small and large classrooms. The authors use the variation in group sizes which imply restrictions in the within and between group variance to identify peer-effects.

Not all peer effect studies rely on randomization of individuals. For example a recent study by Cornelissen, Dustmann, and Schönberg (2017) analyses peer effects between workers' wages using a dataset on wages for Germany from 1989-2005. They use an econometric strategy that allows them to estimate simultaneously the fixed effect of a worker's wage and the fixed effect of the worker's peer group. This latter fixed effect is interpreted as the skills of the peers, defined as all co-workers in the same firm and occupation (estimated on all co-workers). To deal with worker sorting the authors condition on a set of fixed effects: worker FE, time-varying occupation FE and time-varying firm FE. Given the long panel data on which the authors are able to differentiate workers, occupation and firms, this strategy works because there is some worker mobility between occupation and firms leading to variation in the peer group formation. The findings on peer effects accord with the general literature, with larger peer effects among more repetitive professions, e.g. supermarket check-out workers, and significant but smaller for more skilled professionals such as architects and physicians.

An obvious concern is that the circumstances in which there is randomization as in Graham (2008) or rich panel datasets as in Cornelissen et al. (2017) are limited. Instead, Lee (2007) defines a spatial econometric model with peer group fixed effects for cross-sectional data, which, under certain conditions, allow the identification of the peer effect. The peer and contextual effects are identified using this method when there is a sufficient variation in group size. Lee (2007) highlights that group fixed effects are important since group unobservables may cause spurious effects which may be confused with group interaction effect. The model was expanded to include endogenous peer group formation in Lee, Liu, and Lin (2010). Lin (2010) extends the Lee (2007) model to analyses peer effects in secondary school students GPA achievement. The extension is due to the availability of survey data on friendship, which produces an unbalanced peer grouping, since reporting of friendships might not be reciprocal, although it requires the assumption that friendship formation is exogenous to GPA grades, i.e., not motivated by academic purpose. The results Lin (2010) reports using a non-reciprocal friendship peer groups and a reciprocal friendship peer group (attributing a symmetric friendship as long as one of the individuals have named the other as a friend) are quite similar. Bramoullé et al. (2009) also used the Lee (2007) model to estimate the peer effects between secondary school students on consumption of recreational services. The authors highlighted the need for peer groups of different sizes and for the linear independence of the peer group network matrix and its powers[34]. The correlated effects were, as in Lee (2007) and Lin (2010), either absent or treated as networks fixed effects, i.e. peer group fixed effects. Burridge, Elhorst, and Zigova (2016) use a specification similar to Lee et al. (2010) testing for peer effects by comparing a spatial Durbin model, where peer effects are defined with a spatial error Durbin model, where pseudo-peer effects are defined among the error term. The authors conclude that there are no productivity peer effect among the 2580 researchers in economics, finance and business across the 83 Universities in Austria, Germany and German speaking Switzerland.

In health care, there are two different types of studies, since the peer effects can be analysed at health care authority or provider and at individual level. Yang, Lien, and Chou (2014) analysed the peer effects between physicians' prescriptions of second generation antipsychotics (whose benefits were unclear at the time) in Taiwanese hospitals. The authors explore the variation on the physicians peer groups between 1997 and 2010. Although doctors may be attracted to some hospitals due to its characteristics, the second generation antipsychotics prescription behaviour is unlikely linked to the reasons the hospital would hire a doctor. The authors report positive peer effects, with higher values among younger doctors. At the institutional level, Guccio and Lisi (2016) explored the role of peer effects in the hospital sector using the incidence of caesarean

[34] Later in Section 3.3. we will describe the importance of these conditions for the identification of peer effects.

sections for first time mothers. Because of concern about caesarean in Italy a hospital would be audited by the local health authority if its caesarean rate was much higher than its peers. The authors using a spatial econometrics model and a dataset of Italian hospitals and from 2007 to 2012, reported that hospital i's caesarean section rate is affected by its peers' caesarean section rates rather than their supply factors.
Peer effects are defined in this chapter as the direct influence on GP practices quality by their peers' quality performance. The peer effect between GP practices is due to the learning environment created by the PCTs, which had the responsibility to develop relationships across GP practices. Since GP practices are small organisations, we believe that they perceived each other as peers within a PCT, because they served similar populations and faced similar budget constraints. The availability of quality indicators at GP practice level from the QOF and GPPS in several platforms meant that GP practices could compare themselves. Considering that GP practice quality is linked to their revenue, by QOF points and by attracting more patients, practices had the incentive to learn and improve their quality.

To identify the impact of peer effects on GP practice quality, we construct a peer group weight matrix based on the GP practices' local health care authority and a contextual group weight matrix that is based on the GP practice surgeries' location. In the peer group weight matrix we weight the influence of GP practices using their size. In the contextual group weight matrix we use the inverse distance to other practices. The empirical analysis is conducted using linear spatial econometric panel models that are estimated by quasi maximum likelihood, to identify the peer and contextual effects. We find that there are positive and significant peer effects between GP practices regarding quality.

The chapter is organised as follows. The next section outlines the institutional setting; Section 3.3 discusses the methods and Section 3.4 the data. Section 3.5 presents the results and Section 3.6 discusses these.

3.2. Institutional Setting

The English National Health Service (NHS) is a tax-financed system and free at point of use (with the exception of small charges for medicines (dispensed by general practice). NHS primary care is provided by family doctors, known as General Practitioners (GPs), organised mainly in small groups known as general (GP) practices[35]. Almost all GP practices are limited liability partnerships owned by the GPs. GP practice revenue is determined by a national capitation formula, which takes account not only the number of patients but their demographic mix and morbidity. There are quality incentives from the Quality and Outcomes Framework (QOF) and GP practices are also paid for providing specific services including vaccinating and screening target proportions of the relevant practice population. Although practices are reimbursed for the costs of their premises, they have to fund all other expenses, such as hiring practice nurses and clerical staff, from their revenue.

Between April 2004 and March 2012 general practices were grouped in Primary Care Trusts (PCTs). These organisations were responsible for commissioning primary and secondary care services and in some circumstances providing services, running community hospitals and community health services. PCTs were responsible for holding and organising local health care budgets for hospitals and community health care services, as well as primary care infrastructure and prescribing (NHS, 1999). General practices can choose to have the General Medical Services (GMS) negotiated nationally by the Department of Health and the British Medical Association or a Personal Medical Services (PMS) contract negotiated with the local PCT. Under PMS contracts practices agrees to provide additional services to those in GMS and were paid extra for them. PCTs are required to set local clinical standards for practices and to monitor their performance (NHS, 1999). They also liaise with the Local Medical Committee (LMC).

From 2002 to 2006 there were 303 PCTs in England. Each PCT on average had a population of 170,000. PCT boundaries were set within Local Authorities (LAs), for example in London almost all the PCTs matched the London borough councils[36] (Rivett, 2017). However, in some other parts of the country PCTs crossed LAs borders, for example in the West Midlands, Shropshire and Staffordshire PCTs included the Cannock Chase District LA, a small part of the South Staffordshire District LA and a small part of the Lichfield District LA. During those four years PCTs were involved in implementing several health reforms including the introduction of a new financial system of Payment by Results, the expanding use of the private sector, the advent of patient choice, the introduction of new pay and contracting arrangements for NHS staff through Agenda for Change and the implementation of the European Working Time Directive (House of Commons, 2006). PCTs controlled 80% of the NHS budget, which stood at £76 billion in 2005.

In 2006, PCTs were re-organised and reduced to 152. The aim was to reduce administrative costs and improve commissioning of secondary care[37]. The advantages of larger PCTs, managing risk

[35] GPs are not NHS employees, apart from a small proportion directly employed by Primary Care Trusts (PCTs).

[36] The only exception is the South West London 2002 PCT that comprised two London boroughs, namely, the Merton and the Sutton London boroughs.

[37] Since April 2008, when a GP refers a patient to a consultant led service, patients may choose any clinically appropriate secondary care provider for the first outpatient appointment. This choice can include any NHS provider and many independent sector providers.

and economies of scale, clashed with the advantages of being small, adaptable to local needs and being close to primary care. The Creating a Patient-led NHS document (Department of Health, 2005) set a plan to reduce PCTs in order to reduce costs by £250 million and improve commissioning (House of Commons, 2006). New PCT boundaries were set to overlap more with the local authority social services boundaries. While 54 remained the same, 249 were merged (see Table A. 15in Appendix 3.1). The merges ranged from two to six PCTs (PCT Leeds). Eighty six per cent of the 2006 PCTs overlapped with the 380 LA boundaries or London boroughs. Twelve LAs remained divided between two to three 2006 PCTs (see Table A. 16 in Appendix 3.1). PCTs interactions with GPs was also reinforced with the introduction of Practice Based Commissioning (PBC). This initiative had as an objective the improvement of primary care services by enabling healthcare professionals from GP practices or the locality to have an indicative budget from the PCT to decide how services are funded to meet the needs of the local population to improve primary care and management of long term conditions. The difference between the PBC and the 1990's GP fundholding system was that the PCT still held the budget and the resources freed up from practice, or localities, effective commissioning could only be used to improve patient services and not directly to improve the practices services (Department of Health, 2005; House of Commons, 2006).

In April 2004 NHS implemented a national pay for performance scheme known as the Quality Outcome Framework (QOF). This scheme was intended to raise clinical quality, especially to prevent chronic condition events. The 2004/5 QOF had 146 quality indicators relating to clinical care for 10 chronic diseases, organisation of care and patient experience (HSCIC, 2005) . The QOF performance is evaluated through points, and in 2004/5 there were 1050 points available. Given that each point was worth approximately £120, an average practice in the England (with around 5500 patients and three practitioners) has a potential increase in gross earnings of £42,000 per GP (Roland 2004). Since the QOF was design with absolute performance measures, i.e., the performance is not set relatively to the performance of other practices, and the expected achievement and value in points is set before the start of the financial year, it does not give incentives to competition. The QOF results, by indicator and GP practice, are available publicly.

In 2007 NHS England introduced GP Patient Survey (GPPS) to examined patients' satisfaction with their general practice[38]. The survey assessed patients' experience of healthcare services provided by general practice, including experience of access to GP surgeries, making appointments, the quality of care received from GPs and practice nurses, satisfaction with opening hours and experience of out-of-hours NHS services. The first GPPS results were published in June 2007.[39] The results of two GPPS questions were incorporate in the QOF patient experience domain from 2008/9 to 2010/11, namely the percentage of patients who were able to obtain a consultation with a GP within 2 working days (QOF – PE7) and the percentage of patients who were able to book an appointment with a GP more than 2 days ahead (QOF – PE8). These and other GPSS indicators were also available in the NHS Choices website. This website was launched in 2007 to

[38] More information on GP patient survey is available at https://gp-patient.co.uk/default?pageid=1 (consulted on the 21st of July 2017).

[39] There were changes to the sampling procedure, questions and questions wording of the GP patient satisfaction survey along the years. For more detailed information consult https://gp-patient.co.uk.

help patients understand and choose health care providers in their area (from GP practices to A&E services) and provide health information on many disease areas.

Given the responsibility of PCTs to develop relationships with the GP practices, we believe that GP practices, as small organisations (on average a GP practice has 4 GPs), saw each other as peers within a PCT, since they served similar populations and faced similar budget constraints. The availability of quality indicators at GP practice from the QOF and GPPS in several platforms meant that GP practices could compare themselves. Knowing about the performance of other local practices is important to a practice because it provides information of what level of performance on QOF is possible given the characteristics of local population and because patient choice of practice is, in part, affected by its quality relatively to other nearby practices (Santos et al., 2017).

3.3. Methods

We use a spatial econometric panel model to test for the peer effects between GP practice quality decisions:

$$y_{it} = \rho \sum_{j \in F_i} p_{ij} y_{jt} + \sum_{k=1}^{K} \varphi_k \sum_{j \in Q_i} c_{ij} x_{jt}^k + \sum_{k=1}^{K} \beta_k x_{it}^k + f_i + a_t + \lambda \sum_{j \in F_i} p_{ij} \mu_{jt} + \varepsilon_{it} \qquad (17)$$

Where y_{it} is the quality of GP practice *i* at time *t*, x^k_{it} is the *k* characteristic of GP practice *i* at time *t*, $\sum_{k=1}^{K} \sum_{j \in Q_i} c_{ij} x_j^k$ is the weighted average of the characteristics of GP practice *i* contextual group, Q_i is the set of all practices in *i's* contextual group excluding *i*, $\sum_{j \in F_i} p_{ij} y_{jt}$ is the weighted average of GP practice *i* peer group quality decisions, F_i is the set of all practices in *i's* peer group excluding *i* , $\sum_{j \in F_i} p_{ij} \mu_{jt}$ is the weighted average correlated effect, a_t is the time effect and f_i a cross-sectional GP practice fixed effect. We want to estimate the peer effect ρ, i.e., the effect of *i*'s peers on *i*. The contextual group of practices Q_i is the set of practices whose characteristics may affect practice *i*'s performance. The peer group of practices F_i is the set of practices whose performance may affect *i*'s performance.

Box 1- Definitions

Peer effect: ρ is the effect of the peer group <u>behaviour</u> $\sum_{j\in F_i} p_{ij} y_{jt}$ on GP practices i's own quality.

Contextual effects: ϕ_k are the effects of the contextual group <u>characteristics</u> $\sum_{j\in Q_i} c_{ij} x_{jt}^{k}$ on i's quality.

Correlated effect: is the effect λ of the peer group <u>unobservables</u> $\sum_{j\in F_i} p_{ij} \mu_{jt}$ on i's own quality

The identification of peer effect, or social spillover, is difficult because there is a reciprocal effect between the individual and her peer group and the peer group formation might be endogenous, i.e., the formation of the peer group might be explained by the same factors that explains the individuals behaviour. Manski labelled this identification problem as "the reflection problem" in his seminar paper in 1993. He describes how the reflection problem arises when researchers try to identify the peer effect, i.e., the impact of the average behaviour of a group on the behaviour of individuals that comprise the group. He argues refers that the identification of the peer effect is possible if the factors that explain the formation of the peer groups and the factors that explain the behaviour of the individuals are moderately related, but not functionally dependent or statistically independent, i.e., factors that explain the group formation must be related to the factors that explain the performance but most not determine it. For example, rurality will be related to the formation of practices peer groups (PCTs) but does not solely determines the performance of practices.

The reflection problem arises out of the presence of $\sum_{j\in F_i} p_{ij} y_{jt}$ as a regressor. In economic terms this means that it is difficult to distinguish between the contextual, the correlated and the peer effect, i.e., the influence of the average group characteristics, average non-observable characteristics and the group behaviour on the behaviour of the individual, respectively. The identification of the peer effect is only possible under certain conditions (Manski, 1993). Those conditions are related mostly to the formation of the peer group and the relation of the peers average quality with the practice characteristics. It is necessary that the formation of the peer group is not explained by the variables affecting the GP practice behaviour or decisions, i.e., the factors that explain the peer group formation (*I*) are not a function of practice characteristics (X). In our study the peer group was defines exogenously by the definition of the PCT boundaries. The exogeneity of the peer group implies that whilst the average quality of the peers $\left(\sum_{j\in F_i} p_{ij} y_{jt}\right)$ does vary with the practice *i* characteristics, but it should not be a linear function of those characteristics. For example, the average behaviour of the peers varies with some of the variables affecting the practice *i* quality decisions since peer groups will likely have more GP practices within the same group in an urban setting than in a rural one.

Thus, the identification of the peer effect is linked to the definition of the peer group, which should be exogenous, and the relationship between $\sum_{j \in F_i} p_{ij} y_{jt}$ and the explanatory factors of the GP practice quality decisions (X).

The formation of the peer group is crucial since it should be exogenous to the GP practices' own quality decisions but moderately related to its' characteristics, given that the identification of the peer effects between GP practices relies on the exogenous variation of the peer group quality decisions $\left(\sum_{j \in F_i} p_{ij} y_{jt} \right)$, the contextual group characteristics $\left(\sum_{k=1}^{K} \sum_{j \in Q_i} c_{ij} x_j^k \right)$, the GP practice quality decisions *(y_{it})* and on the GP practice characteristics $\left(x_j^1, \ldots, x_j^k \right)$. In our study, GP practices are peers within the 2006 Primary Care Trusts (PCTs). As explained in Section 3.2, within a PCT, GP practices served similar populations, faced similar budget constraints. Moreover, PCTs monitored and compared the GP practice activity, promoting a spread of good practice in their GPs forums. In this re-organisation of PCTs in 2006 into larger areas, GP practices could not choose which PCT they would be in, so the peer group is exogenous. The peer group is formed by a set of GP practices that belong to the same PCT, but GP practice *i* does not belong to its peer group. We specify the weighted average of peers quality as $\sum_{j \in F_i} p_{ij} y_{jt}$, where p_{ij} indicates if GP practice *i* and *j* belong to the same PCT, being $p_{ij}>0$ if they do and $p_{ij}=0$ otherwise, F_i is the GP practice *i*'s PCT members and y_{jt} is the quality of GP practice *j* at time *t*. This also specifies that GP practice *i* is not included in the average quality of the peer group, which allows for greater variation in the average peer quality since the average quality of peers will be different for each practice *i*. We also specify $\sum_{\substack{j \in F_i \\ j \neq i}} p_{ij} = 1$, so $\sum_{\substack{j \in F_i \\ j \neq i}} p_{ij} y_{jt}$ can be interpreted as the weighted average of peers' quality. p_{ij} will be specified has the influence of practice *i* on *j*, using practices *i* and *j* sizes.

The peer group and the contextual group may differ. In our study, a GP practice might be located near a PCT boundary and although being influenced by the average quality decision taken by the GP practices in that PCT, it might also be influence by the characteristics of the GP practices that are geographically nearer. We specify the average contextual characteristics as $\sum_{j \in Q_i} c_{ij} x_{jt}$ where c_{ij} indicates if GP practice *i* and *j* belong to the same contextual group, being $c_{ij}>0$ if they do and $c_{ij}=0$ otherwise, Q_i is the group of GP practices that belong to GP practices *i*'s contextual group and x_{jt} is the characteristic of GP practice *j* at time *t*. We specify $\sum_{j \in Q_i} c_{ij} = 1$ and therefore interpret $\sum_{j \in Q_i} c_{ij} x_{jt}$ as the weighted average of the contextual group characteristics.

Note that we use the peers quality decisions, $\sum_{j \in F_i} p_{ij} y_{jt}$, instead of $E\left(y | l \right)$, the mean of peers quality decisions given the factors that explain GP practices peer group formation (*l*). This assumes that the expectation of GP practice *i* regarding its peers' quality decisions is equal to the observed weighted average. Given that this is a weighted average of quality variables publically available within a PCT, where in 2006 each PCT had at least 8 GP practices and on average 47 GP practices, the expectation and observed average should be similar. Several studies, as Lee (2007), Lin (2010) and Burridge et al. (2016) also used this approach, proxying the expected value of y_{jt} by its contemporaneous value.

We estimate a Spatial Durbin Model (SDM) using Belotti, Hughes, and Mortari (2017) strategy of a quasi-maximum likelihood (QML). The Maximum likelihood estimator (MLE) is historically used for spatial econometric models since, as highlighted in (Anselin, 1988), Ordinary Least Squares estimator are bias is biased and inefficient if a model includes the average of the outcome on the right-hand side. The SDM in equation (18) is our preferred model since it allows estimating of the peer and contextual effects simultaneously[40].

$$y_{it} = \rho \sum_{j \in F_i} p_{ij} y_{jt} + \sum_{k=1}^{K} \varphi_k \sum_{j \in Q_i} c_{ij} x_{jt}^k + \sum_{k=1}^{K} \beta_k x_{it}^k + f_i + a_t + \varepsilon_{it} \qquad (18)$$

We do not estimate simultaneously the peers, contextual and correlated effects as in equation (17) since this would overfit the model[41].
To alleviate the concern regarding the inclusion of the contextual effects which may contribute to an over fitting the model, we also estimate a model known as the Spatial Autoregressive Model (SAR):

$$y_{it} = \sum_{k=1}^{K} \beta_k x_{it}^k + \rho \sum_{j} p_{ij} y_{jt} + f_i + a_t + \varepsilon_{it} \qquad (19)$$

In this specification the focus is on the peer effects and we expect that ρ will be higher since it will capture omitted contextual effects. This model implies that GP practice i quality decisions do not depend on the weighted average characteristics of nearby practices, i.e., practices in the same context.

Empirically, peer effects have also been estimated using the two stages least squares (2SLS) estimation procedure, where in the first stage researchers regress the average behaviour of the peer group on all the explanatory variables of individual behaviour and on an instrument (which should be correlated with the average peer group behaviour but not with the behaviour of individual *i*), and in the second stage, regress the behaviour of individual *i* on predicted average peer group behaviour and all the explanatory variables. However, as Angrist (2014) highlighted, this technique will only uncover casual peer effects in studies which research design allows peer characteristics to be unrelated with individual characteristics, producing an independent peer group variation, i.e. orthogonal to explanatory variables. The use of weak IVs, as for example a set of dummy variables (e.g. states and years) will fail to satisfy the exclusion restriction required for a casual interpretation of 2SLS estimates.

[40] The spatial Durbin model, presented in equation (17) can be extended to include time dynamics, i.e, to include in the right-hand side the quality decision of GP practice *i* at time *t-1* ($y_{i,t-1}$)and the weighted average of peers quality decision at time *t-1* $\sum_{\substack{j \in F_i \\ j \neq i}} p_{ij} y_{j,t-1}$. However, there is not much variation on the quality decision over time, as shown in Table 3-1 and Table 3-4, which prevents the models to converge.

[41] We also estimate a peer effects model using an a-spatial Mundlak model. The results are reported in Appendix 3.6.

The peer effect model from equation (17) has been linked to the social interaction literature, where individuals maximize the utility of their decisions given their characteristics, the average decisions of their peer group and the average characteristics of their contextual group. The microfoundations of these models is reported in Blume et al. (2015) , where the authors review a set of necessary conditions that allow the identification of the peer effect, which we will refer to below. In fact, equation (17) peer effect model is also referred by Manski (1993) as a "spatial correlation" model. With the author emphasizing that this type of model is appropriate for small-group interactions, i.e., for samples for which the members know each other and choose their decisions only after having been selected into the sample. Manski also highlights that the behaviour of each member in the sample varies with a weighted average of the decisions of the other sample members. This is exactly what we have in our study since all GP practices are organised in small peer groups and we test whether they change their decisions in accordance with a weighted average of the peer group quality.

The term "spatial correlation" model originates from the spatial econometrics literature, which has labelled the model in equation (17) of Spatial Durbin Model (Anselin, 1988; Elhorst, 2014; LeSage, 2009). Re-writing equation (17) in matrix notation, we obtain[42]:

$$y = \alpha + \rho Py + CX\varphi + X\beta + \varepsilon \qquad (20)$$

where p_{ij} is an element of the *P* matrix and c_{ij} is an element of the *C* matrix. These matrices are known in the spatial econometrics literature as weight matrices since they weight the relationship of GP practice *i* and *j*. The specification of these weight matrices that define the peer groups (P) and the contextual groups (C) is important for the identification of the peer effect and several authors discuss a common set of necessary restrictions with this purpose, e.g. Blume et al. (2015), Bramoullé et al. (2009) and Lin (2010). The peers weight matrix *P* defines the peers for each GP practice *i* as all other GP practices within the same Primary Care Trust (PCTs). While the relationship between GP practices is reciprocal, some GP practices are likely to be more influential within the peer group. We proxy the GP practice influential power by its relative size, proxying the size of the GP practice by its number of surgeries, number of GPs and GP practice list size[43]. These three measures capture different dimensions of GP practice size, which depends mainly on their organisation framework. GP practices with several surgeries, which will translate into a wider catchment area, might have a bigger influence on their peer group since they will have patients registered from several areas of the PCT. While GP practices with a high number of GPs, disregarding the number of sites might be more influential in their peer group by representing a higher percentage of the primary care doctors in the group. The GP practices with larger practice lists size might also have a bigger influence on their peer group for representing a big proportion of the PCT patients. This last measure is associated with the number of GPs and number of surgeries.

We specify the peers' weight matrix to reflect this GP practice influential power as follows:

[42] Equation (20) in a panel framework *Py* represents the kronecker product of $(I_t \otimes W)y$. $(I_t \otimes W_{nxn})$ is a *ntxnt* matrix and y is a *ntx1* vector, while *CX* represents the kronecker product of $(I_t \otimes C)X$ which results in a *ntxk* matrix .

[43] We used the GP practice average FTE GPs and patient list from 2006 to 2011.

$$\begin{cases} p_{ij} = \dfrac{\dfrac{\text{size}_j}{\text{size}_i}}{\sum_i \dfrac{\text{size}_j}{\text{size}_i}} \text{ if GP practice i and j belong to the same PCT} \\ p_{ij} = 0 \text{ if GP practice i and j do not belong to the same PCT} \end{cases} \quad (21)$$

In equation (21) we use the ratio of the size in each of the peers *j* by the number of surgeries that *i* has. The further division by $\sum_i \frac{size_j}{size_i}$ is to row-standardised the weight matrix. This is a standard procedure that allows a better interpretation of Py as the weighted average outcome of the peers. We expect the three different specifications to give similar values of *ρ*. The P weight matrix also specifies that the peers have a reciprocal relationship with all GP practices belonging to the peer group during the whole study period. Given that some GP practices exert more influence than others, when a GP practice is larger *(l)*, with more sites, GPs and patients than their peers *(f)*, p_{fl} will be set to high value to reflect that the leader *(l)* influences strongly its peers *(f)* and p_{lf} will be small since the peers *(f)* have less influence in the leader practice.

To capture the peer effect, we have used the weighted average quality of the peers, as $\sum_{j \in F_i} p_{ij} y_{jt}$ in equation (18). Nonetheless, Sacerdote (2011) discusses the peer effects described in some of the education literature where peer effects only take into account the best (shining light) and the worst (bad apples) student (Lazear, 2001). The focus of the analysis when using bad apples is on how a student with bad performance and/or behaviour might affect his/her classroom peers. On the other hand, the focus of the analysis when using shining light, i.e. the highest in the peer group, could raise the other classmates' achievements. However, Sacerdote (2011) notes that is more difficult to think of ways in which a great student could raise her classmates' achievement than it is to think of ways in which a terrible student could harm an entire classroom. In our case study, with a primary care quality model, the opposite is more likely: while it is easy to think of ways a high performance practice could influence its peer group, it is quite difficult to think of how a bad practice might have an influence. Moreover, a shining light/bad apple model implies that there is no variation in the peer group for individuals in the same class and this might undermine the identification of peer effects (Angrist, 2014; Blume et al., 2015). For those reasons we use the fact that GP practices are likely to be more aware and consequently more influenced by the bigger practices since those will have greater visibility. This is the rationale to weight the practices' relationship by practice size. If bigger practices are the shining lights then the peer model using weighted average will basically have similar results to a shining lights model.

We set the contextual weight matrix *C* to define the GP practices that belong to each contextual group using a metric distance measure. This contextual specification ignores the peer group boundaries, for example a GP practice that is near a PCT boundary will be influenced by the context of both sides of the boundary since its patients are likely to live on both sides. We use the minimum distance between GP practices branches/surgeries to set the context. The contextual group row standardised weight matrix using an inverse distance specification with a 5km threshold is set as follows:

$$\begin{cases} c_{ij} = \dfrac{\frac{1}{d_{ij}}}{\sum_i \frac{1}{d_{ij}}} \text{ if } d_{ij} \le 5km, i \ne j \\ c_{ij} = 0 \quad\quad \text{if } d_{ij} > 5km \text{ or } i = j \end{cases} \tag{22}$$

This implies that although the minimum distance between GP practice *i* and *j* and *j* and *i* is the same, the contextual influence is not reciprocal between GP practice *i* and *j*. Usually GP practices share the same context since if practice surgeries are located in the same area they will draw patients from the same areas and share the local amenities, for example the accessibility to the practices by public transport. However, practice *i* and *j* might have a different set of practices within the 5km radii and considering that the row standardisation will weigh the influence of all practices within that context, c_{ij} might be different from c_{ji}.

The contextual group should capture what is happening in the geographical area context around the practice, which includes, for example, disease incidence, socioeconomic and demographic characteristics and also the number of GPs in the area. These characteristics are important as a local environment conditional for practice quality decisions. The peer groups are wider than the contextual groups because they are linked to the commissioning group and the relationships developed within that group to improve their performance. Therefore, the peer group is set by PCT and the contextual group is set by distance. These two groups will not have the same members. In most cases, the contextual group will have a subset of the peer group since PCTs are geographically wide and the contextual groups are set to 5 and 17.2km. When a GP practice is located near the PCT boundary, the contextual group will have different members from the peer group, because it will include practices in the neighbouring PCT. It is important that the local context includes those contextual characteristics since there are no formal constraints to a practice catchment area, so patients living within the boundaries of the neighbouring PCT may choose to register with the practice.

Blume et al. (2015), Bramoullé et al. (2009) and Lin (2010) show that the linear independence of the four matrices I, P, C and PC (respectively the identity, peer, contextual and multiplication of peer and contextual matrices) is necessary for identification of the parameters of interest *(φ,ρ,γ)* since the linear dependency of the matrices will imply a linear dependency among the parameters. We test this using the rank of the matrix[44]. Blume et al. (2015) also show that a sufficient condition for identification of the parameters of interest is that there exist two GP practices *i* and *j* such that $\sum_k p_{ik} c_{ik} \ne \sum_k p_{jk} c_{jk}$. This implies that if the two weight matrices are symmetric, it is not possible to distinguish the influence between practices. In our study, two GP practices that belong to the same peer group might be exposed to a different context. Within a

[44] The linear independence of the matrices implies that none are a linear combination of the others, and that E(PY|X) is not perfectly collinear to (X, CX), which allows the identification of the parameters of interest (ρ,γ and ϕ). We calculate the rank of the matrix [I,P,C,PC] to test the linear independence of I, P, C and PC matrices. The rank of the matrix corresponds to the maximal number of linearly independent columns, so if the (Nx4N) matrix [I,P,C,PC] has a rank of 4N the 4 matrices are linearly independent.

peer group, in this case, a PCT, GP practices can be located in different towns with a different demographic, socioeconomic and morbidity profile.

3.3.1. Falsification tests

We also undertook falsification tests. We performed a double randomisation of GP practices and peer groups (PCTs), to allow a falsification test of the peer and contextual effect. A random GP practice location was attributed to each GP practice *i*, which implied that the context, define by the average GP practice and population characteristics of GP practices nearby, is from another context, i.e., from another part of the country. The PCT code was also separately randomised, so the peers are actually defined by a group of "fake peers" and the peer effects will be measured by the average quality decisions of the "fake peers".

The coefficient of the average quality of GP practices of the "fake peers" should not be significant, given that the GP practices were selected randomly to the "fake peer group". The same rational for the contextual effect, the coefficient on the average GP practice and population characteristics of GP practices that do not belong to the same context should not be significant.

Given that we are looking into peer effects on decisions on quality, we use a GP characteristic to perform a second falsification test. We test peer effects between GP practices, using the real peer and contextual socio-matrices on the average age of the GPs in a practice.

The falsification test is done by estimating the following model:

$$age = X\beta + CX\gamma + \rho_{age}Page + f + a + \varepsilon \quad (23)$$

We expect the coefficient p_{age} to not be significant since the average age of GPs within a GP practices should not be influenced by the average age of GPs in the peer group practices.

3.4. Data

We construct a balanced panel data set spanning the years 2006 to 2011 on GP practices by linking different NHS administrative data sets, including General Medical Statistics, Quality Outcome Framework, GP Patient Satisfaction Survey, Hospital Episode Statistics together with information on GP practice locations. We also attribute to GP practices small area census and socio-economic data from Neighbourhood Statistics using the NHS Attribution Data Set, which reports the number of patients registered with each practice from each small area (Lower Super Output Area). We only include practices that have more than 1000 patients both across the observation period and also the year prior to the study period (2005) and the year following (2012). These restrictions ensure that GP practices were not entering or exiting the primary care market during this period since such practices tend to display different behaviour.

3.4.1. The decision variable: GP practice quality.

To understand the peer effect on GP practices on quality decisions, we use five variables that capture two different attributes of primary care quality: (i) clinical quality and (ii) patient accessibility to GP appointments.

Ambulatory Care Sensitive Conditions (ACSCs) emergency admissions

The first clinical quality variable is derived from hospital admissions dataset Hospital Episode Statistics (HES). ACSCs emergency admissions, are defined as hospital emergency admissions that could be prevented or reduced through management of the acute episode in the community or by preventive care (Purdy et al.). Therefore, the ACSCs are specifically a set of disease groups or more precisely of ICD10 codes. Using the admission method and diagnostic fields in Hospital Episode Statistics (HES), we count the number of emergency ACSCs admissions for each practice (from the patients' GP practice code recorded on the HES episodes) in each financial year from 2006/7 to 2011/12, so for example, the 2006 ACSCs emergency admissions are collected from 1st April 2006 to 31st March 2007.

As highlighted in the previous chapters, there are several sets of conditions seen as ACSCs in the literature. Bardsley et al. (2013) compared the set of conditions they defined as ACSCs with the conditions used by Purdy et al. (2009) and by Australian Victoria State Health Department (2009) and concluded that some conditions were split, creating more specific conditions but essentially the same principal diagnosis of admission. When we compared the conditions used in Harrison et al. (2014) with the ones used in the NHS Outcomes Framework (Department of Health, 2013) besides the different way the conditions were grouped (acute and chronic versus incentivised and non-incentivised) the major differences was the inclusion by the NHS outcomes framework of dehydration and gastroenteritis, influenza and dental conditions in acute ACSCs conditions and the exclusion of stroke, pelvic inflammatory disease and gangrene conditions. We define ACSCs emergency admissions as the set of incentivised and non-incentivised by the QOF as Harrison et al. (2014) since those were contemporaneous to the study period and given the introduction of QOF in 2004 it is likely that a great focus was on the achievement and impact of the QOF (Doran et al., 2006) .

There is evidence that the introduction of the QOF reduced the incentivised ACSCs emergency admissions (Dusheiko et al., 2011; Harrison et al., 2014). However, the variation of ACSCs emergency admissions is sensitive to the hospitals policies and community services, as the trust admissions Emergency Department schemes (avoidance of admission schemes versus an admissions with quick discharge scheme), the integration between services (especially between health and social care), the availability of services out of hours (support services that avoided admissions, as primary care, social services and mental health services) and the perception in the community services that it is easier and safer to admit patients (O'Cathain et al., 2014). Therefore, measuring peer effects of ACSCs emergency admissions decisions at GP practice level might not reveal the expected results due to the role that other providers have on ACSCs emergency admissions decisions.

Quality Outcome Framework (QOF) total points

Practices receive points according to their performance on QOF indicators from the four domains: clinical, organisational, patient experience, and additional services. Although each point carries the same reward, around £125 for the average practice, most of the indicators on the patient experience, organisational and additional services domains are related to managerial procedures and not to patient clinical procedures.

Between 2006/7 and 2011/12[45] the QOF structure was reasonably stable, apart from the abolition of the square root adjustment in the practice disease prevalence factor in 2009/10[46].

The total available QOF points are 1000 in the whole period (2006/7 to 2011/12), but there was a shift of points away from patient experience towards the clinical and organisational domain. In 2011/12 the clinical domain had more 7 indicators (87 versus 80), one more clinical area (20 versus 19) and 6 more points (661 versus 655), while the organisational domain had two more indicators (45 versus 43), one more area (6 versus 5) and 81 more points (262 versus 181). The additional services domain also had one more indicator (9 versus 8), the same number of areas (4) and 8 more points (44 versus 36). Conversely, the patient experience domain experienced a reduction of 3 indicators (1 versus 4), 1 area (1 versus 2) and 33 points (75 versus 108).

Total QOF points might not mirror the quality of GP practices accurately given the mixture of indicators, i.e., some indicators measure directly a health outcome (e.g. Epilepsy 8: epilepsy seizure-free in the past 12 months) while others simply reflect managerial procedures (e.g. a clinical register such as CHD01 – "The practice can produce a register of patients with coronary heart disease"; or an organisational register such as RECORDS08 – "There is a designated place for the recording of drug allergies and adverse reactions in the notes and these are clearly recorded"). However, GP practices and patients can readily observe total QOF points, and moreover the total points are attributed to features that are within the decision capacity of GP practices.

Population achievement from the Quality Outcome Framework (QOF)

We also measure clinical quality using a measure derived from the QOF clinical domain, the population achievement.

The use of the total clinical domains points might also not be appropriate given the suggestion that some practices game their scores by exception reporting patients for whom it would be difficult to achieve a clinical indicator (Doran et al., 2008; Gravelle et al., 2010). We therefore measure clinical performance on an indicator as the percentage of patients with the relevant condition for whom the indicator has been achieved. Clinical quality for a condition is the average of the percentage scores on indicators for that condition, weighted by the maximum points achievable for each indicator. We measure overall clinical quality as a maximum points weighted average of the condition clinical scores and refer to it as population achievement (for more information consult Appendix 2.1).

Accessibility of GP appointments using the General Practice Patient Survey (GPPS).

The accessibility of GP appointments is measured by the patient's reported satisfaction with access on the GPPS[47]. We construct patient reported measures of quality using responses to two questions to the administered survey (usually to random 5% sample of patients in each practice)

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[45] QOF data is collected by NHS digital for each financial year, so for example for 2006/7, the data is collected between 1st April 2006 and 31st March 2007.

[46] From 2004/5 to 2009/10 the price per QOF point is the product of the national average price per point by the adjusted practice disease prevalence factor and the list size of the practice relative to the national average list size, where the adjusted practice disease prevalence factor is the square root of the practice disease prevalence rate divided by the unweighted average of the square roots of the practice prevalence rates in all practices (Gravelle, Sutton, & Ma, 2007). In 2010/11 and 2011/12 there is not an adjustment.

[47] *We used the weighted GPPS responses available at https://gp-patient.co.uk/*

that were available through the study period (2006/7-2011/12) and did not suffer a significant wording change. The GPPS data were attributed to the financial years using the fieldwork dates (for more information please see Appendix 2.2.).

Able to see GP fairly quickly (*urgent appointment*) is the proportion of patients that answer they were able to get an appointment on the same day or on the next 2 days the surgery was open. This will capture the decision of GP practices regarding the availability of urgent appointments. The results of this indicator were included in the QOF patient experience domain from 2008/90 to 2010/11 (Appendix 3.2).

Able to book advance appointment (*advance appointment*) is the proportion of patients that responded that they were able to get an appointment with a doctor more than 2 full weekdays in advance. This is an indicator of the GP practices' decisions on availability of advance appointments. This indicator was also included in the QOF patient experience domain from 2008/90 to 2010/11 (Appendix 3.2).

3.4.2. The GP practice and population characteristics and the contextual effect

The data on GP practices characteristics that affect the quality decisions of the GP practice can be categorised in GP practice and population characteristic.

GP practice characteristics

We collected data on GP practice type of contract (GMS versus PMS[48]) number of full time equivalent GPs, proportion of female GPs, proportion of GPs trained in the UK, in the EU or outside the EU, proportion of salaried GPs and average GP age in each GP practice from the General Medical Statistics (GMS)[49]. The quality of a GP practice is influenced by its human resources, the number of professionals as well their experience and qualification. While GPs qualified outside the UK may have some language and cultural barrier, female and male GPs have different consultation styles, preventive and referral behaviour (Jefferson et al., 2013). The age of the GP is a proxy for experience and investment in keeping their knowledge and skills up to date and we include the average age of GPs in the practice. There has been a recent rise in the proportion of GPs who are salaried. They are paid considerably less than GPs who are partners in their practices. They will also be less involved in the GP practices decisions and may have different motivation which will reflect on their efforts towards the QOF scores and availability for extra appointments.

We collect the total practice list, the number of male patients and the number of patients in specific age groups to take into account the different demand that practices face by different age and gender groups from the GMS.

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[48] Since the APMS and PMSPCT contracts only appear in the 2009 GMS dataset, we have included those in our PMS dummy variable. This way, from 2009 onwards the variable is actually defined as GMS versus PMS, APMS and PMSPCT. We expect to find a positive impact of the PMS contract on quality, because those were defined locally by the PCTs to address the population needs.

[49] We have attributed the data from, for example, 30th September 2006 to the financial year of 2006/7 since the date of the snapshot is exactly in the middle of the financial year.

To capture the complexity of health needs a GP practice faces, we also collect data on the proportion of patients that reside in a nursing home[50] and the number of patients in each of the QOF disease registers (Coronary heart disease, Stroke and transient ischaemic attack, Hypertension, Diabetes mellitus , Chronic obstructive pulmonary disease, Hypothyroidism, Cancer, Mental Health, Asthma, Heart Failure, Palliative Care, Dementia, Atrial fibrillation, Epilepsy, Chronic kidney disease, Obesity and Learning Disabilities).

Socioeconomic deprivation is a proxy for health need and an important characteristic of health-care seekers, as discussed by O'Cathain et al. (2014), since deprivation encapsulates a whole range of social and cultural characteristics, and people in socially deprived areas not only have high levels of morbidity, but might have other constraints regarding access to healthcare, for example transport difficulties. We use the NHS Attribution Data Set (ADS) to attribute the Population rate claiming incapacity benefit and severe disability allowance[51] and the Education Skills and Training deprivation score to GP practices (see attribution strategy in Appendix 2.3.). While the first measure will capture the population that are economically inactive due to sickness or disability, so not only economically sensitive but also with complex health profiles, the second measure concerns a population (children, young people and adults) with educational disadvantage, which will be reflected on their employment type and status and income.

Contextual effects

The contextual effects are defined as the influence of the average group characteristics on the quality decision of GP practice i . Since GP practice catchment areas usually overlap and often cross PCT boundaries, we defined the contextual group weight matrix based on distance between GP practices (see Section 3). The objective is to capture the social, economic and health complexity of the population (GP practice characteristics) and the health care provision (population characteristics) in the catchment area of the GP practices. The population and health care provision characteristics that surround the GP practice surgery locations will have an influence on their quality decisions, because they will capture the health profile of the population from which the practice draws its patients and the characteristics and number of the health care staff in the area from which they are likely to recruit. Therefore, the contextual effect variables are a weighted average of the GP practice and population characteristics presented in this Section, using the inverse distance between GP practices as the weight.

The GP practice surgeries locations were collected from NHS choices, QOF and NHS Technology Reference data Update Distribution (TRUD). These were used to calculate the contextual socio-matrices.

[50] The data for the list of patients registered in nursing homes is extracted yearly on 30th September, so we have attributed the data from, for example, 30th September 2006 to the financial year of 2006/7 since the date of the snapshot is exactly in the middle of the financial year.

[51] A quarterly snapshot of the incapacity benefits, also known as Disability Living Allowance (DLA) data is collected yearly at the end of February, May, August and November. Since we wanted to attribute the data to the financial year, we used the yearly August snapshot to attribute, for example, the data from August 2006 to the financial year of 2006/7.

3.5. Results

3.5.1. The decision variable: GP practice quality

Table 3-1 presents the descriptive statistics for the five measures of quality[52]. The proportion of ACSCs emergency admissions (per 1000s patients) is the variable with wider standard deviation (SD), over 35% of the average. The within variation is the sum of the squares of each practices' observation from its mean (calculated over time), and indicates variation in practice quality across years. The within variation is higher for the proportion of ACSCs emergency admissions (per 1000 patients) and lower for total QOF points (17.24% and 3.12% of the average, respectively). The between variation is the sum of squares of differences between the practices means and the whole-sample mean, and indicates variation across practices in quality. The between variation is also higher for ACSCs emergency admissions and lower for total QOF points (33.11% and 3.41% of the average, respectively).

While the average proportion of ACSCs emergency admissions was higher in 2010, the Population Achievement has its higher average in 2008 and the total QOF points and the GPPS variables had the highest averages in 2007.

Table 3-1: Descriptive statistics for GP practice quality variables

		Proportion of ACSCs emergency admissions (in 1000s patients)	Population Achievement	Total QOF points	Urgent appointment	Advance appointment
Overall	Average	12.455	79.712	961.451	83.4%	73.8%
STD	Overall	4.649	6.211	44.476	10.7%	15.7%
	Between	4.124	3.925	32.802	9.0%	13.8%
	Within	2.147	4.813	30.037	5.8%	7.5%
Percentile	5	5.301	66.642	885.869	63.0%	44.7%
	95	20.568	87.286	999.171	97.0%	95.7%

Note: These descriptive statistics include all 7062 GP practices in the 6 years panel, so 42372 (7062*6) observations

Table 3-2 reports the correlation between the quality variables. As expected the correlation is low, less than 50%. This is unsurprising since we choose these quality variables to capture different aspects of the provision of primary care. The highest correlation is between the population achievement and the total QOF points. The GPPS variables have a correlation coefficient of 0.32. The low correlation between the satisfaction of patients with the ability to book an urgent appointment (within 2 days) and the ability to book an advance appointment (more than 2 full weekdays in advance) indicates that practices might have different management strategies regarding those types of appointments.

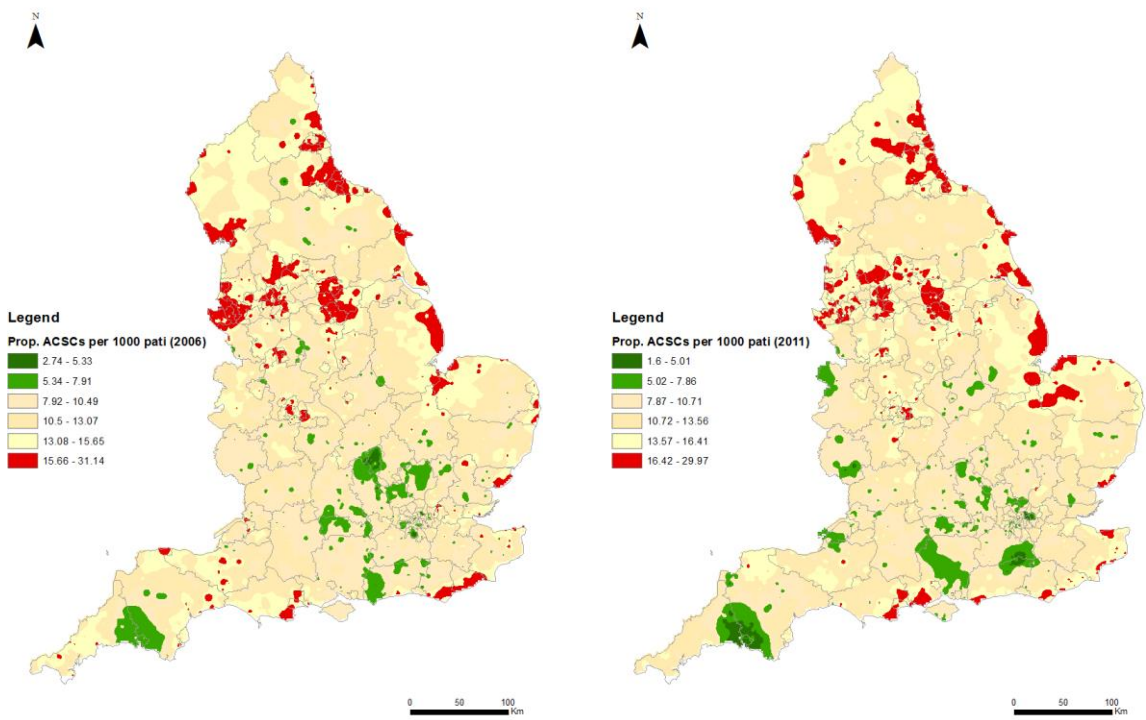
[52] Since we are estimating a spatial balanced panel model, we dropped 3936 observations for practices that were not open for the whole period. We have also dropped six observations for a Practice located on the Isle of Scilly.

Table 3-2: Correlation between quality variables

	Proportion of ACSCs emergency admissions (in 1000s patients)	Population Achievement	Total QOF points	Urgent appointment
Population Achievement	-0.0567	1		
Total QOF points	-0.053	0.5038	1	
Urgent appointment	-0.0572	0.1717	0.2844	1
Advance appointment	-0.1416	0.1665	0.2229	0.3167

The maps at GP practice level using the Inverse Distance Weighting (IDW)[53] show the spatial pattern of the five quality variables we analyse. In all the figures below the intervals are set by the standard deviation, which highlights the areas that have two or more standard deviations from the average. Figure 16 shows that in the North, in red, more GP practices have a proportion of ACSCs per 1000 patients that is two or more SD higher than the average. In the North West, specifically in the Liverpool area there was an improvement in 2011. While in the South, the areas in green are formed by GP practices that have proportion of ACSCs per 1000 patients that is two or more SD lower than the average.

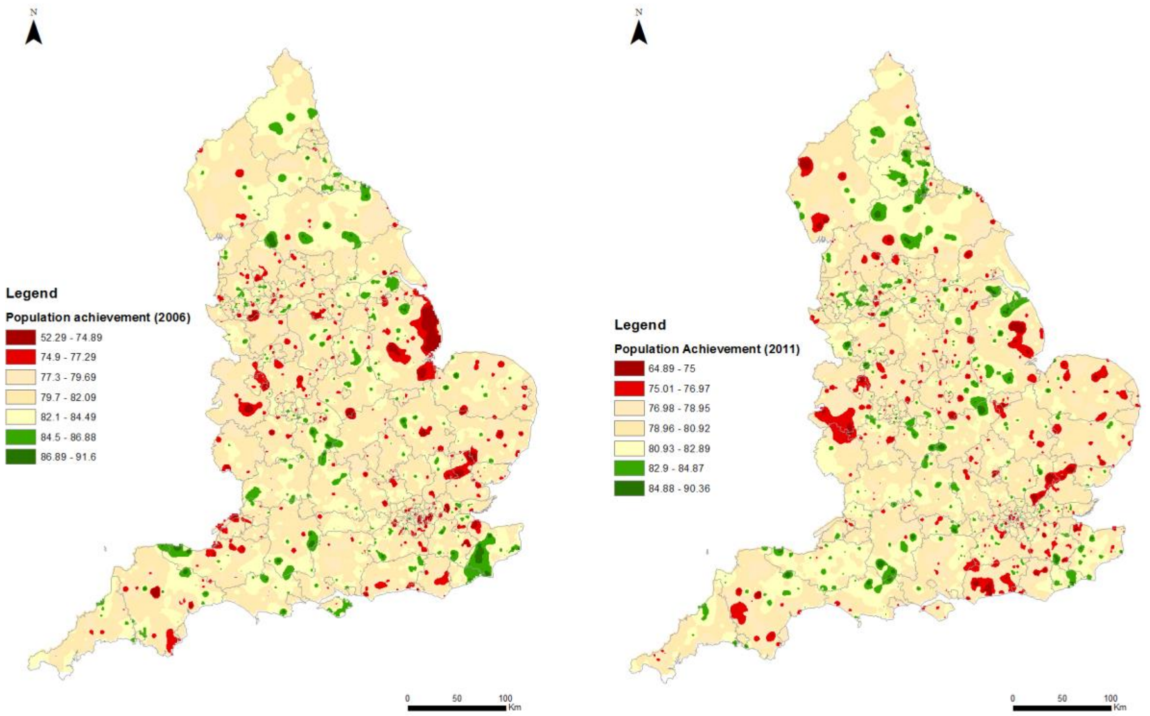
Figure 16 - The spatial pattern of Proportion of ACSCs emergency admissions in 2006 and 2011



[53] Inverse Distance Weighting (IDW) interpolation technique is explained in Section 1.4.

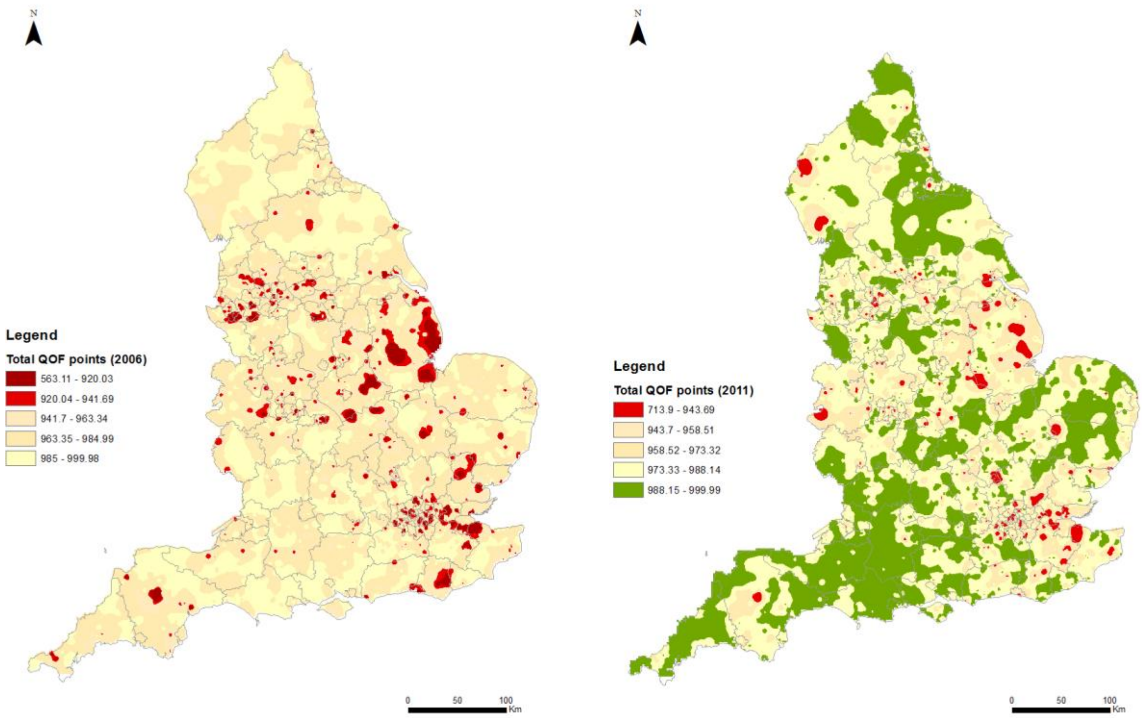
The population achievement has much less variation that the proportion of ACSCs per 1000 patients. Lincolnshire PCT area in 2006 and in the Shropshire County PCT area in 2011 area the areas highlighted in red in Figure 17 as the areas with a smaller population achievement.

Figure 17 - The spatial pattern of Population Achievement in 2006 and 2011



The total QOF points have a small variation. In Figure 18 we observe a big difference in the spatial pattern for 2006 and 2011 because in 2006 there are only GP practices with a total QOF points two or more SDs lower than the mean, while in 2011 there are GP practices with a total QOF points two or more SDs lower and higher from the mean. The London metropolitan area and the South East Coast are the areas in 2006 and 2011 in red, with a smaller (two or more SDs) than average total QOF points.

Figure 18 - The spatial pattern of Total QOF points in 2006 and 2011



Regarding the spatial pattern of the satisfaction with the ability to see a GP fairly quickly, i.e., to book an urgent GP appointment, the areas that are two or more SDs from the mean are scattered across England as reported in Figure 19, and there is a considerable change between 2006 and 2011. For example the London metropolitan area that was highlighted in 2006 for low satisfaction with the ability to book an advance appointment seemed (in red) to improve in 2011.

Figure 19 - The spatial pattern of satisfaction with ability to book urgent appointment in 2006 and 2011

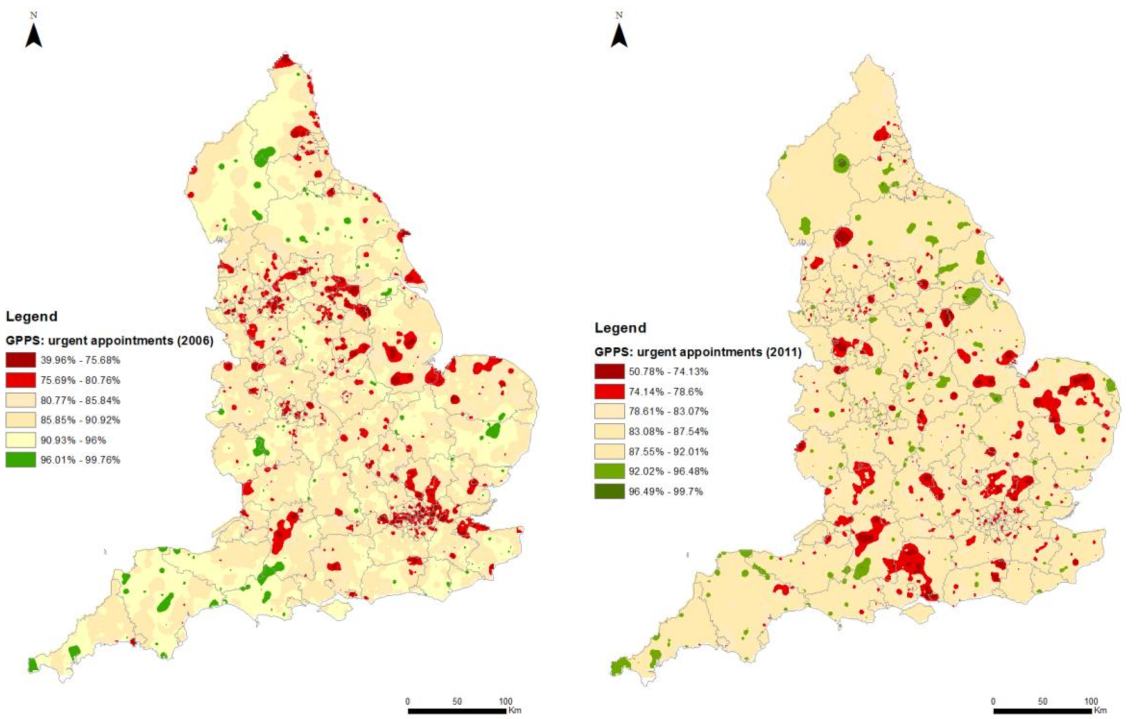
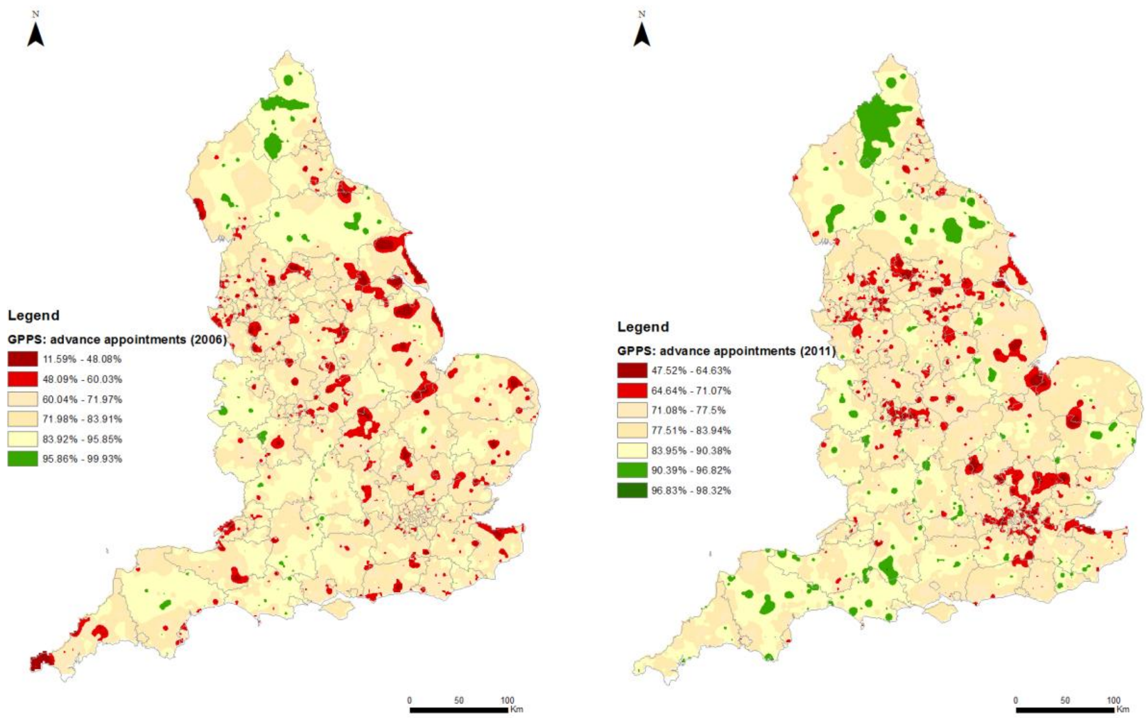


Figure 20 reveals the spatial pattern for the satisfaction with the ability to book advance GP appointments. The GP practices with higher satisfaction are more concentrated in the North East and South West and, contrarily to the satisfaction with the ability to book urgent GP appointments, the practices from London metropolitan area seems to be worst in 2011.

Figure 20 - The spatial pattern of satisfaction with ability to book advance appointment in 2006 and 2011



We had already reported that the quality measures are not highly correlated, but the figures above show that the quality measures present quite distinct spatial patterns. This assures us that if we find significant peer effects for all of the quality measures, it is not due to an underlying spatial pattern of quality across England.

3.5.2. Controls: GP practice and population characteristics

The number of GP practices within PCT boundaries (2004 or 2006) and within different radii varies greatly. Table 3-3 presents descriptive statistics for the number of GP practices within different peer group weight matrix specifications. There were on average 47 practices within a PCT in 2006.

This is important since variation on the size of the peer groups is necessary to allow the identification of the peer effect. The weighting by the size of other GP practices will be quite relevant for the PCTs with more GP practices, for example, when we use the number of surgeries, in the Hampshire 2006 PCT there are 98 GP practices with one surgery, 31 with 2 surgeries and 5 with 3 surgeries.

We define the contextual socio-matrices using the minimum distance between GP practices surgeries. There are on average 30 GP practices within a 5km radius. However, for 378 GP practices there are no other GP practices within 5km. This implies that the contextual effects of the GP practice and population variables for these GP practices is zero since there is not a supply of primary care and by default the GP practice variables will also be set to zero. To understand the impact of this definition, we also define the contextual group weight matrix for a 17.4km radius since this is the minimum distance for which all the GP practices will have at least one GP practice in their context. The average number of GP practices for 17.4 km is quite large, 229 GP practices, with a maximum of 1062. This is due to the metropolitan areas of London, Birmingham and Manchester.

Table 3-3: Number of GP practices within different networks

	N	Average	SD	P5	P95	Min	Max
Number of GPs Practices within							
PCTs 2006	152	46.46	22.69	19	88	8	134
Number of Peers within							
PCTs 2006	7062	56.47	25.46	23	98	7	133
5 km	7062	30.61	34.31	0	114	0	216
10 km	7062	97.28	118.24	4	474	0	527
17.4 km	7062	229.22	272.33	14	905	1	1062

The average quality across the peers is reported in Table 3-4. The overall average of the peers' quality is, not surprisingly, similar to the overall average reported in Table 3-1. However, as expected, the standard deviation is much smaller, especially the within standard deviation, meaning that for a GP practice the average quality of the peers will vary but will also be similar across the years.

Table 3-4: Descriptive Statistics of the Peers

	Overall	STD			Percentile		Average	
	Average	Overall	Between	Within	5	95	2006	2011
Proportion of ACSCs emergency admissions (in 1000s patients)	12.49	3.07	2.9	0.98	7.76	17.59	12.55	12.74
Population Achievement	79.06	4.41	0.99	4.3	68.45	83.11	80.45	79.56
Total QOF points	964.85	17.75	10.59	14.25	933.36	989.72	970.96	978.2
Urgent appointment	82.70%	4.55%	3.55%	2.85%	74.50%	89.62%	84.64%	83.52%
Advance appointment	72.13%	5.68%	4.77%	3.07%	62.91%	81.56%	72.09%	74.96%

Note: These descriptive statistics are for peer groups defined by 2006 PCTS with relationships weighted by FTE GPs. Include all 7062 GP practices in the 6 years panel, so 42372 (7062*6) observations

Table 3-5 presents the GP practice characteristics. In average there is a GP per 617 patients and 4.4 Full Time Equivalent (FTE) GPs per practice. The average proportion of GP salaried increased 45% between 2006 and 2011, being on average 19% of GPs in 2011. The proportion of female GPs also increase between 2006 and 2011 by 12.7%, with practices having on average 42% of Female GPs in 2011. On the contrary, the proportion of GPs qualified in Europe (not including the UK) decreased in 4.5%, with an average GP practice having 5% of GPs qualified in Europe (not including the UK).

Table 3-5: Descriptive Statistics: GP practice characteristics

	Overall	STD			Percentile		Average		Growth Rate *
	Average	Overall	Between	Within	5	95	2006	2011	
FTE GPs per 1000 patients	617.1	213.3	179.7	115.0	322.8	992.3	614.8	621.9	1.2%
FTE GPs	4.436	2.941	2.842	0.757	1	10	4.319	4.560	5.6%
PMS contract	0.428	0.495	0.487	0.089	0	1	0.430	0.415	-3.3%
Average GP age	48.258	6.807	6.200	2.810	39.3	62	48	48.4	0.8%
Proportion of Female GPs	0.397	0.257	0.235	0.103	0	0.8	0.374	0.421	12.7%
Proportion of GPs qualified:									
in the UK	0.705	0.363	0.351	0.092	0	1	0.707	0.703	-0.6%
in Europe	0.048	0.130	0.120	0.049	0	0.333	0.049	0.047	-4.5%
outside Europe	0.247	0.356	0.344	0.090	0	1	0.244	0.250	2.6%
Proportion of salaried GPs	0.169	0.217	0.183	0.118	0	0.6	0.131	0.191	45.3%

Note: These descriptive statistics are for peer groups defined by 2006 PCTS with relationships weighted by FTE GPs. Include all 7062 GP practices in the 6 years panel, so 42372 (7062*6) observations
* Growth rate from 2006 to 2011

The GP practice population characteristics are presented in Table 3-6[54]. On average a GP practice has a practice list with 7089 patients, which increased 4.7% between 2006 and 2011. We observed the highest growth in the number of patients under 4 years old (13.9% growth rate). A practice has on average 3.8% of its practice list residing in a Nursing Home, which decreased in 3.5% between 2006 and 2011. The population rate claiming incapacity benefit and severe disability allowance attributed to GP practice had the largest decreased, with a negative growth rate 17.9% between 2006 and 2011. The disease registers with the highest increase were the palliative care, with 127.4% increased, and the cancer register, with 104.6% increase. As expected, the between variation is higher than the within variation, i.e., there is more variation across the GP practices than within one GP practice along the of six years panel.

[54] Descriptive statistics on practices' patient list by gender and age band are reported in Appendix 3.4.

Table 3-6: Descriptive Statistics - Population characteristics

	Overall	STD			Percentile		Average		Growth Rate *
	Average	Overall	Between	Within	5	95	2006	2011	
Practice list (in 1000s)	7.09	3.99	3.969	0.459	2.27	14.28	6.916	7.244	4.7%
Prop of Patients residing in a Nursing Home	0.04	0.05	0.045	0.010	0.00	0.127	0.039	0.038	-3.5%
Socioeconomic deprivation									
Population rate claiming incapacity benefit and severe disability allowance	0.05	0.02	0.024	0.005	0.02	0.096	0.057	0.047	-17.9%
Education Skills and Training deprivation score	22.38	13.82	13.773	1.193	5.23	49.24	22.51	22.28	-1.0%
QOF disease registers (in 1000s)									
Coronary Heart Disease (CHD)	0.25	0.17	0.165	0.018	0.06	0.553	0.246	0.248	0.6%
Stroke and transient ischaemic attack	0.12	0.09	0.084	0.012	0.02	0.279	0.113	0.128	13.5%
Hypertension	0.94	0.58	0.572	0.083	0.26	2.013	0.871	0.999	14.8%
Chronic obstructive pulmonary disease (COPD)	0.11	0.08	0.080	0.016	0.02	0.263	0.099	0.123	24.5%
Hypothyroidism	0.21	0.14	0.135	0.025	0.05	0.461	0.178	0.229	28.3%
Cancer	0.1	0.07	0.068	0.030	0.02	0.238	0.064	0.131	104.6%
Mental Health	0.05	0.04	0.036	0.008	0.01	0.124	0.049	0.059	20.2%
Asthma	0.42	0.26	0.255	0.035	0.11	0.891	0.403	0.433	7.6%
Heart Failure	0.05	0.04	0.038	0.009	0.01	0.123	0.055	0.052	-4.4%
Palliative Care	0.01	0.01	0.009	0.008	0.00	0.029	0.007	0.015	127.4%
Dementia	0.03	0.03	0.028	0.008	0.00	0.087	0.028	0.039	39.6%
Atrial Fibrillation	0.1	0.08	0.074	0.012	0.01	0.238	0.091	0.109	20.5%
Diabetes Mellitus (over 17yrs old)	0.3	0.18	0.173	0.040	0.09	0.618	0.254	0.338	33.0%
Epilepsy (0ver 18yrs old)	0.04	0.03	0.028	0.004	0.01	0.097	0.042	0.045	7.5%
Chronic kidney disease (over 18 yrs old)	0.22	0.19	0.181	0.065	0.02	0.583	0.168	0.249	47.8%
Obesity (over 16 yrs old)	0.58	0.37	0.352	0.096	0.16	1.260	0.513	0.635	23.8%
Learning Disabilities (over 18 yrs old)	0.02	0.02	0.019	0.006	0.00	0.060	0.018	0.026	44.0%

Note: These descriptive statistics include all 7062 GP practices in the 6 years panel, so 42372 (7062*6) observation. *Growth rate from 2006 to 2011s

3.5.3 Contextual variables

When we specify the contextual group weight matrix using a 5km radius, there are 378 GP practices for which there is not another practice within the context, so the contextual characteristics are set to zero for those practices. This is reflected on Table 3-7 and on the table presented in Appendix 3.7 by the zero on the 5th percentile for all contextual GP practice and population characteristics. The overall averages are also smaller than the ones reported on Table 3-1. On average, a GP practice has within 5km other GP practices with 16% of salaried GPs and at least one GP practice has in its context an average of 36% of salaried GPs.

Table 3-7 : Contextual GP practice characteristics (using 5km contextual inverse distance weighted weight matrix)

	Overall	SD			Percentile		Average	
	Average	Overall	Between	Within	5	10	2006	2011
FTE GPs per 1000 patients	575.36	176.42	168.13	53.47	0	806.77	572.81	581.95
FTE GPs	4.19	1.99	1.95	0.39	0	7.63	4.08	4.32
PMS contract	0.42	0.31	0.31	0.04	0	1	0.42	0.40
Average GP age	45.86	11.41	11.35	1.17	0	54.22	45.65	45.98
Proportion of Female GPs	0.37	0.15	0.14	0.04	0	0.57	0.35	0.40
Proportion of GPs qualified:								
in the UK	0.65	0.26	0.26	0.04	0	1	0.65	0.65
in Europe	0.05	0.05	0.05	0.02	0	0.14	0.05	0.05
outside Europe	0.25	0.21	0.21	0.04	0	0.65	0.25	0.25
Proportion of salaried GPs	0.16	0.12	0.10	0.06	0	0.36	0.13	0.18

Note: These descriptive statistics include all 7062 GP practices in the 6 years panel, so 42372 (7062*6) observations

The context of some population characteristics also varies considerably from the average. On average a GP practice has within its context other practices with a practice list smaller than 7000 patients; however, there is at least one GP practice that has on its context a weighted average of practice list of over 11000 patients. The same is observed for Education Skills and Training deprivation score, which GP practices in the 95th percentile having a context with twice of the deprivation score (see Appendix 3.7).

3.5.4 Peer effects model results

Table 3-8 report the peer effect[55] for our preferred Spatial Durbin Model (SDM) when considering different peer effect socio-matrices, i.e, when defining peers as all other GP practices within the same Primary Care Trust (PCT) and weighting the GP practice influence power of peers by its list size, number of FTE GPs and number of branches/surgeries. The coefficient is always positive and significant, showing that peers influence positively in term of quality decisions. The peer effect seems stronger on the proportion of ACSCs emergency admissions, population achievement and the satisfaction with the ability to book an urgent appointment. Overall the peer effect is quite similar across the three peers' socio-matrices specifications.

Table 3-8: Spatial Durbin Model results - Peer effects coefficient for different peer group weight matrices

Peer group weight matrix with influence weighted by	Total QOF points (all domains)	Proportion of ACSCs emergency admissions (in 1000s patients)	Population Achievement (QOF)	Urgent appointment	Advance appointment
FTE GPs	0.395***	0.686***	0.454***	0.431***	0.367***
	(0.015)	(0.007)	(0.011)	(0.013)	(0.014)
GP practice List Size	0.411***	0.690***	0.469***	0.434***	0.373***
	(0.014)	(0.007)	(0.011)	(0.012)	(0.013)
Number of branches/surgeries	0.409***	0.682***	0.493***	0.453***	0.385***
	(0.013)	(0.007)	(0.011)	(0.012)	(0.014)

Table 3-9 reports effects of practice characteristics and contextual variables. The results of the peer effects models for the SDM with a peer group weight matrix using 2006 PCTs as peer groups and weighted by the number of FTE GPs, show that the peer effect is stronger for the proportion of ACSCs emergency admissions and population achievement, possibly because GPs could have discussed their management strategies regarding QOF during PCT and local medical committees meetings.

The coefficient of 0.454 for the peer effect of population achievement among practices implies that a standard deviation increase in the quality of the peers measured by an increase of 3.06% on the achievement of the QOF clinical domain implies an increase on GP practice *i* quality of 2.002%. A standard deviation increase in the total QOF points of the peers (about 18 QOF points) implies an increase of 7 total QOF points for GP practice *i*. The peer effect for the two GPPS variables is quite similar, a standard deviation increase in the average peer satisfaction with the ability to book an urgent (or advance) appointment (about 5%), would increase the satisfaction with the booking of urgent (or advance) in 1.96% (or in 2.08%) in GP practice *i*. The same is observed for ACSCs emergency admissions, the coefficient of 0. 686 implies that a increase in the quality of the peers, i.e., a decrease of 3 ACSCs emergency admissions per 1000 patients across

[55] Since the peer effects model is a linear model, the marginal effect is the linear regression coefficient.

the peers, implies a decrease on the quality of GP practice *i* relating to 2 additional ACSCs emergency admissions per 1000 patients.

The PMS contract increases significantly the satisfaction of patients with the ability to book advance GP appointments and decreases the population achievement and the total QOF points. This is explained by the different calculation of the QOF for GP practices with a PMS contract[56] and by the fact that a PMS contract may signal a population with special health needs. Most of the contextual GP practice and population characteristics are not significant. The coefficient of -0.00081 for the contextual FTE GPs per 1000 patients implies that a SD increase on the weighted average of FTE GPs in the context (176.42) would decrease the proportion of ACSCs emergency admissions (in 1000s of patients) by -0.14. The GPPS quality variables are included as explanatory and contextual variables for the ACSCs emergency admissions and QOF derived quality models and reciprocally the proportion of ACSCs emergency admissions and QOF derived quality variables are included as explanatory and contextual variables in the GPPS quality models. The quality variables are significant as explanatory but not as contextual.

[56] PMS practices received a smaller award for QOF to allow for the fact they may have been directly contracted to provide additional services to some type of patients.

Table 3-9: Peer effects models – quality as a decision variable

	Total QOF points	Proportion of ACSCs emergency admissions (in 1000s of patients)	Population achievement	Urgent appointment	Advance appointment
Peer Effect	0.395***	0.686***	0.454***	0.431***	0.367***
	(0.015)	(0.007)	(0.011)	(0.013)	(0.014)
GP practice own characteristics					
FTE GPs per 1000 patients	0.000768	0.000338***	-0.000133	0.0000249***	0.0000146***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
PMS contract	-9.795***	-0.0952	-0.789***	0.00252	0.00997*
	(1.503)	(0.108)	(0.197)	(0.003)	(0.004)
Average GP Age	-0.0686	-0.0562*	-0.125*	-0.000558	0.00183
	(0.396)	(0.028)	(0.052)	(0.001)	(0.001)
Urgent appointment	53.40***	-0.923***	0.142		
	(2.628)	(0.189)	(0.345)		
Advance appointment	25.33***	-0.372**	1.769***		
	(1.890)	(0.136)	(0.248)		
Population achievement		-0.00622*		0.0000972	0.000699***
		(0.003)		(0.000)	(0.000)
Contextual characteristics					
FTE GPs per 1000 patients	0.00186	-0.00081***	-0.000473	0.00000274	0.0000156*
	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)
PMS contract	-0.643	0.232	0.443	-0.000112	-0.0327***
	(3.243)	(0.233)	(0.425)	(0.006)	(0.008)
Average GP Age	-1.703	0.0532	-0.110	-0.00539**	0.00146
	(1.043)	(0.075)	(0.137)	(0.002)	(0.003)
Urgent appointment	6.355	0.222	-0.904		
	(5.531)	(0.396)	(0.725)		
Advance appointment	5.366	-0.0118	0.604		
	(3.761)	(0.271)	(0.493)		
Population achievement		0.00403		-0.0000400	0.000127
		(0.005)		(0.000)	(0.000)
Observations	42372	42372	42372	42372	42372
AIC	399995	177463	227905	-132085	-104431
BIC	400679	178164	228589	-131418	-103764
FE	Yes	Yes	Yes	Yes	Yes

Note: Number of observations = 42372. The models use the Peer group weight matrix on which influence is weighted by number of FTE GPs The models also include all the other GP practice and population characteristics and contextual characteristics presented in Table 3-5 and Table 3-6.
Standard errors in parentheses. *p<0.05, ** p<0.01, ***p<0.001.

The effect of a quality increase by peers will depend on the variation (SD) of the weighted average of peers' quality (reported in Table 3-4) and on the peer effect coefficient. We weighted the peers' group weight matrix because we believe that larger GP practices have a greater influence. If the larger GP practice in each peer group had an increase in quality of a SD, i.e., one single GP practice in each of peer groups had an increase of a SD as reported in Table 3-4, the weighted average proportion of ACSCs emergency admissions (in 1000s of patients) would decrease to 12.34, of the population achievement would increase to 79.49, the total QOF points to 966.35, the patients satisfied with the ability to book an urgent would increase to 85.52% and the patients satisfied with the ability to book an advance appointment would increase to 75.60%. As reported in Table 3-10, on average the impact of a standard deviation increase on the quality of the largest practice in a PCT would be small, an increase of 44.48 total QOF points on the largest GP practice only increase the weighted average QOF total points by 1.07 and it would imply an increase less than a QOF point on its peers.

Table 3-10: Impact of a standard deviation increase in the quality of the largest practice in each peer group

	Prop of ACSCs emergency admissions (in 1000s patients)	Population Achievement	Total QOF points	Urgent appointment	Advance appointment	N (PCTs * year)
Impact (change in weighted average * peer effect)	-0.13	0.12	0.42	1.18%	1.25%	912
Change in the weighted average	-0.18	0.27	1.07	2.74%	3.42%	912
Observed:						
PCT weighted average	12.52	79.23	965.28	82.78%	72.18%	912
PCT weighted SD	2.15	3.93	13.87	2.96%	3.27%	912
PCT weighted P5	9.54	69.34	941.72	77.35%	66.80%	912
PCT weighted P95	15.90	82.37	986.07	87.27%	77.46%	912
After a SD change in the largest GP practice:						
PCT weighted average	12.34	79.49	966.35	85.52%	75.60%	912
PCT weighted SD	2.14	3.93	13.85	2.90%	3.19%	912
PCT weighted P5	9.36	69.62	942.73	80.52%	70.38%	912
PCT weighted P95	15.69	82.64	986.85	89.90%	80.77%	912

The increase of a standard deviation in the performance of the largest practice in each PCT will have a different impact on each PCT as reported in Table 3-11. For example the impact of the standard deviation increase of 44.48 total QOF points implies an increase between 0.32 and 0.53 total QOF points.

Table 3-11: Variation on impact of the increase of a SD on the largest practice quality

		Proportion of ACSCs emergency admissions (in 1000s patients)	Population Achievement	Total QOF points	Urgent appointment	Advance appointment	N (PCTs * year)
Impact	Average	-0.13	0.12	0.42	1.18%	1.25%	912
	SD	0.02	0.02	0.07	0.19%	0.20%	912
	P5	-0.16	0.09	0.32	0.89%	0.95%	912
	P95	-0.10	0.15	0.53	1.48%	1.57%	912
Difference	Average	-0.18	0.27	1.07	2.74%	3.42%	912
	SD	0.03	0.04	0.17	0.43%	0.54%	912
	P5	-0.23	0.20	0.81	2.07%	2.59%	912
	P95	-0.14	0.33	1.34	3.42%	4.27%	912

If we consider an exogenous impact, e.g. new guidelines regarding phone and web contacts with patients, it would likely be reflected in the fixed effects of the GP practices. An increase in the fixed effect of a GP practice would have a direct and indirect effect, i.e., it would increase the quality of the GP practice and it would also increase the quality of the peers since from equation(17):

$$y = X\beta + \rho P y + CX\varphi + f + \varepsilon$$

can be re-written as:

$$y = (I - \rho P)^{-1}(X\beta + CX\varphi) + (I - \rho P)^{-1} f + (I - \rho P)^{-1}\varepsilon$$

and so the first derivative of *y* with respect to *f* is:

$$\frac{\partial y}{\partial f} = (I - \rho P)^{-1}$$

$(I - \rho P)^{-1}$ is a 7062 by 7062 matrix. As shown by LeSage (2009) and Elhorst (2014), the main diagonal elements of this matrix are the direct effects, while the off diagonal elements are the indirect effect, i.e. the effect of GP practice *i* on the peer GP practice *j*.

The impact of an increase on the fixed effect of the GP practice with more FTE GPs in a big PCT (with 88 GP practices), in a median PCT (with 42 GP practices) and in a small PCT (with 5 GP practices) is reported in Table 3-12. The direct and indirect effect of the unit increase in the FE is always bigger in small PCTs. While the average indirect effect of the larger GP practice in its peer group decreases with PCT size, the same does not happen with the total average indirect effects because this last effects included not only the indirect effect of GP practice *i* on GP practice *j*, but also the indirect effect of GP practice *j* on GP practice *k*.

Table 3-12: Impact of a unit increase in the fixed effect of the largest practice in the peer group

PCT type	N GP practices	Quality variable:	Larger GP practice			Total average indirect
		Direct	Indirect			
			Average	(min, max)		
		Total QOF points (all domains)				
Small	19	1.03	0.05	0.02	0.07	0.33
Median	42	1.01	0.02	0.01	0.03	0.23
Large	88	1.01	0.01	0.00	0.02	0.30
		Proportion of ACSCs emergency admissions (in 1000s of patients)				
Small	19	1.19	0.17	0.09	0.25	1.11
Median	42	1.04	0.04	0.02	0.09	0.64
Large	88	1.03	0.02	0.00	0.04	0.97
		Urgent appointment				
Small	19	1.03	0.05	0.02	0.06	0.29
Median	42	1.01	0.01	0.00	0.03	0.21
Large	88	1.00	0.01	0.00	0.01	0.27
		Advance appointment				
Small	19	1.04	0.06	0.03	0.08	0.38
Median	42	1.01	0.02	0.01	0.04	0.27
Large	88	1.01	0.01	0.00	0.02	0.35

However, when we estimate our preferred model for small and large PCTs (defined as PCTs without less and more than 46 GP practices respectively) separately, the results show stronger peer effects among GP practices in large PCTs.

Table 3-13: Peer effects models - for large and small PCTs

	Total QOF points	Proportion of ACSCs emergency admissions (in 1000s of patients)	Population achievement	Urgent appointment	Advance appointment
Peer Effect					
Large PCTs (46 or more GP practices)	0.409***	0.716***	0.486***	0.523***	0.423***
	(0.022)	(0.011)	(0.016)	(0.017)	(0.020)
Small PCTs (less than 46 GP practices)	0.370***	0.649***	0.396***	0.329***	0.302***
	(0.020)	(0.011)	(0.016)	(0.019)	(0.019)

Note: The number of observations is 25110 for Large PCTs and 17262 for Small PCTs. The models use the Peer group weight matrix on which influence is weighted by number of FTE GPs The models also include all the other public and contextual characteristics presented in Table 5-5 and Table 5-6.

The peer groups were established in 2006 after the PCTs were restructured as described in Section 2. We test if the strength of the peer effects changes over time; given that GP practices were assigned to the peer group in 2006 we expect the effect to be stronger in the last three years. Table 3-14 shows the results of the peer effects model (SDM) for the whole period, for 2006 to 2008 and 2009 to 2011. The peer effects are stronger in the latest period for all quality measures, expect for ACSCs emergency admissions, which indicates that the peer effect became weaker with the number of interaction the peers had across the years.

We obtain the same results when we use the 2004 PCTs as peer groups. We expect that over time peer groups defined by 2004 PCTs before the reorganisation would become less relevant to practice. Table 3-14 reports results using peer groups defined by 2004 PCTs. The effects for 2006-2011 are smaller than when we define peer group by 2006 PCT boundaries and becomes smaller over time.

Table 3-14: Peer effect coefficient for three periods of analysis

	Total QOF points	Prop of ACSCs emergency admissions (in 1000s)	Population achievement	Urgent appointment	Advance appointment
Peer Effect using 2006 PCTs					
2006 to 2011	0.395***	0.686***	0.454***	0.431***	0.367***
	(0.015)	(0.007)	(0.011)	(0.013)	(0.014)
2006 to 2008	0.362***	0.691***	0.227***	0.317***	0.289***
	(0.021)	(0.010)	(0.023)	(0.021)	(0.021)
2009 to 2011	0.390***	0.590***	0.244***	0.439***	0.374***
	(0.020)	(0.014)	(0.016)	(0.017)	(0.019)
Peer Effect using 2004 PCTs					
2006 to 2011	0.305***	0.624***	0.358***	0.341***	0.284***
	(0.012)	(0.006)	(0.010)	(0.010)	(0.011)
2006 to 2008	0.277***	0.631***	0.181***	0.223***	0.206***
	(0.018)	(0.009)	(0.019)	(0.017)	(0.017)
2009 to 2011	0.288***	0.508***	0.196***	0.366***	0.282***
	(0.017)	(0.012)	(0.014)	(0.014)	(0.016)

Note: Number of observations = 42372 for 2006 to 2011 model, 35310. The models use the Peer group weight matrix on which influence is weighted by number of FTE GPs. The models also include all the other GP practice and population characteristics and contextual characteristics presented in Table 3-5 and Table 3-6

The distance between practices can be small or large depending on their location. An urban practice is likely to have other practice nearby while the same is not true for a practice in a rural location. If test if practices influence other nearby practice irrespectively of their PCT membership. We use as peer groups all practices within 5km for urban GP practices and within 17.4 km for rural GP practices, and weighed their relationship between practices by their size (number of GPs).

The results displayed in Table 3-15 show that the peer effect is quite smaller than when we specified the peer groups by PCT membership (see Table 3-9). This corroborates our hypothesis that the GP practices peers are define by PCT membership rather than distance. Nevertheless, GP practices that close by (within 1km) are likely members of the same PCT.

Table 3-15: Peer effect model - using distance to specify peer groups

	Total QOF points	Prop of ACSCs emergency admissions (in 1000s)	Population achievement	Urgent appointment	Advance appointment
Peer Effect	0.149***	0.426***	0.233***	0.198***	0.132***
	(0.008)	(0.006)	(0.008)	(0.008)	(0.008)

Note: Number of observations = 42372. The models use the peer group weight matrix on which influence is weighted by number of FTE GPs The fixed effect models also include all the other GP practice and population characteristics and contextual characteristics presented in Table 3-5 and Table 3-6.
Standard errors in parentheses. *p<0.05, ** p<0.01, ***p<0.001.

In Section 5.3., we highlighted that when using the contextual group weight matrix defined by 5km radius, there are 378 GP practices for which there is not another practice within the context, so the contextual characteristics are set to zero for those practices. We test if this has major implications we estimate the peer effects model using a contextual group weight matrix defined by 17.4km radius, which is the minimum distance that allows all the GP practices to have at least another practice in the context. The results reported Appendix 3.8 Table A. 25 are very similar to the ones in Table 3-9. The peer effects are slightly smaller while the contextual effects are stronger and significant. The peer effect on a SDM model when we drop the 378 GP practices that do not have another practice within 5km is slight smaller (Appendix 3.8

Table A. 26) than in our preferred model (shown in Table 3-9).

If we drop the contextual effects and estimate a Spatial Autoregressive Model (SAR) the peer effects for the three different peer effects weight matrices and five quality measures reported in Table 3-16 are quite similar, slightly higher, to those reported before for the SDM model in Table 3-8. In fact, in a SAR model the peer effects incorporate the contextual effects.

Table 3-16: Spatial Autoregressive Model - Peer effects coefficient for different peer socio-matrices

Peer group weight matrix with influence weighted by:	Total QOF points (all domains)	Prop of ACSCs emergency admissions (in 1000s)	Population Achievement (QOF)	Urgent appointment	Advance appointment
FTE GPs	0.398***	0.688***	0.459***	0.454***	0.378***
	(0.014)	(0.007)	(0.011)	(0.012)	(0.013)
GP practice List Size	0.692***	0.413***	0.473***	0.458***	0.384***
	(0.007)	(0.014)	(0.011)	(0.012)	(0.013)
Number of branches/surgeries	0.683***	0.496***	0.411***	0.475***	0.398***
	(0.007)	(0.011)	(0.013)	(0.012)	(0.014)

Standard errors in parentheses. *p<0.05, ** p<0.01, ***p<0.001.

3.5.5 Falsification test

When we perform the double randomization of GP practices into different 2016 PCTs and into other surgery locations, the coefficients on the GP practice own GP practice and population characteristics are similar to the baseline model, however, as expected, the "fake peer" effect is not significant in any of the quality models as reported in Table 3-17.

Table 3-17: Falsification test - Spatial Durbin model with random peers and context

Peers group weight matrix with influence weighted by	Total QOF points (all domains)	Prop of ACSCs emergency admissions (in 1000s)	Population Achievement (QOF)	Urgent appointment	Advance appointments
FTE GPs	0.0120	-0.0412	-0.00477	0.0203	-0.00223
	(0.024)	(0.023)	(0.018)	(0.020)	(0.020)
GP practice List Size	0.00677	-0.0306	-0.00807	0.0211	0.00120
	(0.024)	(0.024)	(0.019)	(0.020)	(0.020)
Number of branches/surgeries	-0.0148	-0.0233	-0.0382	0.0230	0.00711
	(0.022)	(0.023)	(0.021)	(0.021)	(0.021)

The contextual effects are almost all not significant as reported in Table 3-18. This is reassuring and provides confidence that the above reported peer effects represent real effects.

Table 3-18: Spatial Durbin Model - Falsification test - using random peers and context

	Total QOF points	Prop of ACSCs emergency admissions (in 1000s)	Population achievement	Urgent appointment	Advance appointment
Peer Effect	0.0120	-0.0412	-0.00477	0.0203	-0.00223
	(0.024)	(0.023)	(0.018)	(0.020)	(0.020)
GP practice own characteristics					
FTE GPs per 1000 patients	0.000987	0.000183	-0.000171	0.0000275***	0.0000136***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
PMS contract	-10.34***	-0.0691	-0.726***	0.00306	0.00803*
	(1.506)	(0.116)	(0.200)	(0.003)	(0.004)
Average GP Age	-0.0296	-0.0191	-0.135*	-0.000865	0.00169
	(0.400)	(0.031)	(0.053)	(0.001)	(0.001)
Urgent appointment	55.55***	-1.261***	-0.148		
	(2.618)	(0.201)	(0.347)		
Advance appointment	25.84***	-0.518***	1.807***		
	(1.895)	(0.146)	(0.251)		
Population achievement		-0.00805**		0.0000684	0.000698***
		(0.003)		(0.000)	(0.000)
AIC	400630	183238	229375	-130901	-103684
BIC	401313	183939	230059	-130234	-103018
FE	Yes	Yes	Yes	Yes	Yes

Note: Number of observations = 42372. The models also include all the other GP practice and population characteristics and contextual characteristics presented in Table 3-5 and Table 3-6. However, the contextual characteristics are different because they derive from a fake contextual weight matrix. Standard errors in parentheses. *p<0.05, ** p<0.01, ***p<0.001.

When we use our peer effects approach, i.e., the Spatial Durbin Model with the peers weighted matrix based on 2006 PCT membership and GP practice influence power proxied by practice size and the contextual matrix based on the location of GP practice surgeries, but using the average age of GPs within the practice as a decision variable, the peer effect is also not significant as reported in Table 3-19.

Table 3-19: Falsification test: using average GPs age in the practice as a decision (dependent) variable

Peers group weight matrix with influence weighted by :	Peer effect	
GP practice List Size	0.00572	(0.021)
FTE GPs	0.0149	(0.023)
Number of branches/surgeries	0.0112	(0.023)

This again reassures and provides confidence that the peer effects reported from Table 3-9 to Table 3-16 represent real effects.

3.6 Discussion

The importance of peer effects among GP practices is related to the use of this channel to promote quality clinical practice, guidelines and incentives. We tested the existence of this effect by using an empirical strategy that allows the identification of the parameters of interest, namely the peer effect, which overcomes the Manski (1993) "reflection problem" by imposing restrictions regarding the peer and contextual group. Using a spatial econometric model we disentangled for the first time, the influence of peers and contextual effects on GP practice quality decisions. The model took into account the identification restrictions highlighted by Blume et al (2015), Angrist (2014) and others. The sensitivity analysis and the falsification tests show that the results are robust and that peer effects are important. The Primary Care Trust re-organisation in 2006, allowed us to identify 152 exogenous peer groups, which are groups formed by the Department of Health without an enrolment choice for GP practices. Since some GP practices will be more influential, we weighted the peers' relationship by GP practice size. This implies that the local health authorities might target larger GP practices to spread quality decisions.

The fact that we used a balanced panel model implies that we dropped from this study, practices that were open for just a part of the study period (2006/7 to 2011/12). Unbalanced spatial panel models are still being developed. The difficulty in the development of these models is the increase in the computation time due to a different weight matrix for each period. However, the primary care market is quite stable. GP practices are in the market for a long time, with just a small number of GP practices that open and close each year.

The positive and significant peer effects that emerge among GP practices within the same PCT indicates that GP practices are influenced in their quality decisions by their peers' quality decisions. When we consider a targeted increase in the quality of the PCTs' largest practice, the impact of that increase on its peers was small. Nevertheless, these results are important to show how quality decisions will spread among peer groups of GP practices.

Peer effects are an interesting mechanism of knowledge transfer. Their existence between GP practices is relevant for the adoption of guidelines and technologies. Inviting the GP practices with greater influence to pilot schemes, will not just increase the quality of the practice itself but also spill over to its peer practices, benefiting more patients. The local health authorities have been reorganised again in 2013 to smaller groups (Clinical Commissioning Groups: CCGs). Practices could influence which CCG they were assigned to. In future work it would be important to understand if the peer effects are stronger among these new peer groups, considering the endogeneity of the peers' network formation.

4. Competition and quality: Evidence from the English family doctor market

4.1. Introduction

Quality competition is pervasive and important. Quality is a key component of service products such as, transport, telecoms, banking, education and healthcare. Competition on quality is a central component of industrial organisation (product differentiation, bundling, price discrimination). But the relationship between quality and competition is hard to study empirically. Quality is multi-dimensional and often difficult to measure, product prices and quality are typically set together and market structure and quality are jointly determined. Empirical studies on quality competition are relatively scarce.[57]

One area where an understanding of the empirical relationship between quality and market structure is central is healthcare. Healthcare accounts for over 10 percent of the economy of most developed countries. The quality of care can have large, and long-lasting, effects on the health of the consumer. Injecting greater competition into heavily regulated healthcare markets is a popular reform model in many jurisdictions (Gaynor, Propper, & Seiler, 2016; Glied & Altman, 2017; OECD, 2012; Siciliani, Chalkley, & Gravelle, 2017). But this takes place against the backdrop of a long-term trend of provider consolidation in healthcare markets (Fulton, 2017; Gaynor & Town, 2011). Understanding the relationship between quality and market structure in healthcare is therefore important.

Theoretically, the relationship between competition and quality is ambiguous (Gaynor & Town, 2011), even in markets where price is regulated (Brekke Kurt, Siciliani, & Straume Odd, 2011; Gravelle, 1999). Empirically, the bulk of the literature on the relationship between competition and quality in the hospital sector points towards a positive relationship where price is regulated (Gaynor & Town, 2011).[58] In this paper we examine the relationship between quality of care and market structure in local physician markets. This has been much less researched and the empirical evidence is scarce (Gaynor & Town, 2011). Yet, as in the hospital sector, physician markets are becoming more concentrated and much of this is below the radar of regulatory authorities (Capps, Dranove, & Ody, 2017). If effort is to be spent promoting competition there is a need to know whether this will increase quality.

We study family physician firms (known as general practices) in the English National Health Service (NHS). General practices provide primary care (healthcare outside the hospital or nursing home setting) and act as gatekeepers to almost all other services provided by the NHS. They are small businesses, typically run by a partnership of 4-5 as general practitioners (GPs) who employ nursing and other staff. Almost all practices operate in a single small local market. In common with most European countries, care is free at point of use. Payments to practices are determined nationally and the institutional set-up gives practices have an incentive to compete for patients. Patients can only register with one practice and around 75% of practice revenue comes from the number of patients registered with the practice. As patients face zero prices, any competition has to be in terms of quality. Figure 21 shows the market structure for England (as measured by the Herfindhal-Hirschman Index (HHI) of concentration of practice registrations) across the small

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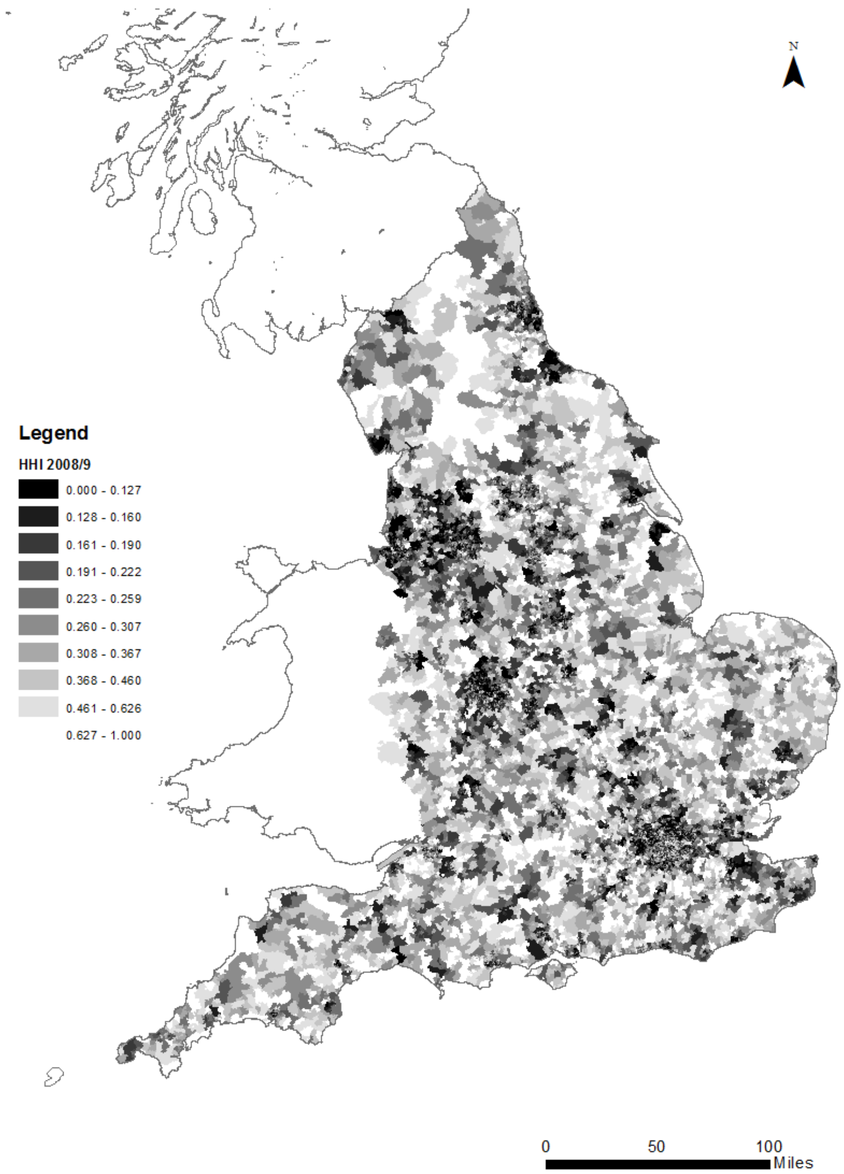
[57] Examples include the media (Berry & Waldfogel, 2001; Fan, 2013), airlines (Mazzeo, 2002), supermarkets (Matsa, 2011).

[58] For recent evidence from the UK see Cooper, Gibbons, Jones, and McGuire (2011), Gaynor, Moreno-Serra, and Propper (2013),Bloom, Propper, Seiler, and Van Reenen (2015). Gravelle , Moscelli, Santos, and Siciliani (2014) find more mixed results.

areas from which GP practices draw their potential patients. The figure shows considerable variation in market concentration. Some markets are unconcentrated, others are highly concentrated. Markets in urban areas are, as expected, much less concentrated than those in rural areas but even within urban and rural areas there is considerable variation. In this setting, patient choice of practice has been shown to be responsive to quality (Santos et al., 2017). Thus, the pre-requisites for competition between providers to improve quality exists: the question is whether it does.

Figure 21- Family doctor market structure, England 2008



Notes: HHI is sum of squared shares of Lower Super Output Area populations registered at each general practice in England. LSOAs have mean populations of 1500. Shades are deciles of HHI distribution

To answer this, we study the universe of all GP practices (over 8000) in England between 2005 and 2012.[59] We use seven practice-specific measures of quality, some relating to the quality of medical care as judged by national clinical standards and others relating to patient reported satisfaction with their chosen practice. Our empirical strategy is to exploit changes in market structure at the local level. We primarily focus on exploiting within-practice changes in the number of GPs in other local rival practices. In addition to using practice fixed effects to control for time-invariant practice and local area unobservables, we also control for potential selection of practice by patients and selection of patients by practices. This design allows us to address the potential endogeneity which would arise if areas with better amenities attract more doctors and/or healthier patients for whom it is easier to achieve higher clinical quality. Our large sample allows us to examine heterogeneity with respect to initial levels of potential competition and quality. Finally, we also exploit a policy change that increased supply of physicians in some areas but not in others.

Our results show that an increase in the number of GPs in rival practices is associated with an increase in both clinical quality and patient reported quality. None of our results suggest that greater competition reduces quality. The effect of increased competition is larger for practices that are producing lower quality, but the impact of competition is similar across more or less concentrated markets. However, in common with results from studies of pay for performance and other policies to improve the quality of care provided by family doctors (Scott et al., 2011), we find the magnitude of the effect of a change in competition is not large.

Our findings contribute directly to the literature on quality competition in physician markets and to the debate about whether policies to strengthen competition in these markets should be pursued. In the European setting where there is no price competition amongst providers (providing the ideal setting for examining pure quality competition), there are few studies of the physician market and quality. In the main this literature lacks the exogenous variation needed for causal inference, uses a limited number of outcomes measures, some of which have an ambiguous relation to quality, or analyses small area, rather than firm (physician practice) variation.

Schaumans (2015) and Pike (2010) exploit only cross–sectional variation. The former examines the effect of competition in the Belgian family doctor market on pharmaceutical prescriptions. Prescriptions have no direct effect on practice revenue or cost but may make the patient feel that the doctor is taking their health concerns seriously. The unit of analysis in Schaumans (2015) is the small area and she finds little effect. Pike (2010) undertakes analysis at the physician practice level and, as our study, uses a distance based measure of competition and examines a subset of the quality measures we examine here. He finds that practices with more nearby practices have higher quality. However, as the data is cross-sectional in both cases, the associations found may reflect many other factors than local competition between doctors.

Brekke Kurt, Holman, Monstad, and Straume Odd (2017) have rich data at the individual physician level and exploit the fact that Norwegian doctors practice in different settings (their own offices and other clinics). They argue that this means that they face greater competition for patients when they practice in their own offices and thus will provide higher quality in this setting. They examine only one outcome: the dispensation of 'sick notes', which are documents which allow individuals to take time off work with no financial penalty. The setting provides a very robust

[59] All our data are for UK financial years, which run from 1 April to 31 March.

design which allows controls for physician effects, patient effects and physician-patient pair effects. But the interpretation of the results as indicative of the relationship between competition and clinical quality is more questionable. The outcome measure is not a measure of clinical quality but one of patient-rated quality which, at the societal level, may be rather an ambiguous measure if physicians over-prescribe notes to attract patients. More problematic is that the definition of competition: what they examine is not local competition but physician behaviour under different contracting arrangements.

The closest research to the present paper is Dietrichson, Ellegård, and Kjellsson (2016). This exploits a reform in Swedish primary care which led to greater entry of providers in municipalities where there was lower availability of providers pre-reform. The authors study both clinical and patient satisfaction measures of quality at the municipality level. They find small improvements in subjective overall quality measures, but no change in avoidable hospitalisations or patient satisfaction with access to primary care. However, although their policy experiment provides a nice context, their unit of analysis is not the firm (the practice) but the municipality. This means that they cannot rule out the possibility that average municipal quality was affected by other municipality level factors, such as an overall increase in the physician-patient ratio, rather than increases in competition facing providers.

Research on market structure in physician markets where price and quality are set simultaneously is mainly from the USA and is also limited compared to studies of hospital markets. The research primarily focuses on the impact on prices rather than quality (Baker, Bundorf, Royalty, & Levin, 2014; Sun & Baker, 2015). It also has to address the fact that prices are increasingly set by complex bargaining between insurers and hospital (see, for example, Clemens & Gottlieb, 2016). The European setting, in which prices are set nationally and patients are generally fully insured, provides a cleaner setting for an examination of the relationship between quality and market concentration in small localised physician markets. It is also particularly relevant to discussions about increasing the role for regulated prices as a way of promoting quality competition in the US healthcare market (Glied & Altman, 2017).

The next Section provides a brief account of the institutional framework for English general practices and of policies potentially affecting the amount of effective competition that practices face. Section 4.3 sets out the estimation methods and strategies for identifying the effect of competition. Section 4.4 describes the data. Results are in Section 4.5. and Section 4.6 concludes.

4.2. Institutional background

The English NHS provides health care which is tax-financed and free at point of use.[60] NHS primary care is provided by family doctors (GPs) organised into small groups, known as general practices. All individuals resident in England are entitled to register with a general practice, and have incentives to do so, as the practices both provide primary care and act as the gatekeeper for elective (non-emergency) hospital care.

[60] A small charge is made for dispensed medicines, but because of exemptions on grounds of age or low income, this is only applied to around 10% of prescriptions.

There are over 8000 general practices in England with an average of just over 4 (4.2) GPs and 6,600 patients (Health and Social Care Information Centre, 2015).[61] Most are located at a single site though around 15% have more than one. Almost all are owned by partnerships of their GPs. Larger groups and chains have been absent until recently and are still rare. The NHS contracts with the practice rather than the individual GPs. Practices are paid by a mix of lump-sum payments, capitation, quality incentive payments, and items of service payments. Around 75% of practice revenue varies with the number of patients registered with the practice.[62] Practices are reimbursed for the costs of their premises and information technology but fund all other expenses, such as hiring nurses and clerical staff, from their revenue. A very rough estimate, under the assumption that average revenue and cost per patient are constant, is that an additional patient registered with the practice produces revenue of £135, expenses of £80, and net income of £55 per practice partner.[63] Thus practices have an incentive to attract patients.

The operation of practices is overseen by area-based NHS administrative bodies known, during the period of our study, as Primary Care Trusts (PCTs). PCTs contained on average 350,000 patients and 55 practices. Practices are required to accept all patients who live within their agreed catchment area set by agreement with their PCT unless they notify the PCT that they are full and temporarily not accepting patients for between 3 and 12 months. Around 2% of practices have such closed lists at any one time.[64,65] However, while some practices may be temporarily closed, this does not mean there is no choice for patients. On average patients in small homogenous geographical areas that contain on average 1500 people are registered with 13

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[61] There are some single-handed GPs (i.e. practices with only one GP) but there are a minority. GPs do not work across practices.

[62] Over 50% is from capitation payments determined by a national formula which takes account of the demographic mix of practice patients and local morbidity measures. Quality incentives from the national Quality and Outcomes Framework (QOF) (Roland 2004) generate a further 15% of practice revenue and for a given quality level QOF revenue increases with the number of patients. Practice payments for providing specific services including vaccinating and screening target proportions of the relevant practice population also increase with the total number of patients registered with the practice.

[63] In 2009/10 there were 26,420 GP contractors (i.e. joint owners rather than salaried employees) in England with average gross income £287,100l, expenses of £168,700 and net income of £109,400. There were 2066 registered patients per GP contractor. See: GP Earnings and Expenses 2009/10, http://www.hscic.gov.uk/pubs/gpearnex0910 (last accessed 10 March 2015); General and Personal Medical Services, England 2001-2011, http://www.hscic.gov.uk/catalogue/PUB05214 (last accessed 10 March 2015).

[64] House of Commons, Hansard Written Answers for 28 Apr 2008.

[65] Practices with closed lists are not eligible for certain types of payments for providing additional services. Consequently some practices designate themselves as 'open but full'. Estimates suggest that in 2007 up to 10% of practices were 'open but full' at any time (National Audit Office, 2008) but, since the designation is unofficial and has no legal force, its extent and effect on patients signing up to the practice are unclear. GPs can deregister patients if there is a fundamental breakdown in the doctor-patient relationship. It has been estimated that each year 0.1% of patients are deregistered (Munro, Sampson, Pickin, & Nicholl, 2002). If a patient cannot find a practice prepared to accept them, they can ask their PCT to find them a practice, and PCTs can assign patients to practices. Around 0.5% of patients are assigned to practices (Audit Commission, 2004).

different practices.[66] This means practices potentially face a high degree of competition for patients. In Section 3 below, we show that over 65 percent of practices have more than 10 potential rival GPs located in practices within 1km, with some having as many as 50 or 60.

Government policy over a relatively long period has been to increase competition between practices. The national body which regulated the location of general practices was abolished in 2002 and replaced by a tendering process, run by the local administrative bodies responsible for over-seeing health care delivery, and intended to make it easier for new practices to be established. Restrictions on the type of organisation which could provide general practice services were also eased in 2004, so that general practices can be run by other NHS institutions such as hospitals, and by private companies, as well as traditional partnerships of GPs. Practices cannot advertise for patients but, in a drive to increase choice by patients in all areas of English healthcare, the national government established a website in 2007 (known as NHS Choices). The website contains information on the characteristics of general practices, including the specialist clinics they offer and results from patient satisfaction surveys. These data are published with the express aim of increasing choice and, through this, improving quality.[67]

During our sample period there was a major national policy initiative to increase the supply of family doctor care. Known as the Equitable Access to Primary Medical Care (EAPMC) policy, the aim was to increase supply in the 38 PCTs (out of a total of 151 PCTs) in which there was evidence of a shortage of GPs relative to patient need (Asaria, Cookson, Fleetcroft, & Ali, 2016; Department of Health, 2007). The policy, funded with £250 million from central government, operated from financial year 2008 to 2011 and increased the supply of GPs in the 38 EAPMC PCTs relative to other PCTs (Asaria et al., 2016). We make use of the policy as one means of identifying the effect of increased competition.

4.3. Empirical strategy

We need to deal with three issues when estimating the impact of market structure on quality in health care markets, including those in primary care. First, measured quality of care may depend on the mix of patient type (case-mix) as well as the effort of the practice. Second, practice location may not be exogenous to the patient or the GP practice. Patients can choose practices and they may sort on unobservables. Practice location is chosen by the practice. As practices are not allowed to refuse patients from within their agreed catchment areas and practices are rewarded on the basis of performance as well as number of patients, it is possible that practices choose to locate in areas in which patients are easier to treat (typically those areas in which patients are healthier and more affluent). If so this will upwardly bias estimates of the impact of

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66 The area is the Lower Super Output Area (LSOA), discussed in more detail in section 4.3 below.

67 The NHS Choices website states: “The idea is to provide you with greater choice and to improve the quality of GP services over time, as GPs providing a good service are naturally more popular.”AboutNHSservices/doctors/Pages/patient-choice-GP-practices.aspx http://www.nhs.uk/ NHSEngland. http://www.nhs.uk/choiceintheNHS/Yourchoices/GPchoice/Pages/ChoosingaGP.aspx. Detailed information on performance of practices in an area under the national pay for performance scheme is also available via http://www.qof.ic.nhs.uk/search/ and information from surveys of patient satisfaction is available at http://www.gp-patient.co.uk/info/.

competition. Alternatively, if practices are less likely to enter near a practice which provides high quality, this will downwardly bias the estimated effect of competition on quality.[68]

We have a detailed set of patient characteristics (discussed in Section 4.4) which we can use to control for case-mix. However, because of potential selection by either patient or practice, the characteristics of patients in a practice may be endogenous. To deal with this, we adopt a number of strategies. We first compare models with and without controls for the characteristics of patients on the practice list. If the results are robust to exclusion of these measures, it suggests that selection on observables is not a problem and hence possibly there may be no bias from selection on unobservables. Second, we replace the actual practice case-mix with measures of the same characteristics for the local population from which the practice could potentially draw its patients. Third, as our data is a panel we control for practice fixed effects, which controls for non-time varying attributes of the local population and other attributes of the local area that may attract or deter practices from locating there.

Although a fixed effects specification removes omitted variable bias due to the correlation of unobserved time invariant practice characteristics with quality and competition, it does not allow for the possibility that changes in competition are endogenous in that, for example, practices with lower quality are more likely to face new local rivals. We allow for this in two ways.

First, we undertake analyses using only those practices located in areas with homogeneous socio-economic characteristics. We argue that practice location and patient selection of practices in these homogenous areas is exogenous to amenities and unobserved population type, because the amenities and population type does not differ within these areas. Hence in such areas we can identify the effect of market structure by its within area variation (as in Gravelle, Scott, Sivey, & Yong, 2016). We therefore carry out a sub-set of analyses only for practices in small geographical areas characterised by low variance in their population type as measured by small area social and economic deprivation of the population (more details are provided in Section 4.5.4).

Second, we exploit the EAPMC policy. As noted above, the policy increased the number of GPs in EAPMC PCTs relative to non-EAPMC PCTs (Asaria et al., 2016). More importantly, it increased our measure of competition: practices located in EAPMC PCTs faced a larger increase in the number of GPs in nearby rival practices than practices located outside EAPMC PCTs (Appendix 4.4 Table A. 31). We use this policy initiative to test for the effect of increasing the number of rivals. To do this, we estimate a difference-in-difference model comparing the changes in quality in practices before and after the introduction of the EAPMC in the 38 EAPMC PCTs with the changes in quality in practices in 113 non-EAPMC PCTs. To allow for the fact that treated PCTs are not random (by definition they are those where there was thought to be a shortage of family doctor care), we also examine just those practices located either side of the border of an EAPMC PCT. Details of how we do this are provided in Section 4.5.3 below.

Our baseline model is

$$y_{jt} = \beta_t + \delta m_{jt} + \mathbf{x}'_{jt}\boldsymbol{\beta}_x + \alpha_j + \varepsilon_{jt} \tag{24}$$

[68] This is similar to the problems encountered in estimating the effects of hospital competition (see, for example, Kessler and McClellan (2000) for the USA and Gaynor et al. (2016) for the UK).

where y_{jt} is the quality of practice *j* in year *t*, β_t is a year effect common to all practices, m_{jt} is the measure of competition facing practice *j* in year *t*, $\mathbf{x}_{jt}$ is a vector of case-mix controls measured either for the practice list population or for the local population, and α_j is the time invariant practice fixed effect. The data period is eight financial years 2005-2012. We estimate this model for all practices in England and also for practices located in homogeneous area. The coefficient of interest is δ.

To exploit the EAPMC policy, we estimate intention to treat difference-in-difference models:

$$y_{jt} = \beta_0 + \beta_1 D_t^A + \delta D_j^E D_t^A + \beta_t + x_{jt}\beta_x + \alpha_i + \varepsilon \qquad (25)$$

where D_j^E is a dummy for the practice being in one of the EAPMC PCTs, D_t^A is a dummy for a year after the introduction of EAPMC (2009 onwards). To isolate the effect of the policy, we estimate the model for a shorter period than model (24). We use the three years before the policy and three years after and drop the year of the policy introduction, so the data covers financial years 2005 to 2011, omitting 2008. We have included fixed effects and time effects. Standard errors are clustered at PCT level. The coefficient of interest is δ.

The selection by the Department of Health of PCTs to be in EAPMC was based on the measures reported in the NHS Next Stage Review Interim Report (http://www.nhshistory.net/darzi-interim.pdf). The Department of Health used a range of indicators to determine those PCTs with greatest needs[69] namely on measures of primary care capacity (FTE GPs and FTE Practice Nurses per 100,000 weighted population), health outcomes (male life expectancy, female life expectancy, cancer mortality amongst under 75s, cardiovascular mortality amongst under 75s, health domain of the index of multiple deprivation, percentage of patients with diabetes whose HbA1c is 7.5 or less and percentage of patients with hypertension whose BP reading is 150/90 or less) and patient satisfaction (percentage of patients seen within 48 hours, percentage of patients able to book an appointment more than two days ahead, percentage of patients satisfied with their practice telephone system, percentage of patients able to see a specific GP and percentage of patients satisfied with practice opening hours). We argue that this implies that any increase in competition in the EAPMC PCTs were therefore not related to unobserved time varying factors affecting quality, such as changes in the population types which affect the attractivess of an area to GPs and are correlated with patient outcomes.

4.4. Data

4.4.1. Quality

To capture the multi-dimensional nature of health care quality we use several measures of clinical quality and patient reported experience.

[69] The standardised distance from the England average was calculated in each indicator for each PCT. These distances were assigned a different weight for each of the domains, specifically, 60 per cent for capacity, 30 per cent for health outcomes and 10 per cent for patient satisfaction. Each PCT was then ranked based on the sum of the weighted differences.

Clinical quality. We measure the clinical quality of care in the practice with data from the national Quality and Outcomes Framework (QOF)[70]. Almost all practices take part in the QOF, which rewards practices for achievement on a large number of quality indicators. Better achievement increases the number of QOF points (up to a maximum of 1050 in 2004-2005 and 1000 thereafter) and practices are paid an average of £125 per point. We use the percentage of total available points which the practice achieved as a measure of quality (*QOF points*). It has the merit of being simple and readily observable.

However, total QOF points has some drawbacks as a measure of clinical quality. First, only around two thirds of the points are for indicators of clinical quality for specific conditions. Second, for most clinical indicators, achieving the indicator for an additional patient does not affect the number of points awarded if the percentage of relevant patients for whom the indicator is achieved is less than a lower threshold (usually 40%) or above an upper threshold (which ranged from 60% to 90%). Hence we also measure reported achievement (*RA clinical*) which is weighted average of the percentage of patients reported eligible for the indicator for whom the indicator is achieved, taken over the 42 clinical indicators which were consistently defined between 2005 and 2012. The weights are the maximum points available for the indicators. Third, there may be selective exception reporting of patients as ineligible for an indicator (Doran et al., 2006; Gravelle et al., 2010). We therefore also measure performance on an indicator as the percentage of patients with the relevant condition, rather than the percentage of those declared eligible by the practice, for whom the indicator has been achieved.[71] *PA clinical* is the maximum points weighted average percentage of population achievement for the 42 indicators used in RA clinical.

As a final measure of clinical care quality we use the number of emergency hospital admissions of practice patients for Ambulatory Care Sensitive Conditions (ACSCs). These are conditions for which emergency admissions could be reduced by good quality primary care.[72] We use the admission method and diagnostic fields in Hospital Episode Statistics (HES) to count the number of emergency ACSCs admissions (incentivised and non-incentivised ASCS emergency admissions) for each practice (using the patients' GP practice code recorded on the HES episodes) in each financial year from 2006/7 to 2011/12, so for example, the 2006 ACSCs emergency admissions are collected from 1st April 2006 to 31st March 2007. We use the definition provided by Harrison et al. (2014) to count the number of emergency admissions for ACSCs per 1000 patients (*ACSC rate*) for each practice in each year from 2005 to 2012.[73]

Patient reported quality. We construct patient reported measures of quality using responses to three questions in the national General Practice Patient Survey (GPPS)[74] administered to a random 5% sample of patients in each practice from 2006 onwards[75]. *Open hrs sat* is the

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[70] QOF data is collected by NHS digital for each financial year, for example for 2006/7, the data is collected between the 1st of April 2006 and the 31st of March 2007.

[71] Population achievement is explained in Appendix 2.1.

[72] Some ACSCs are incentivised by the QOF (e.g. diabetes, asthma) whereas others are not (e.g. anaemia, cellulitis and perforated ulcer).

[73] *We use the admission method and diagnostic fields in Hospital Episode Statistics (HES) to count the number of emergency ACSCs admissions (incentivised and non-incentivised ASCS emergency admissions) for each practice (using the patients' GP practice code recorded on the HES episodes) in each financial year from 2006/7 to 2011/12, for example, for 2006 ACSCs emergency admissions are collected from the 1st of April 2006 to the 31st of March 2007.*

[74] *We used the weighted GPPS responses available at https://gp-patient.co.uk/*

[75] The GPPS data were attributed to the financial years using the fieldwork dates (for more information please see Appendix 2.2.)

percentage of respondents satisfied with their GP surgery opening hours (available for 2006-2012); *Care sat* is the proportion of patients satisfied with overall care in their practice (available for 2008-2012); *Recommend* is the proportion of patients who would or might recommend their practice (available for 2009-2012).[76]

4.4.2. Competition

As noted above, competition in general practice care is geographically defined as patients seek care by going to their practice in person (or, more rarely, a practice GP coming to their home). As a result, the probability that a patient is registered with a practice declines rapidly with the distance of the practice from their home. Around 40% of patients register with the nearest practice. A study of a large English region found that the median distance to the nearest practice was 0.84km (mean = 1.2km) and the median distance to the chosen practice was 1.48km (mean =1.88km). The same study also found that the cross-practice elasticity of demand with respect to quality declined rapidly with distance (Santos et al., 2017).

Based on this, we use 1km[77] as the size of the GP practice market. In defining the number of rivals within this market, we had two choices. The first was the number of rival practices with a branch surgery within 1km of any branch of the target practice. However, over the period we study the number of practices fell from 8451 in 2005 to 8088 in 2012 as small practices have closed. But the total number of GPs increased from 32,738 to 35,415, resulting in an increase in the number of GPs in each practice and a fall in the ratio of patients to GP (from 1613 to 1574). Thus changes in the number of practices within a given distance from a given practice are a poor measure of the change in the capacity of rival practices to enrol its patients. The second choice was the number of full time equivalent (FTE) GPs in rival practices within 1km and we use this as our measure of competition.[78] Because FTE GPs in a GP practice varies between 1 and 10, the number of GP practices does not fully reflect the size of the competing primary care services that can be available. This is why the FTE GPs in the GP practices within 1km is our preferred measure of competition. Since a practice is competing with several rival practices we do not believe that there is a problem from simultaneity bias arising if the quality of the practice affects the number of nearby practices and GPs. If the quality of a practice increases this could in principle attract patients from other practices and so affect their viability or the number of GPs they contain. But the effect of an increase in the quality of a practice which will be spread over more than one

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[76] The wording of the questions changed somewhat over the sample period but we assume that including year dummies in the regression models will allow for this. In other work on the determinants of ACSC admission rates using these variables, we also interacted them with year dummies and found that the interactions were small and rarely significant (available from the authors on request).

[77] However, in preliminary work when we tested for competition by including the number of practices within different radii intervals in the same model (<0.5km, 0.5km-1km, 1km-1.5km, 1.5km-2km, 2km-2.5km, 2.5km-3km, 3km-3.5km, 3.5km-4km, 4km-4.5km, 4.5km-5km) the only significant competition measure was under 0.5km. If we use a competition measure for the FTE GPs of the nearest five practices, this would imply that a GP practice in a rural area would have in its competition measure, practices that are further than 20km away. Moreover, given that in East Midlands the median distance to the chosen practice was 1.48km (Santos et al 2017) it is unlikely that GP practice competes in a geographical area outside its catchment area.

[78] For replication purposes we also estimated cross sectional model using the same measure of competition as Pike (2010), in which competition was measured as vector of the number of practices within 500m bands from 0-500m to 4500-5000m. We obtained broadly similar results (available from the authors).

practice and may take several years to change the list size of other practices significantly (Santos et al, 2017).[79]

4.4.3. Covariates

Practice quality may be influenced by the number and type of patients, so we control for a patient volume and case-mix. We use measures of practice demographics (list size and proportion of patients in 12 age and gender groups) from the General Medical Services (GMS)[80] dataset and patient morbidity (prevalence of 10 conditions included in the QOF, and the proportion of patients resident in nursing homes[81]). In addition, we use two small area measures of socio-economic status (SES) of the practice population. These are: (a) the proportion on invalidity and disability social security benefits[82] and (b) a measure of overall deprivation (the Index of Multiple Deprivation).[83] Both these measures are recorded for small areas (Lower Super Output Areas, LSOA) with mean populations of 1500.[84] For each practice, we attribute the weighted mean of the LSOA data where the weights are the proportion of individuals registered with the practice and living in each LSOA (Appendix 2.3).

To allow for endogeneity in practice populations we construct case-mix measures for the potential population rather than those on the practice list. For the demographic variables, we use the total population and age/gender proportions for a larger (administrative) area than the immediate neighbourhood. We use the Median Super Output Area (MSOA) in which the practice is located. These have an average population of around 7200.[85] We include the MSOA population to allow for the possibility that a practice may perceive itself as facing less competition from a given number of GPs in rival practices if the local population is greater. For the morbidity measures, we replace practice prevalence of QOF conditions and the proportion of its patients in nursing homes with the practice list size weighted mean of these variables taken over the practice and its five nearest rivals. We replace the two LSOA based measure of SES with the corresponding MSOA level variables.[86] Summary statistics for all covariates are in Table A. 28.

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[79] These include models with the number of rival practices as well as, or instead of, the number of GPs in rival practices, and allowing for non-linear effects. We do not use competition measures, such as the Herfindahl-Hirschman Index, which are based on market shares because these are endogenous. Using predicted market shares based on choice models which exclude quality, as in the literature on hospital competition (Kessler & McClellan, 2000) would be complicated given that the number of practices is orders of magnitude greater than the number of hospitals. Since the main non-quality factor affecting demand is patient to practice distance, it would likely produce competition measures highly correlated with our measures.

[80] We have attributed GMS data from, for example, 30th September 2006 to the financial year of 2006/7 since the date of the snapshot is exactly in the middle of the financial year.

[81] The data for the list of patients registered in nursing homes is extracted on 30th September of each year, so we have attributed the data from, for example, 30th September 2006 to the financial year of 2006/7 since the date of the snapshot is exactly in the middle of the financial year.

[82] A quarterly snapshot of the incapacity benefits, also known as Disability Living Allowance (DLA) data is collected at the end of February, May, August and November. Since we wanted to attribute the data to the financial year, we used the August snapshot of each year, for example we attribute the data from August 2006 to the financial year of 2006/7.

[83] The IMD combines measures of social and economic deprivation covering seven domains and is used by central government to allocate funding for public services.

[84] We use LSOAs defined according to 2001 census boundaries. There were 32,482 LSOAs in England.

[85] There were 6781 MSOAs in England during the most of the period covered by our data. LSOAs are nested within MSOAs.

[86] These are the proportion of the population in the practice MSOA who are on invalidity and disability benefit and the Index of Multiple Deprivation in the practice MSOA.

4.4.4. Sample selection

Our main estimates use an unbalanced panel of all practices in England after dropping practice-year observations in which the list size was under 1000 or there was missing data on covariates.[87] To examine the impact of potential endogenous selection of location by practices we re-estimate our baseline model (24) on a sub-sample of practices in areas that are homogeneous in terms of SES. Our assumption is that within these areas the lower variation in SES of the population will mean that practices have less incentive to locate at one address versus another. In choosing homogenous areas we face a trade-off. Using a larger geographical unit will provide more within-area variation in practice competition and hence increase precision in estimating the effect of competition. But it will make it less plausible that there is little within-area variation in unobserved factors that might affect practice location. PCTs contain around 50 practices and have populations of over 300,000 on average, so are too large. Instead we use the smaller areas defined by Parliamentary Constituencies, which contain on average 15 GP practices and a population of just under 100,000. We select a subset of Parliamentary Constituencies which are homogeneous in terms of SES. To do this, we compute the coefficient of variation in SES (as measured by the overall IMD score) across the LSOAs contained within each Parliamentary Constituency.[88] As our homogenous sample we select all practices in Parliamentary Constituencies in the bottom quintile of the distribution of the coefficient of variation of the IMD.

4.4.5. Summary statistics

Figure 22 shows the spatial distribution of the GP practice surgeries across England in 2010 and the PCTs which were part of the policy initiative we exploit (the EAPMC programme).

[87] We have dropped 32854 observations for practices that were not open from 2004 to 2006, 69 observations for practices with a list size of less than 1000, 8 observations for a GP practice located in the Isles of Scilly and 1200 observations because the Practice did not have full information for the quality measure or for the practice characteristics.

[88] On average there are just over 60 LSOAs per Parliamentary Constituency.

Figure 22 - EAPMC PCTs and all GP surgeries, England 2010

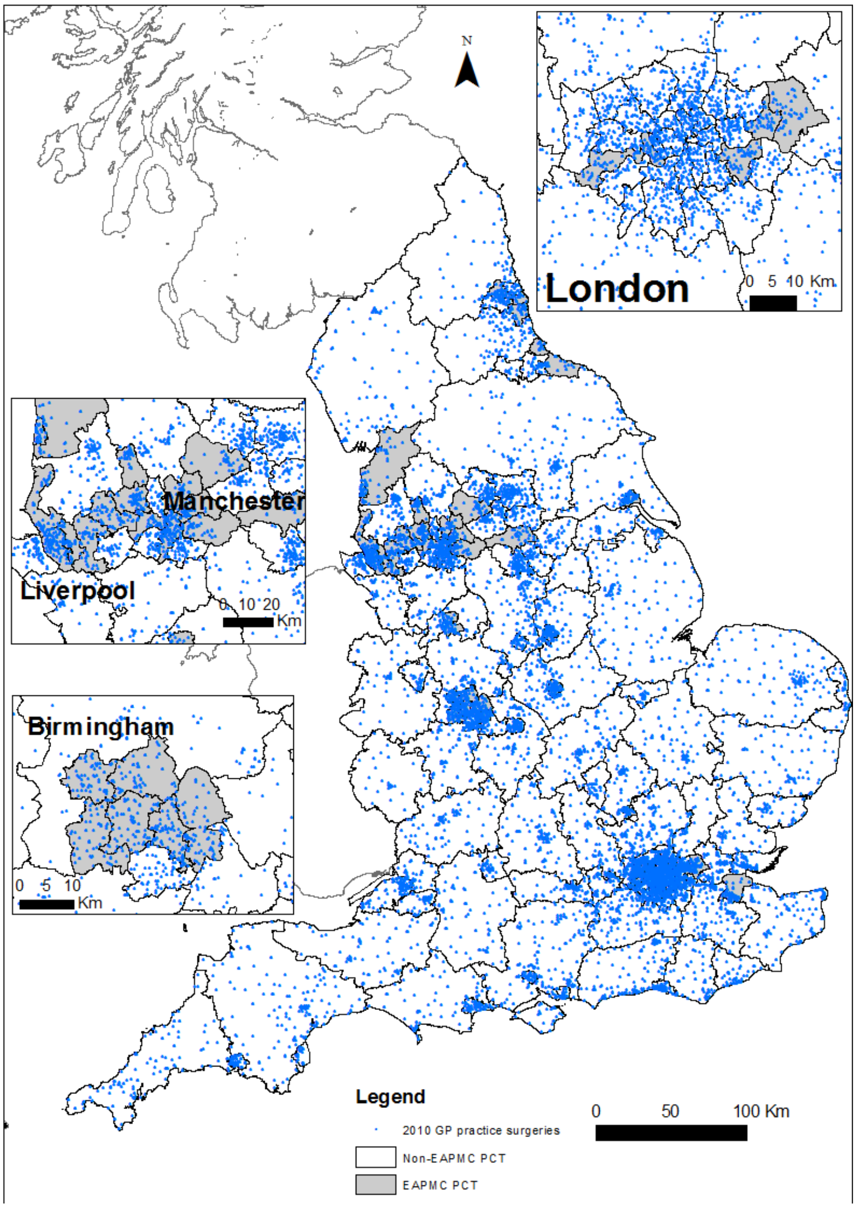
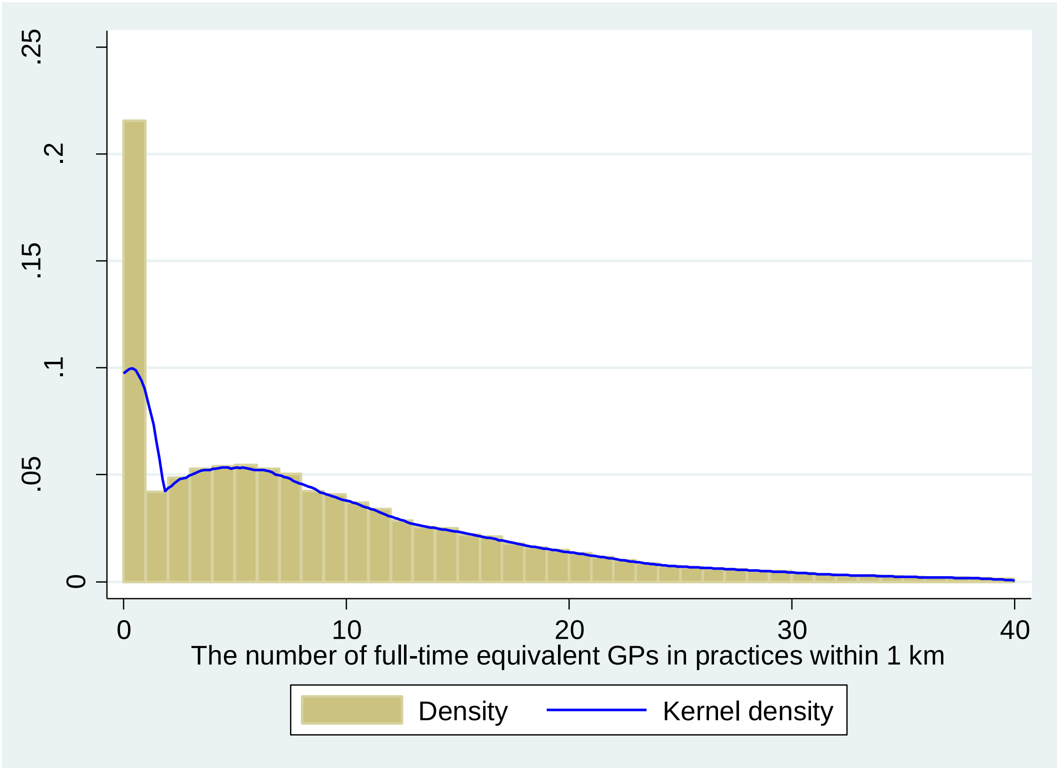


Figure 23 shows the frequency distribution of our main measure of potential competition for a practice: the number of full time equivalent doctors in other practices which have a branch surgery within a 1km radius of any branch of the practice. Under 15% of practices have no rivals GPs within 1km. As shown in Figure 22, these practices are predominantly in rural areas. However, as Figure 23 shows, many practices face a large number of rival GPs. About 20% have between 1 and 10, and the remaining 65% have more than 10 (again reflected in the relatively low HHI indices of the bottom 40% of the HHI distribution shown in Figure 21).

Figure 23 - Market structure distribution (full-time equivalent GPs in practices within 1 km)



Notes. Data pooled for period 2005/06-2012/13. Practices with over 40 rivals are censored in the Figure.

Summary statistics for our key variables are in Table 4-1. The first 7 rows present the measures of quality. Higher numbers indicate higher quality, with the exception of the ACSC rate where a higher positive number is a worse clinical outcome. All measures exhibit considerable variation, and a relatively high proportion of this is within-practice, aiding identification. The last three rows present our measures of competition: the numbers of GPs in rival practices within 1km, 0.5km and 2km. There are on average 8.73 GPs within 1km and over 25 within 2km.

Table 4-1: Quality and competition measures: summary statistics

	Years		Mean	SD	Min	Max	Obs
Quality							
PA clinical	2005-12	Overall	79.13	4.93	5.90	97.33	63968
		Between		4.52	6.06	95.80	8329
		Within		2.81	25.75	107.54	$\bar{T}$: 7.68
RA clinical	2005-12	Overall	85.21	4.79	5.90	100.00	63968
		Between		4.31	6.17	97.55	8329
		Within		2.99	28.29	116.57	$\bar{T}$: 7.68
QOF points (% of maximum)	2005-12	Overall	95.90	5.39	11.84	100.00	63970
		Between		4.91	11.84	100.00	8329
		Within		3.52	32.64	127.80	$\bar{T}$: 7.68
ACSC admissions per 1000 patients	2005-12	Overall	12.43	4.97	0.00	69.54	64000
		Between		4.32	0.00	35.88	8348
		Within		2.57	-10.56	49.21	$\bar{T}$: 7.67
% satisifed with opening hours	2006-12	Overall	82.48	6.72	0.00	100.00	55913
		Between		5.80	47.96	98.89	8279
		Within		3.51	24.62	108.89	$\bar{T}$: 6.75
% satisfied with care	2008-12	Overall	90.14	6.60	40.16	100.00	39684
		Between		6.02	57.33	100.00	8103
		Within		2.79	66.56	107.59	$\bar{T}$: 4.90
% would recommend practice	2009-12	Overall	82.77	10.62	23.00	100.00	31555
		Between		10.01	34.28	100.00	8024
		Within		3.76	50.66	104.69	$\bar{T}$: 3.93
Competition							
FTE GPs in practices within 1km	2005-12	Overall	8.73	8.79	0.00	67.45	64676
		Between		8.84	0.00	57.46	8351
		Within		1.24	-12.26	24.48	$\bar{T}$: 7.74
FTE GPs in practices within 500m	2005-12	Overall	3.58	4.70	0.00	45.99	64676
		Between		4.67	0.00	37.67	8351
		Within		0.74	-4.49	17.42	$\bar{T}$: 7.74
FTE GPs in practices within 2km	2005-12	Overall	25.46	24.52	0.00	153.43	64676
		Between		24.46	0.00	146.49	8351
		Within		2.61	-0.65	51.85	$\bar{T}$: 7.74

Notes: $\bar{T}$ = average number of years of observations per practice. PA: population achievement; RA: reported achievement; QOF: Quality and Outcomes Framework; ACSC: ambulatory care sensitive condition; FTE: full time equivalent.

Table A. 29 presents the cross-section correlations across practices in 2009-12 of the quality and competition measures. While the quality measures are generally positively correlated (note the ACSC rate is a negative quality measure) the coefficients suggest that they are picking up different aspects of practice quality. The three clinical measures based on the QOF are highly correlated with each other but are very weakly correlated with the ACSC rate. The three patient based measures are reasonably strongly correlated with each other, especially overall satisfaction and the percentage who would recommend the practice. The clinical and patient reported measures are poorly correlated.

The numbers of rival practices and the numbers of GPs in nearby practices are highly correlated cross-sectionally. In the cross-section both are negatively correlated with quality, but, as we show below, this is due to differences in population characteristics between more and less densely populated areas.

4.5. Results

4.5.1. Baseline model

Table 4-2 reports the coefficients[89] on competition and measures of goodness of fit from models estimated for the full sample of all practices over the full period for which the data are available. *Panel A* shows the pooled OLS results with no controls for practice population or morbidity. There are significant negative relationships between the number of rival GPs faced by a practice and both clinical quality and patient satisfaction (as in Table A. 29). *Panel B* includes controls for the characteristics of patients in the practice and shows that once these are allowed for the association between number of rivals and quality becomes positive, particularly for the patient satisfaction measures. *Panel C* allows for unobserved practice heterogeneity by adding in practice fixed effects and shows that controlling for this strengthens the positive relationship between rivals and quality and patient satisfaction. In *Panel D* we address the possibility that practices may select patients based on patient morbidity. We replace the actual patient covariates with measures of the demographics and morbidity of the potential patient pool on which the practice could draw. The coefficients estimates are close to those of *Panel C*, indicating that patient selection may not be a large issue in our context.[90] To further allow for unobserved differences in patient case-mix, we restrict the sample to practices in areas that are more homogeneous in population characteristics.

[89] Since we are estimating linear regression models, the coefficients are the marginal effects.

[90] Full results for *Panel D* are in Appendix 4.3 Table A. 30

Table 4-2: Competition and quality

	Covariates					Competition	Quality measure						
							(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Practice		Local			PA clinical	RA clinical	QOF points	ACSCs	Open hrs sat	Care sat	Recommend
	FEs	Demog	Morbid	Demog	Morbid		2005-12	2005-12	2005-12	2005-12	2006-12	2008-12	2009-12
Panel A	N	N	N	N	N	N rival GPs	-0.039***	-0.033***	-0.073***	-0.008	-0.059***	-0.143***	-0.243***
							[0.005]	[0.005]	[0.005]	[0.006]	[0.007]	[0.008]	[0.013]
R^2							0.022	0.026	0.045	0.002	0.028	0.050	0.054
Obs							63,968	63,968	63,970	64,000	55,913	39,684	31,555
Panel B	N	Y	Y	N	N	N rival GPs	0.006	0.011*	0.007	-0.015***	0.031***	0.047***	0.053***
							[0.006]	[0.005]	[0.005]	[0.004]	[0.007]	[0.007]	[0.011]
R^2							0.103	0.084	0.172	0.458	0.185	0.358	0.377
Obs							63,623	63,623	63,625	63,467	55,241	39,225	31,248
Panel C	Y	Y	Y	N	N	N rival GPs	0.038**	0.015	0.000	-0.031**	0.096***	0.071***	0.058*
							[0.015]	[0.016]	[0.018]	[0.011]	[0.017]	[0.018]	[0.028]
Within R^2							0.0843	0.0885	0.110	0.0528	0.0847	0.0921	0.117
Obs							63,623	63,623	63,625	63,467	55,241	39,225	31,248
Practices							8,276	8,276	8,276	8,269	8,247	8,070	7,985
Panel D	Y	N	N	Y	Y	N rival GPs	0.053***	0.028	0.011	-0.008	0.111***	0.090***	0.080**
							[0.015]	[0.016]	[0.019]	[0.012]	[0.017]	[0.018]	[0.028]
Within R^2							0.0485	0.0542	0.0783	0.0101	0.0822	0.0791	0.104
Obs							63,968	63,968	63,970	64,000	55,913	39,684	31,555
Practices							8,329	8,329	8,329	8,348	8,279	8,103	8,024

Notes. Competition measure: *N rival GPs*: number of FTE GPs in other practices with at least one branch within 1km of a branch of the practice. All models include year dummies. Practice demography: list size, proportion of list in 12 age/gender bands. Practice morbidity: prevalence of QOF conditions, proportion of patients in nursing homes, attributed proportion of patients on invalidity/disability benefit, attributed income deprivation score. Local demography: total population and proportions of population in age/gender groups in the MSOA in which the practice is located. Local morbidity: prevalence of QOF conditions averaged across practice and its 5 nearest practices, proportion of patients in nursing homes averaged across practice and its five nearest practices, proportion of patients on invalidity or incapacity benefit in the MSOA in which the practice is located, income deprivation score in the MSOA in which the practice is located. Square brackets: robust SEs clustered at practice level.*** p<0.001, ** p<0.01, * p<0.05

We re-estimate our preferred model (from Table 4-2, *Panel D*) using the sample of practices in the most homogenous Parliamentary Constituencies. The results are in Table 4-3. The coefficient estimates on the number of rival GPs for the clinical quality measures are close to those for the full sample. The coefficient estimates for the patient ratings are larger for satisfaction with opening hours, but smaller and no longer statistically significant at the 5% level for the other two measures of patient satisfaction. But broadly the results are similar to those using the full sample, again suggesting that selection may not be a major issue in this market.

Table 4-3: Competition and quality within homogeneous Parliamentary Constituencies

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
	PA clinical	RA clinical	QOF points	ACSC	Open hrs sat	Care sat	Recommend
	2005-12	2005-12	2005-12	2005-12	2006-12	2008-12	2009-12
N rival GPs	0.061*	0.035	-0.004	-0.069***	0.146***	0.062	0.048
	[0.027]	[0.030]	[0.034]	[0.021]	[0.029]	[0.032]	[0.046]
Within R2	0.0813	0.0621	0.0680	0.0240	0.0622	0.0536	0.0723
Obs	15,769	15,769	15,771	15,810	13,842	9,773	7,754
Practices	2,081	2,081	2,081	2,087	2,072	2,013	1,985

Notes. Competition measure: number of FTE GPs in other practices with at least one branch within 1km of a branch of the practice. Sample: practices in 107 Parliamentary Constituencies in the bottom quintile of the coefficient of variation of the LSOA level Index of Multiple Deprivation. All models include practice fixed effects, year effects, local population (total population and proportions of population in age/gender groups in the MSOA in which the practice is located), local morbidity (prevalence of QOF conditions averaged across practice and its 5 nearest practices, proportion of patients in nursing homes averaged across practice and its five nearest practices, proportion of patients on invalidity or incapacity benefit in the MSOA in which the practice is located). Square brackets: robust SEs clustered at practice level. *** p<0.001, ** p<0.01, * p<0.05.

4.5.2. Robustness tests

We now subject our estimates to a series of robustness tests with respect to the definition of the local market and measure of competition.

In Table 4-4 we vary the definition of local market. We decrease the radius to 0.5km (*Panel A*) and increase it to 2km (*Panel B*). The results show similar patterns for the satisfaction measures at both these distances. The coefficients are slightly smaller than for our baseline model (Table 4-2, Row D) for the smaller distance and the results for the larger market radius of 2km are similar (or perhaps a little stronger) than in the baseline model. For the larger radius, the results for the clinical quality measures are similar to those of the baseline model. The results for the smaller radius show no effect on clinical quality. However, this assumes a very small market relative to the average distance between patients and practices (1.2km) and 40% of practices have no rival GPs within this distance.

Table 4-4: Alternative competition radii

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	PA clinical	RA clinical	QOF points	ACSC	Open hrs sat	Care sat	Recommend
	2005-12	2005-12	2005-12	2005-12	2006-12	2008-12	2009-12
Panel A. Number GPs in rival practices within 500m							
N rival GPs	0.013	-0.003	-0.011	0.022	0.071*	0.067*	0.094*
	[0.024]	[0.026]	[0.029]	[0.020]	[0.029]	[0.030]	[0.046]
Within R2	0.0480	0.0541	0.0783	0.0101	0.0811	0.0782	0.104
Panel B. Number GPs in rival practices within 2km							
N rival GPs	0.045***	0.030***	0.020*	-0.005	0.068***	0.057***	0.057***
	[0.008]	[0.008]	[0.009]	[0.006]	[0.009]	[0.010]	[0.015]
Within R2	0.0494	0.0546	0.0784	0.0101	0.0827	0.0796	0.105
Obs	63,968	63,968	63,970	64,000	55,913	39,684	31,555
Practices	8,329	8,329	8,329	8,348	8,279	8,103	8,024

Notes: Competition measures: *N GPs*: number of FTE GPs in other practices with at least one branch within 500 metres (model A) or 2 km (model B) of a branch of the practice. All models include practice fixed effects, year effects, local population (total population and proportions of population in age/gender groups in the MSOA in which the practice is located), local morbidity (prevalence of QOF conditions averaged across practice and its 5 nearest practices, proportion of patients in nursing homes averaged across practice and its five nearest practices, proportion of patients on invalidity or incapacity benefit in the MSOA in which the practice is located). Square brackets: robust SEs clustered at practice level. *** p<0.001, ** p<0.01, * p<0.05.

We test robustness to our assumption that it is the current innovation in number of rival GPs that matters by replacing the current number with the one-year lagged number of rival GPs. As this shortens our estimation period, we re-estimated our baseline model using the current number of GPs for the same shorter period. Both sets of estimates (Appendix 4.4 Table A. 32) are very similar to our baseline estimates.

We have argued that the number of GPs in rival practices is a better measure of competition than a count of the number of practices because the latter takes no account of rival practices' capacity to take on extra patients. But a counter argument is that a single rival practice with *n* GPs poses less of a competitive threat than two rival practices with *n/2* GPs since practices may be horizontally differentiated by location or other practice characteristics. To test this we add the number of rival practices to our baseline model of Table 4-2, Panel D. The estimated effects of our preferred measure (the number of GPs in rival practices) are unchanged (Appendix 4.4 Table A. 34).

One challenge to our analysis is that the apparent effect of our measure of competition – the number of GPs in rival practices – is due to omitted variable bias arising from the national trend increase in the total number of GPs. If the quality of a practice is affected by the number of its own GPs, then some of the association of the number of GPs in nearby practice with practice quality could be due to correlations in the number of GPs across practices. While our baseline model controls for common time shocks, such shocks may be local. To allow for this, we add the number of own GPs as an additional control. We find that the number of GPs in a practice is, as expected, positively associated with all three of the patient reported quality measures and with two of the four clinical measures. However, adding the number of own GPs to the model (Table A. 34) leads to only very small reductions (around 1/20th) in the estimated effects of our preferred competition measure (the number of GPs in rival practices).

One potential threat to our identification strategy is that what we are picking up are local market wide changes (for example, changes in funding at the PCT level) that lead to increases in both numbers of GPs in the local area, and so the number of rivals, and in own practice quality. To examine this, we add controls for PCT-year effects. This will control for local policies which may have increased quality and number of GPs in all practices, which we could incorrectly attribute to an increase in rival GPs. This is a tough test, as it means all identification comes from practice within-year-PCT variation in number of rivals, which is smaller than the practice within-year variation. The results are reported in Appendix 4.4 Table A. 35. They show that the association with clinical measures becomes small and statistically insignificant, but the association with patient satisfaction remains positive and well defined. As an increase in the number of rivals maybe driven by PCT-level policies, controlling for year*PCT effects maybe over-controlling. If, for example, the within-year PCT increase in number of rivals is what practices respond to, then by adding year-PCT effects we wipe out this legitimate variation.

As a final test of our measure of market structure, we exploit the fact that patients are less likely to choose practices located in a different PCT (Santos et al., 2017). There is no legal or formal administrative reason why patients should not cross PCT boundaries. However, preference for practices within the same PCT may reflect the fact that PCT boundaries sometime follow geographical features such as rivers, railway lines or main roads which may make it harder for a patient to access a practice in a different PCT. The corollary is that practices located near boundaries will face less potential competition than would be suggested by a count of the number of GPs in nearby practices.

We investigate this in Table 4-5 using a dummy variable for a practice having a branch within 0.5km of a PCT boundary. In Panel A we use being near a boundary as a measure of a practice facing less potential competition and regress quality on the near boundary dummy and the covariates. As the boundary dummy is time-invariant we cannot control for practice fixed effects and so estimate a Mundlak (1978) random effects model, adding practice means of all covariates to deal with unobserved heterogeneity. The results show that being near a boundary reduces all seven quality measures.[91] As PCT boundaries are not coterminous with travel to work areas, or with other local government administrative areas, there should be little reason why being close to a boundary should mean a practice is of lower quality other than the fact they face less rivals because patients tend to prefer practices within their PCTs. In *Panel B* we see that adding the dummy to the baseline specification and interacting it with the number of GPs in rival practices makes little difference to the effect of the number of rivals (and all the interaction terms are insignificant) and being near a boundary reduces six of the seven quality measures. The near boundary positive coefficient for ACSCs emergency admissions rate indicates a decrease on quality due to a practice being near a boundary.

[91] The results in Table 4-5 exclude practices that are located near the coast to avoid conflating being near a land with being near a coastal boundary. The results are very similar if we include these practices (available from the authors).

Table 4-5: Location near a PCT boundary

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	PA clinical	**RA clinical**	**QOF points**	**ACSC**	**Open hrs sat**	**Care sat**	**Recommend**
	2006-12	2006-12	2006-12	2006-12	2006-12	2008-12	2009-12
Panel A. Location near a PCT boundary as measure of competition							
Near boundary	-0.194	-0.553***	-0.703***	0.062	-1.111***	-1.355***	-1.777***
	[0.163]	[0.159]	[0.195]	[0.123]	[0.215]	[0.226]	[0.360]
Within R2	0.0362	0.0148	0.0851	0.00734	0.0806	0.0780	0.104
Panel B. Competition from rival practices near a PCT boundary							
N Rival GPs	0.028	0.014	0.007	-0.016	0.095***	0.082***	0.073*
	[0.017]	[0.018]	[0.022]	[0.015]	[0.018]	[0.019]	[0.030]
Near boundary	0.035	-0.301	-0.391	0.292	-0.830**	-1.313***	-2.032***
	[0.212]	[0.203]	[0.251]	[0.173]	[0.297]	[0.301]	[0.504]
Near*N rival GPs	0.031	0.006	0.025	-0.048	0.087	0.042	0.019
	[0.043]	[0.049]	[0.064]	[0.032]	[0.051]	[0.052]	[0.082]
Within R2	0.0362	0.0148	0.0851	0.00734	0.0806	0.0780	0.104
Obs	53,988	53,988	53,990	53,963	54,213	38,468	30,585
Practices	8,001	8,001	8,001	8,020	8,029	7,858	7,780

Notes. Near boundary: dummy variable = 1 if at least one branch of a practice is within 500m of a PCT boundary. All models include practice random effects, year effects, local population (total population and proportions of population in age/gender groups in the MSOA in which the practice is located), local morbidity (prevalence of QOF conditions averaged across practice and its 5 nearest practices, proportion of patients in nursing homes averaged across practice and its five nearest practices, proportion of patients on invalidity or incapacity benefit in the MSOA in which the practice is located) and practice, Mundlak means (means of local time varying covariates). Square brackets: robust SEs clustered at practice level.
*** p<0.001, ** p<0.01, * p<0.05.

Fixed effects estimates in short panels may be downwardly attenuated due to measurement error. As a final robustness test, we collapse our data to two data points per practice - the average for the period 2009-12 and the average for the period 2005-8 - and examine the change in outcomes as a function of the change in number of rivals (with controls for all covariates). The estimates in Table 4-6 show positive effects of the number of rivals on both clinical quality and patient satisfaction. The estimates are a little larger, and better defined, than our baseline specification.

Table 4-6: Long difference estimates

	ΔPA clinical	ΔRA clinical	ΔQOF points	ΔACSCs	ΔOpen hours sat
ΔN rival GPs	0.151***	0.097**	0.089*	-0.135***	0.158***
	[0.033]	[0.035]	[0.042]	[0.028]	[0.034]
R^2	0.021	0.014	0.009	0.017	0.020
Obs	7,845	7,845	7,845	7,845	7,842

Notes: ΔN rival GPs: average FTE GPs in practices within 1km 2009/10-2011/12 minus average FTE GPs in practices within 1km 2005/7-2007/8. ΔQuality and Δcovariates (practice demographics and practice morbidity): average quality and covariates 2009/10-2011/12 *minus* average quality and covariates 2005/7-2007/8. Square brackets: robust SEs. *** p<0.001, ** p<0.01, * p<0.05.

We conclude from these tests that practices which face more potential competition have higher clinical and/or patient-rated quality, that our results are robust to definitions of the market and to measurement error and, while there may be some increases in clinical quality that are driven by some unobserved market level factor that increases both the number of GPs (in the own and other practices) and quality, we do not think that these account for the increases in patient reported quality we see associated with changes in number of rivals.

4.5.3. Exploiting the EAPMC policy

This policy provided incentives to the establishment of new GP practices in the EAPMC PCTs rather than directly incentivising quality. We expected that this implied a greater increase in the number of GP practices and FTE GPs in those areas in the EAPMC rather than in the non-EAPMC PCTs[92]. We test the impact of this increase in competition on quality in Table 4-7**.** We first compare all untreated and all treated practices in *Panel A*. The set of outcome variables is smaller than for the baseline analysis as two of the patient reported outcomes are not available for the full period. Three of the five interaction terms (the intention to treat parameters) suggest that quality improved in EAPMC practices during the intervention period and the effects are statistically significant in two of the cases.

Table 4-7: Exploiting the EAPMC policy

	(1)	(2)	(3)	(4)	(5)
	PA clinical	**RA clinical**	**QOF points**	**ACSC**	**Open hrs sat**
Panel A: all English practices					
After	0.133	-0.245*	-2.223***	-0.039	-0.776***
	[0.113]	[0.111]	[0.125]	[0.153]	[0.190]
After*EAPMC	0.749**	0.784***	0.434	0.128	-0.400
	[0.232]	[0.225]	[0.232]	[0.361]	[0.288]
Within R^2	0.0313	0.0264	0.0825	0.00599	0.0698
Obs	47,838	47,838	47,839	47,879	39,773
Practices	8,214	8,214	8,214	8,216	8,203
Panel B: practices near EAPMC PCT boundary only					
After	0.198	-0.059	-2.476***	-0.138	-0.051
	[0.418]	[0.327]	[0.340]	[0.293]	[0.729]
After*EAPMC	0.947*	0.858*	0.425	-0.045	-0.466
	[0.469]	[0.385]	[0.395]	[0.444]	[0.777]
Within R^2	0.0691	0.0486	0.0759	0.0185	0.0729
Obs	3,867	3,867	3,867	3,866	3,218
Practices	674	674	674	674	672

Notes: Difference in difference estimates. Years: as in Table 2 except 2008/9 and 2012/13 are dropped. After: 2009/10-2011/12. EAPMC: practice is in an EAPMC PCT. Sample for Panel A is all practices, sample for Panel B is all practices within 1km of boundary between EAPMC PCT and non-EAPMC PCT. All models include practice fixed effects, years fixed effects, local population (total population and proportions of population in age/gender groups in the MSOA in which the practice is located), local morbidity (prevalence of QOF conditions averaged across practice and its five nearest practices, proportion of patients in nursing homes averaged across practice and its five nearest practices, proportion of patients on invalidity or incapacity benefit in the MSOA in which the practice is located). Square brackets: robust SEs clustered at practice level.
**** p<0.001, ** p<0.01, * p<0.05*

However, the PCTs selected to receive extra EAPMC funds were not selected randomly. They differ from other PCTs in terms of competition, clinical performance, patient satisfaction and demographics (see Appendix 4.4 Table A. 36). They are poorer, have higher levels of morbidity

[92] The figures in Appendix 4.4 show that not all the quality variables have a parallel trend between EAPMC and non-EPAMC before the policy in 2008. Nevertheless, at least one quality variable, QOF total points. The trends of EAPMC and non-EAPMC PCTs are parallel before the 2008 policy.

and poorer clinical outcomes. This is as expected as the scheme was specifically targeted to those PCTs in which access to GP services was perceived to be poorer. To deal with this we exploit the fact that the treated PCTs are scattered across England (shown in Figure 2) and share geographical boundaries with non-treated PCTs. The populations in areas along these boundaries are likely to be similar in their socio-economic status and their healthcare need. The secondary care (hospital) facilities available to both practices and patients are also likely to be similar as patients cross PCT boundaries to access hospital care. In *Panel B* as a refinement of our difference-in-difference model, we therefore restrict the sample to treated and non-treated practices located within 1km of the shared boundaries.[93] The choice of 1km means treated and control practices will serve very similar populations. The results are in Table 4-4, *Panel B* and are very similar to those in *Panel A* though somewhat less precisely estimated, reflecting the smaller sample size.

4.5.4. Heterogeneity

Our large sample allows us to examine whether there is heterogeneity in the effect of increases in competition for practices with different initial levels of quality and whether there are non-linearities in the effect of increases in rivals for practices facing different initial numbers of rivals. Our prior is that lower quality practices have most incentive to change their behaviour in the fact of an increased competitive threat, as those practices of high quality are already achieving high clinical and patient satisfaction scores. To test this we interact a dummy for a practice being in the highest initial quartile of quality with the number of GPs in rival practices. The results are in Table 4-8. They show, for each measure of quality, that the positive response to competition is muted for those practices which are in the top initial quartile of quality. Replacing the dummy in the interaction term with one for the lowest initial quality shows the same picture.[94]

Table 4-8: Heterogeneity with respect to initial quality

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	PA clinical	RA clinical	QOF points	ACSC	Open hrs sat	Care sat	Recommend
	2005-12	2005-12	2005-12	2005-12	2006-12	2008-12	2009-12
N rival GPs	0.118***	0.100***	0.026	-0.049**	0.151***	0.105***	0.080**
	[0.017]	[0.019]	[0.023]	[0.015]	[0.020]	[0.020]	[0.030]
Q4*N rival GPs	-0.310***	-0.318***	-0.080**	0.147***	-0.193***	-0.112**	0.003
	[0.029]	[0.029]	[0.027]	[0.022]	[0.035]	[0.036]	[0.072]
Within R^2	0.0517	0.0576	0.0793	0.0110	0.0829	0.0793	0.104
Obs	63,856	63,856	63,858	63,904	55,897	39,677	31,553
Practices	8,302	8,302	8,302	8,310	8,275	8,100	8,023

Notes: Q4: practice was in highest quality quartile of average 2005/6 and 2006/7 quality for PA clinical, RA clinical, QOF points and ACSC; in 2006/07 for Open hrs sat, in 2008/09 for Care sat, and in 2009/10 for Recommend. N rival GPs: number of FTE GPs in other practices with at least one branch within 1 km of a branch of the practice. All models include practice fixed effects, year effects, practice demographics and practice morbidity. Square brackets: robust SEs clustered at practice level.
**** p<0.001, ** p<0.01, * p<0.05.*

[93] See Gibbons and Machin (2003) for this approach in the context of school quality.

[94] The interactions of lowest quality quartile with competition are all significant and positive (available from the authors on request).

We undertake a similar exercise to examine heterogeneity in the effect of increased competition for practices facing different initial numbers of GPs in rival practices. We define a dummy variable with value of one if the practice is in the lowest level of initial (defined as the average of financial year 2005 and 2006 value) of competition. Table 4-9 shows that there is no interaction effect: practices facing a low initial level of competition do not react differently to increases in the number of GPs in rival practices they face. We obtain a similar result if we replace the dummy for being in the lowest quartile of competition with one for being in the highest. We therefore conclude that the effect of a change in the number of rival GPs is similar across the large range of local competition we observe in our data.[95]

Table 4-9: Non-linear effects of competition

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	PA clinical	RA clinical	QOF points	ACSC	Open hrs sat	Care sat	Recommend
	2005-12	2005-12	2005-12	2005-12	2006-12	2008-12	2009-12
N rival GPs	0.055***	0.030	0.012	-0.009	0.113***	0.089***	0.079**
	[0.015]	[0.016]	[0.019]	[0.012]	[0.017]	[0.018]	[0.028]
Q1*N rival GPs	-0.214	-0.178	-0.109	0.042	-0.112	-0.005	-0.099
	[0.147]	[0.147]	[0.153]	[0.090]	[0.108]	[0.105]	[0.219]
Within R^2	0.0487	0.0545	0.0785	0.0100	0.0824	0.0790	0.105
Obs	63,879	63,879	63,881	63,906	55,822	39,622	31,508
Practices	8,307	8,307	8,307	8,312	8,261	8,087	8,009

Notes: N rival GPs: number of FTE GPs in other practices with at least one branch within 1 km of a branch of the practice. We use a balanced panel and divide the practice sample into quartiles of the distribution of average competition over the period 2005/6 to 2006/7. Q1: practice was in the bottom quartile of distribution of competition for 2005/6 to 2006/7. All models include practice fixed effects, year effects, practice demographics and practice morbidity. Square brackets: robust SEs clustered at practice level.
**** p<0.001, ** p<0.01, * p<0.05.*

4.5.5. Magnitude of the effects

The results broadly support the view that increased competition between GPs in geographical space increases clinical quality or patient reported quality or both. However, the magnitude of the effect is small. For example, the coefficient of 0.053 in the fixed effects estimates of Table 2, Panel D, indicates that one extra GP in a rival practice increases clinical performance, as measured by population achievement (the percentage of the practice population for whom the QOF clinical indicators have been achieved), by 0.053%. This is only 0.01 of the standard deviation of the clinical quality measure. The effect of one additional GP in rival practices on the percentage

[95] One issue is the pathways by which quality is improved in response to increases in number of rivals. The fact that we find that the coefficients on the competition measure change little when we add the number of own practice GPs to the model suggests that the route by which competition affects quality is not through practices taking on more GPs to counter increased potential competition from rivals. To test this directly, we estimated a model for the number of GPs in a practice. We use the same controls as our baseline model. We found no economically significant effect of the number of GPs in rival practices on the number of own GPs (results available from authors). In the data available we do not observe other practice inputs or other features of practice quality (e.g. opening hours), so are not able to further examine potential pathways by which an increase in rivals leads to changes in own practice quality.

satisfied with care is 0.14 of the standard deviation of this quality measure. The difference-in-difference estimates of the effect of EAPMC are also modest: the clinical measure of population achievement increased by 0.75% in EAPMC practices relative to practices in non-EAPMC PCTs.

While these are small effects, they need to be set in the context of production of clinical quality in general practices. In this setting, individual policy interventions do not have dramatic effects. For example, the UK QOF was the world's largest pay for clinical performance scheme, at a cost of around £1 billion per year. It had no detectable effect on overall population mortality, nor on mortality from ischaemic heart disease one of the most strongly incentivised parts of the QOF (Ryan, Krinsky, Kontopantelis, & Doran, 2016), nor on premature mortality (Kontopantelis et al., 2015). It also had, at best, small effects in improving quality of care for chronic diseases which was its main rationale (Gillam, Siriwardena, & Steel, 2012; Guthrie & Tang, 2016). Other incentive schemes policies for family physicians have had similarly modest effects (Scott et al., 2011). And in similar institutional settings as the UK NHS, both Brekke Kurt et al. (2017) and Dietrichson et al. (2016) also find modest effects of competition on GP quality.

4.6. Discussion

In this paper we examine the relationship between market structure and quality in healthcare. We exploit the universe of all family physician practices in England to examine whether increased potential competition from rivals increases quality. There is no price competition as patients are fully insured, so this is an ideal setting in which to examine the relationship between market structure and quality.

In common with the literature on hospital and physician markets, we define potential local competition, basing the distance defining the local markets faced by providers on studies of patient choice in the English market. To derive plausibly causal estimates we both use within-practice estimators with a large number of controls that allow us to deal with patient and practice selection of location and exploit a policy shock which was intended to increase the availability of family physician care in selected areas. In contrast to most other studies of healthcare markets, we examine the effect on both clinical and patient-assessed measures of quality. We subject our estimates to a number of robustness tests and we also examine heterogeneity in the effect of rivals, thanks to the fact we have data on the universe of all practices (firms) in the market.

We find that the effect of increasing the number of rivals is positive and is larger for those practices which are located at the lower end of the quality spectrum. Our results do not appear to be driven by patient selection of practices or practice selection of patients or endogeneity of GP location. However, the effects are modest. This may reflect the fact that physicians' efforts to improve quality are driven by considerations that are not purely financial, such as a concern for patient wellbeing and professional norms (Bénabou & Tirole, 2006; McGuire, 2000; Rebitzer & Taylor, 2011).

But it may also be due to that fact that entry into this market is still relatively heavily regulated, protecting practices from the impact of rivals.[96] More generally, our results provide support for policies which seek to increase the demand elasticity facing physicians and providers in local

[96] Entry decisions into primary care provision have been heavily influenced by local bodies (Primary Care Trusts and their successors) that are dominated by GPs.

markets. Examples include policies to provide greater information, sharper incentives for provision of quality and the loosening of entry restrictions (as introduced by the governments of the U.S., The Netherlands, Germany, the U.K., Sweden and Norway). The setting we examine – fully covered patients and physicians reimbursed by centrally determined prices or funding – is common in health-care systems. The financial incentives facing family physicians in many health-care systems are similar to those we examine here: to attract patients to earn revenues subject to convex effort costs. This all suggests that the results we find are likely to be generalizable to contexts outside the U.K. setting, although empirical testing of this is clearly required in any specific institutional context.

This chapter shows that an increase in competition, proxied by the number of GPs in nearby practices, has a positive impact on practices quality. EAPMC policy also has a positive impact on quality by giving incentives to "under-doctored" PCTs to attract more GP practices. So we can expect health authorities to focus on attracting more health care professionals to increase the quality of their primary care services. A limitation of this study is the focus on FTE GPs. In future research, using data from 2013 onwards, it will be possible to include the FTE nurses and, from 2015 onwards, FTE of other health care professionals working in a primary care setting.

Finally, although we have shown evidence of a positive effect of competition on quality of care, this does not answer the normative question of whether welfare is unambiguously increased by greater competition. What our results do suggest is that benefits from competition should enter into any social cost–benefit analysis of policies to increase information and relax constraints on choice of family physician (Mays et al., 2014; Siciliani et al., 2017).

5. Does quality affect choice of family physician? Evidence from patients changing general practice without changing their address

5.1. Introduction

In many public healthcare systems where patients face low or zero prices encouragement of competition amongst providers is seen as one way of raising quality (Barros, Brouwer, Thomson, & Varkevisser, 2016; OECD, 2012). A necessary condition for this mechanism to be successful is that patients' choice of provider is influenced by quality. We investigate whether this is so for general practices in the English National Health Service (NHS).

The NHS has a list system for general practice: patients must register with a GP practice. Choice of GP general practice is perhaps the most important healthcare decision made by patients. General practitioners (GPs) manage chronic conditions, provide preventive care, and act as gatekeepers controlling access to secondary care for non-emergency conditions. On average patients consult their GP six times a year (Hippisley-Cox & Vinogradova, 2009).

Each year 9% of English patients choose a new general practice (Health and Social Care Information Centre, 2015). Most do so when they move from one area to another. But each year around 1% of patients change practices without changing their address. Patients who leave one practice and choose another without changing their address are likely to be better informed about local practices, especially the practice they are leaving, than patients newly arrived in the area. In this paper we use these patients as "canaries in a coal mine": if their decisions are not affected by quality it seems unlikely that choices by less well informed new arrivals will be.[97]

Most studies of quality and choice of healthcare provider are for hospitals. They generally find that patients are more likely to choose hospitals with higher quality, whether in the USA (Burns & Wholey, 1992; Cutler, Huckman, & Landrum, 2004; Ho, 2006; Howard, 2006; Pope, 2009; Tay, 2003), the Netherlands (Varkevisser, van der Geest, & Schut, 2012), Italy (Moscone, Tosetti, & Vittadini, 2012), or England (Beckert, Christensen, & Collyer, 2012; Gaynor et al., 2016; Gutacker, Siciliani, Moscelli, & Gravelle, 2016; Moscelli, Siciliani, Gutacker, & Gravelle, 2016). They also find that new information on quality, as provided for example by report cards, leads to changes in demand (Bundorf, Chun, Goda, & Kessler, 2009; Dranove & Sfekas, 2008; Epstein, 2010).

There are fewer studies of the choice of primary care provider. Biørn and Godager (2010) used data from the introduction of a list system in Norway in 2001 where patients had to rank GPs in order of preference. They measured quality by the standardised mortality of patients on the GP's list and demand by the proportion of all patients who ranked the GP as their most preferred. GPs with lower mortality had higher demand.

Santos et al. (2017) examined the choice of practice by over 3 million patients in an English region and found that, although 40% were registered with the nearest practice, choice of practice was also influenced by the age, gender mix, country of qualification of GPs, and by clinical quality of the practice. However, the study was based on the numbers of patients registered with practices at a single point in time. With around 9% of patients changing practice each year, the practice list at any date will reflect decisions over many years by patients who had imperfect information

[97] Canaries are more sensitive to carbon monoxide than humans and until the late 20th century were used by mine rescue teams.

about practice quality when they initially chose the practice and who may have been subsequently deterred from changing practice by the costs of switching.[98]

Thomas, Nicholl, and Coleman (1995) used data on 2617 patients changing practice without change of address in one month in 1991 in five English health authorities. Patients were more likely to join practices with a practice nurse, longer opening hours, and a female GP. Dixon, Gravelle, and Carr-Hill (1997) used pooled data on three English health authorities between 1995 and 1997. They found that the rate of transfer out was smaller in practices with more GPs, with more clinics, and with budgets for elective hospital care which enabled them to achieve shorter hospital waiting times for their patients (Dusheiko, Gravelle, & Jacobs, 2004; Propper, Croxson, & Shearer, 2002). Iversen and Lurås (2011) had panel data on numbers of patients switching from GPs in Norway and report that fewer patients switch from GPs who are female, younger, and who provide a greater volume of services to their patients (which they interpret as a measure of quality as perceived by patients). Nagraj et al. (2013) found that the numbers leaving English practices in 2009/10 without changing their address were smaller in practices with a higher proportion of patients reporting satisfaction with opening hours, overall satisfaction, and that they were able to see their preferred doctor, and that the practice had helpful receptionists. Counter-intuitively, there were more leavers from practices with more GPs per patient.

We contribute to this literature in a number of ways. First, we have more and better measures of quality than in most previous studies. Quality is multi-dimensional and addition to measures of patient reported satisfaction, we have measures of clinical quality derived from data on general practice clinical activities and from information on emergency hospital admissions which are preventable by better care in general practice. Second, because we focus on a small subset of patients, rather than the total practice list, the risk that our practice level measures of quality are endogenous is greatly reduced. Third, we have a five year panel of over 6700 English general practices. This enables us to allow for the possibility that patients react to previous, rather than current, quality. It also means that we can use fixed effects estimation to allow for unobserved time invariant practice characteristics.

The next section sets out the institutional background for general practice in the English NHS. Section 5.3 describes our data. In Section 5.4 we discuss our estimation strategy. Section 5.5 has the results and Section 5.6 discusses their implications.

5.2. Institutional background

Patients face no charges for NHS health care, apart from a small charge (currently £8.20) for 10% of medicines prescribed in general practice. Patients register with a general practice which also acts as the gatekeeper for non-emergency hospital care. On average, general practices have around 6,600 patients and 4.2 GPs (Health and Social Care Information Centre, 2015) and most are partnerships owned by their GPs.

[98] Repeated interactions of patients with their current practice will increase their GP's knowledge of their health and their preferences and this knowledge will be lost if they change practice. Gravelle and Masiero (2000) and Karlsson (2007) model GP competition when quality is an experience good so that patients initially have imperfect information when initially choosing their GP. They show that this dilutes but does not eliminate the incentive for GPs to compete on quality.

Practices are paid a mixture of lump sums, capitation, quality incentive payments, and items of service. Around 75% of practice revenue varies with the number of patients registered with the practice. Over 50% is from capitation payments determined by a formula which takes account of the demographic mix of practice patients and local morbidity measures. Payments for achieving quality measures in the Quality and Outcomes Framework (QOF) generate a further 15% of practice revenue and, for a given quality level, QOF revenue increases with the number of patients. Practice payments for providing specific services, including vaccinating and screening target which are proportions of the relevant practice population, also increase with the total number of patients registered with the practice. Practices are reimbursed for the costs of their premises but cover all other expenses, such as hiring practice nurses and clerical staff, from their revenue.

Patients can apply to join the list of any practice. Practices can only refuse to accept a patient if they live outside a catchment area agreed with their local health authority (Primary Care Trust (PCT)). However, as reported in Section 4.2. previous chapter, practices can also notify the PCT that their list is closed so that no new patients will be accepted for a period of between 3 and 12 months. Around 2% of practices have closed lists at any one time (Monitor, 2015). Practices with closed lists are not eligible for some payments, so that some practices tell potential new patients that they are 'open but full' in an attempt to restrict registration. Possibly up to 10% of practices are open but full at any time (National Audit Office, 2008).

Policy-makers have attempted to encourage competition amongst general practices (Department of Health, 2010). The national body which controlled entry of new practices was abolished in 2002 and a tendering process was introduced to make it easier for new practices to be established, especially in under-doctored areas (Department of Health, 2007). A website, NHS Choices, was set up in 2007 containing information on the characteristics of practices, such as the clinics they offer, and results from patient satisfaction surveys. From 2015 practices have had the option of accepting patients who live outside their catchment area but without the obligation to make home visits, thus widening patients' choice sets (Mays et al., 2014).

5.3. Data

Joiners and leavers. The Department of Health provided the total numbers of patients who joined or left each general practice in England without changing their address in each financial year (1st April to 31st March) from 2006/7 to 2010/11. The data was primarily collected from the 82-89 NHAIS systems in England. The numbers of dead are excluded since the system includes date of death. The number of de-registrations might be slower than new registration, but the NHAIS had an algorithm to exclude duplicate or confused PDS records (https://webarchive.nationalarchives.gov.uk/20160921153441/http:/systems.digital.nhs.uk/ssd/downloads/add-downloads/pdsbpg4_2.pdf). We suspect that even if the number of leavers is underestimated, this happens randomly across English GP practices. The results of the leavers model might be underestimated, and therefore the impact of quality and FTE GPs would likely be stronger. Note that we do not have information on inter-practice transfers (the number who leave a practice j and then join practice k).

Clinical quality. We use three measures of practice clinical quality. Almost all practices take part in the QOF which rewards achievement on a large number of quality indicators. Better achievement increases the number of QOF points (up to a maximum of 1000 points), each point being worth £125. We use *total QOF points* (http://qof.hscic.gov.uk/) as measure of quality[99]. We also construct a measure based on more detailed QOF data because total QOF points, though simple, has a number of drawbacks as a measure of clinical quality. First, only two thirds of QOF points are for clinical indicators. Second, for most clinical indicators, achieving the indicator for an additional patient does not affect the number of points awarded if the percentage of eligible patients for whom the indicator is achieved is less a lower threshold (usually 40%) or above an upper threshold which ranges from 60% to 90%. Third, there may be selective exception reporting of patients as ineligible for an indicator (Doran et al., 2006; Gravelle et al., 2010) to boost rewarded QOF achievement. We therefore compute *population achievement* (*PA*) as a weighted average of the proportion of all patients, whether exception reported or not, with the relevant condition for whom a QOF clinical indicator is achieved (Doran et al., 2006). The weights are the maximum number of points available for each indicator.

Ambulatory Care Sensitive Conditions per 1000 patients is our third measure of clinical quality. ACSCs are conditions for which better management in primary care will reduce the risk of emergency hospital admission for complications. They are commonly used as measures of primary care quality (Agency for Healthcare Quality and Research, 2007; Purdy et al., 2009). We use the admission method and diagnostic fields in Hospital Episode Statistics (HES) to count the number of emergency ACSCs admissions for each practice (using the patients' GP practice code recorded on the HES episodes) for each financial year from 2006/7 to 2011/12, so for example, the 2006 ACSCs emergency admissions are collected from 1st April 2006 to 31st March 2007. Details of the ICD10 codes used to on the ACSCs definition are available in Appendix 1.2.

Patient reported quality. We have three measures of patient experience drawn from the General Practice Patient Surveys (GPPS)[100] administered each year to a 5% random sample of patients in each practice. The first measure is the proportion of respondents who say they can get appointments within the next 48 hours (*urgent appointments*) and the second is the proportion who say they can make appointments more than two days in advance (*advance appointments*). The third is the proportion who report that they are satisfied with their practice's opening hours (*opening hours satisfaction*)[101].

General practitioner characteristics. Previous studies (e.g. Biørn & Godager, 2010; Lurås, 2004; Santos et al., 2017) have suggested that patient choice of practice is also influenced by the number of GPs per patient, and their gender, age, and country of qualification. We therefore extracted data on the number of full time equivalent GPs in each practice, their gender, age, and country of qualification from the annual GP census named General Medical Statistics (GMS)[102].

Locality characteristics. When a practice closes other nearby practices will take on their patients and patients in nearby practices will be less likely to leave without changing address because their choice set of local practices has been reduced. Conversely, when a new practice opens, existing nearby practices may lose patients and they will be less likely to attract patients from other

[99] QOF data is collected by NHS digital for each financial year, for example for 2006/7, the data is collected for the period between the 1st of April 2006 and the 31st of March 2007.

[100] We used the weighted GPPS responses available at https://gp-patient.co.uk/

[101] The GPPS data were attributed to the financial years using the fieldwork dates (for more information please see Appendix 2.2.).

[102] We have attributed GMS data from, for example, 30th September 2006 to the financial year of 2006/7 since the date of the snapshot is exactly in the middle of the financial year.

practices. We include in the models the number of new (open) and closing practices each year within 5km of each practice.

Patients deciding whether to leave or join a practice will compare it with other local practices. We do not know which practice patients move to when they leave a practice, nor from which practice patients have moved when they join a practice. We measure the average quality of other practices within 5km of the practice and expect that a practice will have more leavers and fewer joiners without change of address if the average quality of nearby practices is higher.

Patients who live further away from their practice will, ceteris paribus, obtain less utility from it and so will be more likely to leave without change of address if quality or other practice characteristics deteriorate. We therefore use information on the number of patients in each practice list who live in each Lower Super Output Area (LSOA)[103] to compute the weighted average distance of a practice from the centroids of the LSOAs in which its patients live. In the joiners model we interpret the measure as a proxy for the practice catchment area and hence as a control for practice rationing entry to their lists.

Patient characteristics. Characteristics of the practice population may influence patient propensity to leave or join. For example, older patients may be less likely to leave because they will experience a greater cost from the loss of the knowledge accumulated about them by their current practice. The characteristics of the other patients on the list may also affect the utility that individual patients gain from a practice. For example, a practice with more elderly patients who place higher demands on it will have less time for other patients.[104] We therefore include the proportions of the practice patient list in 12 age and gender bands in the leaving and joining models.

Similarly we include variables to control for patient morbidity (the proportion of practice patients who live in nursing home and the practice level prevalence of 17 conditions including diabetes, Coronary Heart Disease (CHD), stroke and dementia. We also include the weighted average of the proportion of LSOA residents who are in receipt of Incapacity Benefit (IB) and Severe Disablement Allowance (SDA), where the weights are the proportion of the practice patients living in each LSOA[105]. A quarterly snapshot of the IB and SDA data is collected at the end of February, May, August and November. Since we wanted to attribute the IB and SDA data to the financial year, we used the August snapshot of each year, for example we attribute the data from August 2006 to the financial year of 2006/7.

Including patient characteristics will increase precision if they affect leaving or joining rates. It is also possible that patient characteristics affect quality: it may be more difficult to achieve clinical indicators if there are more morbid patients or the elderly may be more likely to report higher satisfaction. Hence we also reduce omitted variable bias.

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[103] There were 32,482 LSOAs in England with mean population of 1500.

[104] In 2008/9 consultation rates for patients aged over 80 were around twice those of the average patient (Hippisley-Cox & Vinogradova, 2009).

[105] For each practice, we attribute the weighted mean of the LSOA data where the weights are the proportion of individuals registered with the practice and living in each LSOA (for a description of the attribution strategy please see Appendix 2.3).

5.3.1. Sample

Our initial raw data sample has 8722 practices contributing 41770 observations. It has mean annual leaving and joining rates of 1.40% and 1.22%, standard deviations of 3.75% and 3.71% and is very positively skewed (Fisher-Pearson coefficients: 14.0 and 13.93). The mean rate is similar to an earlier English study (Dixon et al., 1997) and to Denmark (Bjerrum & Sørensen, 1992) but around one third of the rate in Norway (Iversen & Lurås, 2011). However, some of the leaving and joining rates are artefacts: when a practice closes its patients are transferred to other local practices by the PCT and recorded as leaving the closing practice and joining other practices without change of address. Closure may be a protracted process with a closing practice transferring its patients to other practices over several years and some practices may just downsize rather than close. Practices may sometimes split, with some of the GPs leaving and taking a proportion of the list to their new practice: these patients will be recorded as leaving their original practice and joining the new one without change of address. We therefore restrict the sample to remove outlying and likely artefactual observations. We only include practices which were open continuously from one year before (2005/6) to one year after (2011/12) the period from 2006/7 to 2010/11 (dropping 3522 observations). We have dropped practices which have a leaving or joining rate for non-movers of over 5 per cent in any year 2006/7 to 2010/11 (dropping 2575 observations). We further excluded practices which, in any year between 2006/7 to 2010/11, had a list size of less than 1000 (dropping 97 observations). Nursing homes often contract with nearby practices to provide primary care for their residents so that leaving or joining decisions for these patients may not be made by the patients but by the nursing home. We have therefore dropped practices where nursing home residents (15 observations) are a high proportion of the list (over 30 per cent) and when compared with an overall mean of 0.53 per cent. After also dropping practice-year observations with missing data on explanatories (1925 observations), the estimation sample has 33,636 observations on 6766 practices.

5.4. Methods

5.4.1. Estimation

We have practice level data on the number of patients leaving a practice and the number joining it without change of address. We do not have information on the numbers switching from one specific practice to another specific practice. Some practices have small numbers (including zero) leaving and joining each year and the distributions of leavers and joiners are right skewed.[106] We therefore estimate count data models in which the number n_{jt} of leavers (or joiners) for practice j in year t follows a Poisson process with conditional mean

$$E\left(n_{jt} \middle| \mathbf{x}_{jt}, L_{jt}, \delta_t, \alpha_j\right) = L_{jt} \exp\left(\mathbf{x}'_{jt}\boldsymbol{\beta}_x + \delta_t + \alpha_j\right) \qquad (26)$$

$\mathbf{x}_{jt}$ is a vector which includes practice quality measures, characteristics of the GPs in the practice, and covariates. L_{jt} is a measure of exposure. For the model of leavers L_{jt} is the practice list of patients in practice j in year t. For the model of joiners we measure exposure as the total number of patients in other practices within 5 km who left their practice without change of address in year t. δ_t are year effects and α_j are practice fixed effects. To allow for the possibility that patients only learn about the quality of other nearby practices with a lag we estimate alternative specifications with current and one year lags of the quality variables.

[106] The estimation sample leaving and joining rates have Fisher-Pearson skewness of 1.81 and 2.06.

We use robust standard errors clustered at practice level that ensures valid standard errors, even if the Poisson assumption that the variance equals the mean does not hold. The alternative negative binomial fixed effects specification is not a true fixed effects model except under very strong assumptions (Allison, 2009; Allison & Waterman, 2002; Guimarães, 2008).

By using practice fixed effects we identify the effect of quality and GP characteristics from changes within practices in the numbers of leavers or joiners and changes in practice quality and GP characteristics. Our results are thus not biased by unobserved time invariant practice factors.

Nor do we think that time varying endogeneity is a problem. If we were estimating models for choice of practice by all patients (as in Santos et al. (2017)) then we should have to worry about possible simultaneity bias arising from the effect of the number of patients on quality, especially as measured by patient reports of being able to make urgent or advance appointments. It is also possible that clinical quality depends on unobserved patient characteristics which also affect demand: for example, it may be easier to achieve higher quality with more educated patients and such patients may be more responsive to quality than other patients. But one of the strengths of our data is that the patients we study are a small proportion of the total number registered with the practice and so will have negligible effects on our quality variables which are measured at overall practice level, not for those leaving or joining without change of address.[107]

It is possible that in practices with a target list the number of new patients admitted to the practice list will vary inversely with the numbers who have left. However, the numbers leaving and joining without change of address are a small proportion (around one tenth) of the numbers leaving and joining when they change address, so that the number of leavers without change of address is unlikely to affect the number of joiners without change of address. We therefore estimate separate models for the numbers of patients per year leaving a practice, and for the number joining, without change of address.

5.4.2. Interpretation

We next discuss the interpretation of the estimated coefficients on quality and practice characteristics: whether they reflect decisions by patients and thus reveal the impact of quality on demand and whether they also convey quantitative, rather than qualitative, information about patient preferences.

The marginal effect (ME) of the Poisson model of equation (26) a one unit change in quality q_{jt} on the outcome y_{jt} for practice j at time is:

$$\frac{\partial Ey_{jt}}{\partial x_{jt}} = \beta_x \exp\left(\bar{\mathbf{x}}'_{jt}\beta_x + \delta_t + \alpha_j + \ln \bar{L}_{jt}\right) = \beta_x Ey \tag{27}$$

where Ey is the mean of y over all the years and GP practices.

[107] GPs are allowed to remove patients from the practice list if there is a fundamental breakdown in the doctor-patient relationship. Thus the number of patients leaving a practice without a change of address will include those who are deregistered by GPs. It has been estimated that these deregistrations run at the rate of 0.04% per year (Munro et al., 2002). Even if our practice level quality measures are affected by the number and type of patient on the practice list, deregistrations can have only a negligible effect on the practice level quality measures and so will not be a source of endogeneity. Deregistrations may make a very small contribution to the error term (they are around 1/20th of the average leaving rate) but seem very unlikely to bias estimated coefficients in the leaving model.

The proportional marginal effect of a one unit change in a GP practice characteristic (x) is therefore just the coefficient βx. We report the percentage change from one standard deviation increase in x as $\left(\beta_x SD_x 100\right)$ and the change in number of joiners/leavers $\left(\beta_x EySD_x\right)$. We also report the elasticity that is just $\frac{\partial Ey_{jt}}{\partial x_{jt}} \frac{\bar{x}}{Ey_{jt}} == \beta_x Ey_{jt} \frac{\bar{x}}{Ey_{jt}} = \beta_x \bar{x}$. Where $\bar{x}$ is mean the of x over all the years and GP practices.

Leavers model. Making the weak assumption that patients are more likely to leave a practice when it produces less utility, the signs of the estimated coefficients in the Poisson leavers model are the signs of the marginal utility of quality and other practice characteristics. With stronger assumptions about the decision process we can recover quantitative information about preferences. Suppose that the utility patient *i* obtains from practice *j* is $V_j + \omega_{ij}$ where $V_j = V(\mathbf{x}_j)$ depends on observed practice characteristics $\mathbf{x}_j$ and ω_{ij} is utility from unobserved practice characteristics with identically and independently distributed effects on patients. Patient *i* will leave practice *j* with probability

$$\pi_j = \Pr\left[\omega_{ij} < \max_{k \in S_j}\{V_k + \omega_{ik}\} - V_j\right] = \pi(V_j, \mathbf{V}_{-j}) \tag{28}$$

where S_j is the set of other nearby practices in patient *i*'s choice set and $\mathbf{V}_{-j}$ is the vector of utilities obtainable in all those nearby practices. The number of "successes" (leavers) in *L* identical and independent Bernoulli trials with success probability π will follow the Poisson distribution with mean πL as the number of trials becomes large, the success probability becomes small, and the average number of successes (πL) is held constant (Cameron & Trivedi, 2013). For our sample π (the probability of leaving without address change) is under 1% and the average number of patients in a practice (*L*) is over 7000. It therefore seems reasonable to interpret the ratio of coefficients on practice characteristics *m* and *r* from the Poisson model as the rate at which patients are willing to trade off these characteristics:

$$\frac{\beta_r}{\beta_k} = \frac{\partial \pi / \partial x_{jr}}{\partial \pi / \partial x_{jm}} = \frac{(\partial \pi / \partial V_j)(\partial V / \partial x_{jr})}{(\partial \pi / \partial V_j)(\partial V / \partial x_{jm})} = \frac{\partial V / \partial x_{jr}}{\partial V / \partial x_{jm}} \tag{29}$$

Joiners model. Interpretation of the coefficients in the joiners model is complicated by practices being able to refuse to accept patients if they live outside their agreed catchment area or if the practice has a closed list. Catchment areas restrict the choice set of patients but a patient's choice of practices from within her choice set will still reflect her preferences. Santos et al. (2017) found that the effects of quality, practice characteristics, and distance on choice of practice were not sensitive to varying the assumed radius of the patient choice set between 2km and 10km. Temporary list closures will weaken the relationship between the number joining a practice and patient preferences over practice quality and characteristics. But since most practices (at least 90%) do not have closed lists we think it is reasonable to interpret the signs of estimated coefficients on practice quality and characteristics in the joiners model as conveying information about the signs of their effects on patient utility and demand.[108]

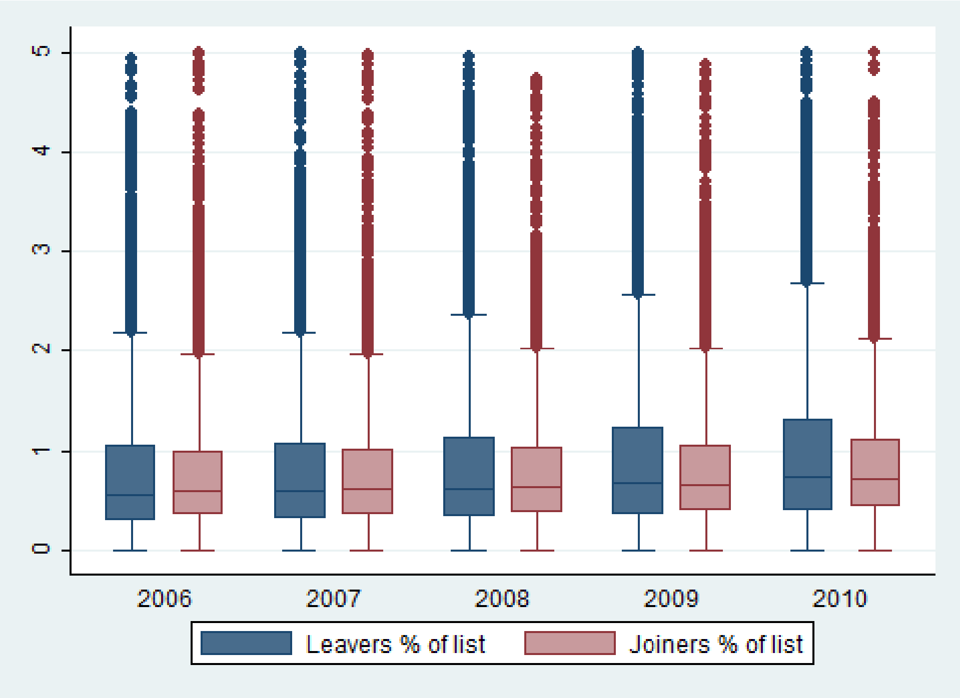
[108] Guimarães, Figueirdo, and Woodward (2003) have shown that the estimated coefficients on the characteristics of alternatives (practices) from a Poisson regression model for the number of individuals who choose each alternative are identical to those from a conditional logit model of choice by individuals maximising utility functions which are linear in the practice characteristics. Hence, if we believe that practice closures are not a problem and we are willing to make the necessary assumption for the conditional logit model that utility is a linear function of the characteristics of the

5.6. Results

5.6.1. Summary statistics

The time series of box plots in Figure 24[109] show that the rates of joining and leaving for the estimation sample are right skewed even after dropping practices with very high rates. The summary statistics in Table 5-1[110] show that mean percentages leaving and joining in our estimation sample for 2006/7 to 2010/11 are 0.88 % and 0.80%. The within practice standard deviations variations in the numbers leaving or joining are a little under half the means and account for a little under half the total variation.

Figure 24 - Leavers and joiners without change of address 2006/7-2010/11



Note. Leavers (joiners) as percent of list size. Estimation sample: 6766 practices continually open 2005/6 to 2011/12 with leaving and joining rates of 5% or less.

Almost all practices scored highly on the QOF, so that the average proportion of total points earned is 0.96 and the measure has relatively little variation across practices (coefficient of variation: 0.046). The other two clinical quality measures, QOF PA and the ACSC emergency admission rate have larger coefficients of variation of 0.079 and 0.378. The patient reported quality measures exhibit more variation than the two QOF based measures and the ACSC admissions measure even more.

Practices have around one GP per two thousand patients and the GPs have an average age of 48. Two fifth of GPs are female and nearly a quarter are qualified outside the UK.

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alternatives, and that the errors ω_{ij} in patient utility functions are additive and have identical and independent Type I extreme value distributions, then the ratios of coefficients estimated by the Poisson model for joiners can be interpreted as patient marginal rates of substitution as in (29).

109 The box and whisker plot lines identify, from bottom to top, the minimum value, the 25th percentile, the median, the 75th percentile and the 75th percentile plus 1.5 interquartile range.

110 To save space we do not report the summary statistics on the average quality of nearby practices. Unsurprisingly, their means are almost identical to those for the practice level variables and their standard deviations smaller.

Table 5-1: Summary statistics

	mean	median	P1	P99	Overall (SD)	Within (SD)	Between (SD)
Patients moving without change of address							
Number of leavers	50.16	38	3	213	44.22	21.86	38.42
Number of joiners	51.87	39	3	227	45.90	22.19	40.17
Leavers as % of list	0.880	0.629	0.066	3.159	0.791	0.347	0.712
Joiners as % of list	0.803	0.638	0.047	3.784	0.625	0.355	0.514
Clinical quality							
QOF points (proportion of total)	0.960	0.971	0.78	1	0.044	0.028	0.035
QOF clinical population achievement (proportion)	0.798	0.811	0.61	0.902	0.063	0.048	0.040
ACSCs emerg. adm. per 1000 patients	12.12	11.68	2.48	24.66	4.58	1.98	4.14
Patient reported quality							
Urgent appointment	0.839	0.858	0.52	0.994	0.107	0.047	0.097
Advance appointment	0.742	0.768	0.31	0.99	0.164	0.063	0.151
Opening hours satisfaction	0.822	0.829	0.64	0.948	0.064	0.030	0.057
GP characteristics							
GPs per 1000 patients	0.573	0.558	0.229	1.103	0.171	0.088	0.147
Average GP Age	48.23	47	36.33	67	6.75	2.522	6.267
Proportion Female GPs	0.3903	0.4286	0	1	0.2561	0.090	0.240
Proportion EU GPs Non UK European qualified	0.046	0	0	1	0.127	0.043	0.120
Proportion Non-UE GPs	0.236	0	0	1	0.354	0.077	0.346
Locality							
Patient to practice distance (km)	0.985	0.750	0.257	3.648	0.731	0.005	0.730
Number new practices within 5km	0.22	0	0	3	0.62	0.532	0.327
Number practices closed within 5km	0.50	0	0	5	0.99	0.626	0.773
Patient characteristics							
Percentage of Nursing Home patients	0.524	0.382	0	2.626	0.579	0.142	0.565
Proportion population claiming IBDSA	0.051	0.047	0.015	0.123	0.024	0.005	0.024
Total patient list	7118	6401	1729	19087	4004	379	3986

Notes. QOF: Quality and Outcomes Framework. ACSC: emergency admissions for ambulatory care sensitive conditions. GPs are full time equivalents. IBDSA: incapacity benefit and disability living allowance. Other covariates include the average quality of practices within 5km, the proportions of patients in 12 age-gender bands, and the practice prevalence for 17 conditions. Statistics for estimation sample with 33,636 practice year observations 2006/7-2010/11. P1: 1st percentile, P99: 99th percentile.

Table 5-2 reports the correlations amongst the six quality measures. The correlations amongst the three clinical measures have the expected signs (remembering that the ACSCs emergency admission rate is a negative measure of quality). The two QOF based measures have low (negative) correlations with the ACSC rate and even the two QOF based measures have a correlation of only 0.31. The patient reported measures of satisfaction with access are more strongly correlated than the three clinical measures and are positive correlated with the two QOF clinical measures. Overall satisfaction with opening hours is however, positively correlated with ACSCs. The table suggests that the measures are picking up different aspects of quality.

Table 5-2: Quality measures correlations

	QOF points	QOF Pop Achievement	ACSC Emerg Admissions	Urgent appointments	Advance appointments
QOF Pop Achievement	0.309				
ACSC Emerg Adms	-0.050	-0.052			
Urgent appointments	0.233	0.175	-0.087		
Advance appointments	0.128	0.172	-0.158	0.323	
Opening hours satisfaction	0.216	0.068	0.142	0.512	0.377

Note. Correlations across 33636 practice-year observations. PA QOF: clinical population achievement on Quality and Outcomes Framework. ACSC: ambulatory care sensitive conditions.

5.6.2. Regression results: leavers

Table 5-3 has the key results from Poisson count data models for the number of patients leaving practices without a change of address (full results are in the Appendix 5

Table A. 37 and Table A. 38). The reported coefficients are the proportionate change in the number of leavers (and also the proportionate change in the leaving rate $y_{jt} = n_{jt}/L_{jt}$) from a one unit change in the explanatory variable.

Table 5-3: Patients leaving a practice without change of address

	(1)	(2)	(3)
	FE	FE	Pooled
Period	2006/7 -2010/11	2007/8 -2010/11	2006/7 - 2010/11
Current/lagged quality	Current	Lagged	Current
QOF total points (prop of available)	-0.373***	-0.328**	-0.198*
	(0.111)	(0.113)	(0.114)
Clinical QOF Pop Achiev (proportion)	-0.0191	-0.0019*	-0.0631
	(0.0753)	(0.0009)	(0.0937)
ACSC. Emerg adm per 1000 patients	0.0040**	0.0039**	0.0142***
	(0.0014)	(0.00157)	(0.0011)
Urgent appointment	-0.754***	-0.297***	-0.774***
	(0.066)	(0.070)	(0.045)
Advance appointment	-0.261***	-0.149**	-0.298***
	(0.047)	(0.057)	(0.030)
Opening hours satisfaction	-0.689***	-0.0744	-0.485***
	(0.098)	(0.106)	(0.082)
GPs FTE per 1000 patients	-0.221***	-0.274***	-0.404***
	(0.034)	(0.040)	(0.028)
Average GP Age	-0.0009	-0.0022	0.0025***
	(0.001)	(0.001)	(0.001)
Proportion female GPs	0.023	0.046	-0.072***
	(0.030)	(0.036)	(0.017)
Prop EU GPs	0.064	0.152	0.295***
	(0.067)	(0.084)	(0.030)
Prop Non-EU GPs	0.193***	0.177***	0.340***
	(0.034)	(0.039)	(0.015)
Patient to practice distance (km)	-0.580	-0.565	-0.184***
	(0.440)	(0.408)	(0.009)
Number new practices within 5km	0.021***	0.011**	0.020***
	(0.004)	(0.004)	(0.006)
Number practices closed within 5km	0.006	0.010**	-0.075***
	(0.003)	(0.004)	(0.005)
AIC	294563	214829	765490
BIC	295035	215280	765970
Observations	33636	26864	33636

Notes: Dependent variable: number of patients leaving a practice without address change. All models also contain: average quality of practices within 5km, practice patient age and gender proportions, QOF condition prevalence rates, proportion of nursing home patients, invalidity benefit rate and year effects. Exposure term: total practice list. Coefficients are proportionate changes from one unit increase. Robust SEs in parentheses.
**: p<0.05; **: p<0.01; ***: p < 0.001*

The column (1) model uses all five years of data and has practice fixed effects. The results suggest that changes in the quality of a practice are negatively associated with changes in the numbers leaving without a change of address. Practices with more QOF points have fewer leavers as do those with lower rates of emergency ACSC admissions. The coefficient on QOF Population Achievement is also negative, though it is statistically insignificant and two orders of magnitude smaller than that on QOF points. The three patient reported access measures (proportions of patients reporting that they were able to make urgent, advance appointments and expressing satisfaction with opening hours) are all statistically significantly negatively associated with the number leaving.

Other practice characteristics are also associated with the number leaving. Practices with more GPs per patient have fewer patients leaving but more patients leave when a higher proportion of GPs qualified outside Europe. Leaving decisions do not appear to be associated with the gender or age of GPs. More patients leave when new practices open nearby. The model also includes the quality and characteristics of nearby practices but these were not statistically significant (see Appendix 5

Table A. 37), perhaps because the average of nearby practice quality in each year exhibited little variation over time.

Results in column (2) which uses one year lags of practice quality and the quality of nearby practices are similar to those in column (1) except that overall satisfaction with opening hours has a much smaller and statistically insignificant association with the number of leavers.

The pooled model (3) has the same explanatories and observations as model (1) but does not include practice fixed effects. Failure to allow for practice effects has a marked effect on estimated coefficients. The pooled model coefficient on QOF points is halved and the coefficient on ACSC admissions increases three fold. The coefficients on GP age and the proportion of female GPs change sign and become significant at 0.1%. The coefficient on GPs who qualified in Europe increases five-fold and becomes significant at 0.1%. The coefficients on the number of practices closing nearby and the average patient distance to the practice now have negative significant coefficients.

5.6.3. Regression results: joiners

In Table 5-3 results for the fixed effects models of the numbers of joiners without change of address are sensitive to whether we use current or lagged values of quality and GP characteristics (column (1) versus column (2)). Since patients who are not currently in a practice may take longer to discover its quality we suggest that lagged quality is more likely to be the relevant quality measure for joiners. In both specifications practices with more patients able to make urgent appointments and with greater reported satisfaction with opening hours attract more non-movers. In column (1) current QOF clinical quality has no effect on patients joining and the current ACSC admission rate (a negative measure of quality) has a positive coefficient. However, in our preferred model in column (2) more patients join practices whose QOF clinical quality was higher in the previous year and lagged ACSC admissions has a very small and statistically insignificant effect. In both specifications patients are more likely to join practices with more GPs per patient, with younger GPs and with fewer new nearby practices. The contrast between the pooled model in column (3) and the two fixed effects models again shows that failing to allow for unobserved practice time invariant factors leads to marked changes in estimated coefficients.

Table 5-4: Patients joining a practice without change of address

	(1)	(2)	(3)
	FE	FE	Pooled
Period	2006/7 -2010/11	2007/8 -2010/11	2006/7 -2010/11
Current/lagged quality	Current	Lagged	Current
QOF total points (prop of available)	0.237	0.265*	0.912***
	(0.129)	(0.131)	(0.186)
Clinical QOF PA (proportion)	-0.153	-0.001	-0.784***
	(0.082)	(0.001)	(0.158)
ACSC. Emerg adm per 1000 patients	0.0056***	0.001	-0.0032*
	(0.002)	(0.002)	(0.002)
Urgent appointment	0.227**	0.201*	0.390***
	(0.075)	(0.082)	(0.065)
Advance appointment	-0.036	0.021	-0.065
	(0.048)	(0.052)	(0.041)
Opening hours satisfaction	0.634***	0.356**	1.269***
	(0.102)	(0.113)	(0.126)
GPs FTE per 1000 patients	0.0949*	0.0866*	0.060
	(0.037)	(0.040)	(0.043)
Average GP Age	-0.0077***	-0.0079***	-0.0161***
	(0.001)	(0.002)	(0.001)
Proportion female GPs	-0.082*	-0.075	-0.029
	(0.037)	(0.041)	(0.024)
Prop EU GPs	0.065	0.051	0.137**
	(0.071)	(0.088)	(0.047)
Prop Non-EU GPs	-0.062	-0.065	0.031
	(0.049)	(0.055)	(0.021)
Patient to practice distance (km)	-0.878	-0.751	1.084***
	(0.574)	(0.538)	(0.029)
Number new practices within 5km	-0.063***	-0.060***	-0.193***
	(0.006)	(0.006)	(0.008)
Number practices closed within 5km	0.007	0.004	-0.162***
	(0.004)	(0.005)	(0.006)
AIC	331907	237817	1577199
BIC	332379	238268	1577679
Observations	33631	26860	33636

*Notes: Dependent variable: number of patients joining a practice without address change. All models also contain average quality of practices within 5km, practice patient age and gender proportions, QOF condition prevalence rates, proportion of nursing home patients, invalidity benefit rate and year effects. Exposure term: total number of patients leaving other practices within 5 km without change of address. Coefficients are proportionate changes from one unit increase.. Robust SEs in parentheses. *: p<0.05; **: p<0.01; ***: p < 0.001*

5.5.4. Effect sizes

Table 5-5 has effect sizes using the results from the fixed effects leavers model with current quality (Table 5-2, column (1)) and from the fixed effects joiners model with lagged quality (Table 5-3, column (2)). We report the estimated effects from a one standard deviation increase on the quality measures and GPs per patient on the number of leavers and joiners without change of address: the proportional change, the change in number of leavers/joiners and the elasticities.

The reductions in the numbers leaving without change of address when quality improves are small but this by itself is a misleading guide to the implications of the model since only a very small number of patients leave practices each year without a change of address. Relative to the average number of leavers of 50 per year the effect of quality is sizeable. For example, a one SD increase in satisfaction with urgent appointments would reduce the number of patients leaving the average practice 8.1%. A 10% increase in satisfaction with opening hours would reduce the number leaving by 5.7%.

The effects of practice quality and GP characteristics on the numbers joining without a change of address are smaller than for the numbers leaving. For example, a 10% increase in satisfaction with opening hours would increase the numbers joining by 2.9%.

The patients' marginal rate of substitution between FTE GPs per 1000 patients and satisfaction with ability to book an urgent appointment is higher for joiners than leavers since it is 0.293 for leavers and 0.431 for joiners. Joiners are more willing than leavers to accept a reduction in ability to book urgent appointments in exchange for an increase in FTE GPs per head.

Table 5-5: Marginal effects of practice characteristics

	Leavers without change of address			Joiners without change of address		
	Change in leavers from 1 sd increase	Proportional change in leavers from 1 sd increase	Elasticity	Change in joiners from 1 sd increase	Proportional change in joiners from 1 sd increase	Elasticity
	($\beta_x EySD_x$)	($\beta_x SD_x 100$)	($\beta_x \overline{x}$)	($\beta_x EySD_x$)	($\beta_x SD_x 100$)	($\beta_x \overline{x}$)
Total QOF points	–0.825	–1.6%	–0.359	0.621	1.2%	0.255
	[–1.307, –0.343]	[–2.6%, –0.7%]	[–0.568, –0.149]	[0.019, 1.22]	[0.04%, 2.4%]	[0.008, 0.502]
Clinical QOF PA (proportion)	–0.060	–0.1%	–0.015	-0.305	-0.6%	-0.072
	[–0.525, 0.405]	[–1.0%, 0.8%]	[–0.133, 0.103]	[-0.932, 0.322]	[-1.8%, 0.6%]	[-0.221, 0.076]
ACSCs. Emerg adm per 1000 patients	0.908	1.8%	0.048	0.26	0.5%	0.013
	[0.291, 1.526]	[0.6%, 3.0%]	[0.015, 0.080]	[-0.483, 1.003]	[-0.9%, 1.9%]	[-0.025, 0.052]
Urgent appointment	–4.054	–8.1%	–0.633	1.111	2.1%	0.17
	[–4.747, –3.360]	[–9.5%, –6.7%]	[–0.741, –0.524]	[0.219, 2.003]	[0.4%, 3.9%]	[0.033, 0.306]
Advance appointment	–2.143	–4.3%	-0.194	0.1812	0.3%	0.016
	[–2.896, –1.390]	[–5.8%, –2.8%]	[–0.262,–0.126]	[-0.699, 1.061]	[-1.3%, 2.0%]	[-0.06, 0.091]
Opening hours satisfaction	–2.228	–4.4%	-0.567	1.192	2.3%	0.293
	[–2.85, –1.607]	[–5.7%, –3.2%]	[–0.725, –0.409]	[0.447,1.937]	[0.9%, 3.7%]	[0.110, 0.477]
FTE GPs per 1000 patients	–1.893	–3.8%	–0.127	0.767	1.5%	0.05
	[–2.465, –1.322]	[–4.9%, –2.6%]	[–0.165, –0.088]	[0.07,1.465]	[0.1%, 2.8%]	[0.005, 0.095]
Av GP age	-0.308	-0.6%	-0.438	-2.751	-5.3%	-0.379
	[-1.079, 0.463]	[-2.2% ,0.9%]	[-0.154 , 0.066]	[-3.854, -1.647]	[-7.4%, -3.2%]	[-0.531, -0.227]
Proportion female GPs	0.303	0.6%	0.009	-0.991	-1.9%	-0.029
	[-0.473, 1.078]	[-0.9% , 2.1%]	[-0.014 , 0.033]	[-2.062, 0.08]	[-4%,0.2%]	[-0.061, 0.002]
Prop EU GPs	3.437	6.9%	0.046	-1.187	-2.3%	-0.015
	[2.239, 4.635]	[4.5% , 9.2%]	[0.03 , 0.622]	[-3.157, 0.783]	[-6.1%, 1.5%]	[-0.041, 0.01]

Notes. s: standard deviation of quality variable; β: coefficient on quality variable; $\overline{n}$ mean number leaving (or joining) without address change; $\overline{q}$ mean quality. Means computed over all practice by year observations. The coefficients for leavers are from column (1) in Table 3 (Poisson fixed effects with current quality) and for joiners are from column (2) in Table 4 (Poisson fixed effects with lagged quality). Square brackets contain the 95% confidence interval.

5.6. Discussion

We find that increases in practice clinical quality, patient reported access, the number of GPs per patient, and the proportion of UK qualified GPs reduce the number of patients leaving a practice without change of address. Since practices cannot directly control exits from their lists, we interpret the results for leavers as being based on patient decisions and thus providing information on patient preferences.

Our results for leavers are qualitatively broadly consistent with Santos et al (Santos et al., 2017) who examined the factors determining the stock of patients i.e. the whole practice list at a single point in time. They also find that QOF points, most other measures of quality, and overseas qualified GPs affect patient choice of practice. However, they found an insignificant effect of patient satisfaction with opening hours once QOF points were allowed for and they found a positive effect of having a higher proportion of female GPs (as in (Biørn & Godager, 2010)). Some of our results are similar to those from the cross section study of leavers by Nagraj et al (Nagraj et al., 2013) but others differ markedly: we find that more patients leave practices with a higher proportion of GPs qualified outside Europe and fewer leave practices with more GPs per patient. We believe our use of practice fixed effects to remove unobserved practice differences will have produced more consistent estimates than with pooled or cross-section data.

The associations of quality and GP characteristics with the numbers joining a practice without changing address are broadly in line with those from the leavers model: practices with higher quality and more GPs per patient will attract more non-movers. The associations are weaker than those in the leavers model, possibly because a minority of practices ration demand by temporarily closing their lists to new patients. It is also possible that patients considering joining a practice without changing their address, though better informed than new arrivals in the area, will be less well informed than those already in the practice and considering leaving it.

Overall, our results show that changes in quality and practice characteristics can have a quantitatively significant impact on patient decisions to leave or join a practice without change of address. The proportional effect of quality on the number of patients leaving a practice without change of address can be sizeable. For example, the elasticity of the number of patients leaving a practice with respect to average satisfaction with practice opening hours is –0.57 [95% CI: –0.73, –0.41]. They thus suggest that, for patients with good information, changes in quality have an impact on choice of practice. More speculatively, they also suggest that making it easier for patients to learn about quality could increase the responsiveness of their decisions to quality and so increase practice incentives to improve quality.

The decision to improve the access of patients to quality indicators of nearby practices will influence patient choice and likely promote an increase in the quality of the services. It was not possible in this study to understand the movement of patients across practices; we did not have the information on inter-practice transfers (the number who leave a practice j and then join practice k). This data would be important to understand if the movement of patients was due to factors that not quality, such as the movement of their GP or provision of extended access.

In future, it would be important to have the patients' inter-practice transfers to understand the dynamics between practices and which factors, including quality, influence the movement of patients. Moreover, it would be interesting to understand if the recent collaboration between practices to provide extended access and the development of large-scale general practices (with collaborations, networks, large organisations) have an influence on patients' informed choice of practice.

Conclusion

This thesis contributes to the variations literature in several ways. Using ACSCs emergency admissions as a quality proxy, we provide insights into the variation in quality across English GP practices and highlight the main practice and population characteristics that influence this type of admissions at GP practice level. We also test for the impact of two mechanisms that might explain variation: peer effects and competition.

The time dynamics of the spatial pattern show that some areas have been affected by high and low ACSCs emergency admissions rates for 10 years. The fact that we do the analysis at GP practice level permits understanding of how heterogeneous is the spatial pattern within the Primary Care Trusts.

Acute and Non-Incentivised ACSCs emergency admissions increased between 2004 and 2013, but nevertheless, the increase was not homogenous across England nor within PCTs. After adjusting for the age and gender structure of the GP practice list, the unexplained variation of Acute and Non-incentivised ACSCs emergency admissions shows local clusters of high and low emergency admissions rates. For example, the 2013 Acute ACSCs emergency admissions spatial pattern shows wider variation and more areas with high indirect STD rates, especially in the M63 motorway corridor between Liverpool and Hull. When we take the difference between the 2013 and 2004 spatial pattern, the areas of Greater Manchester and Hull are especially highlighted by the increase in Acute ACSCs emergency admission indirect STD rate.

The stability of the English spatial pattern of ACSCs emergency admissions reveals that the heterogeneous pattern of quality across GP practices is persistent. The heterogeneity of the spatial pattern is highlighted by the contrast between areas of high and low indirect standardised ACSCs emergency admissions rates. Some areas have an indirect standardised ACSCs emergency admissions rate more than five times higher than others. The persistence of the heterogeneous spatial pattern is revealed by GP practices that are over five years in a local spatial cluster of high indirect standardised ACSCs emergency admissions rates. This persistence is an indicator of inequality of access to healthcare since practices do not provide the needed healthcare to prevent patients from having this type of emergency admission. This underlines the importance of research on the factors that explain the variation.

The space-time dynamics map shows that Liverpool, Greater Manchester and South Yorkshire have GP practices in the spatial cluster of high Acute ACSCs emergency admissions indirect STD rate for at least five years.

Understanding the space-time dynamics of these particular areas is important since it raises questions about the quality, equity, and efficiency of resource allocation and use. Since we have shown that standardisation by age, gender and deprivation does not elevate variation, this raises the question of whether it is due to other factors affecting morbidity or to variations in practices' resources, clinical quality or accessibility. This is the question we address in a Chapter 2.

On studying the determinants of ACSCs emergency admissions at GP practice level we find that the most significant factors to prevent this type of admission are clinical quality and patient access to urgent and advance appointments. These are also the factors that have higher variability across practices and are influenced by the GP practice workforce. We also find that improvement in these factors has a higher impact on the most deprived areas. The effects of a quality increase and/or number of GPs on ACSCs emergency admissions are overall modest.

The rich panel data set at GP practice level, with information on GP practice characteristics from GP supply to patient list demographics and deprivation, allowed us to explore the major driver of ACSCs emergency admission at GP practice level. The results are robust and show that to reduce ACSCs emergency admissions GP practices need to improve not just the number of GPs but also the quality of care and access to advance and urgent consultations.

However, ACSCs emergency admissions are also subject to the Hospital Trust management policies. While some Trusts have a policy to avoid emergency admissions, others have the policy of admitting and then trying to discharge as soon as possible. We are not able to control for this. However, since we use GP practice fixed effects, and it is likely that the GP practice patients go to the same hospital Trust over the years, we believe our results are not biased by the Hospital Trust policy.

It is important to understand that practices work within small areas and are influenced by their peers. When we apply a peer effects model to GP practice quality decisions, we find that the relationship that practices have within their peer group influences the quality they provide. We tested the existence of this effect by using an empirical strategy with the identification of the parameters of interest, namely the peer effect, overcoming the Manski (1993) “reflection problem” by imposing restrictions regarding the peer and a contextual group. Using a spatial econometric model, we disentangled for the first time, the influence of peers and contextual effects on GP practices quality decisions. The model was set up taking into account the identification restrictions highlighted, e.g., by Blume et al (2015) and Angrist (2014). The sensitivity analysis and the falsification tests show that the results are robust and that peer effects are important. The Primary Care Trust re-organisation in 2006, enabled us to identify 152 exogenous peer groups, i.e., peer groups that were formed by the Department of Health without an enrolment choice to GP practices. Since some GP practices will be more influential, we weight the peers’ relationship by GP practice size. This implies that the local health authorities might target larger GP practices to spread quality decisions. A quality increase on the largest practice in the peer group has a positive, though small impact on the quality of the peers. Nevertheless, a peer effect on quality is important since it will increase the magnitude of the effects of policies, which have a direct effect on the quality of practices. The importance of peer effects among GP practices is related to the use of this channel to promote quality clinical practice, guidelines and incentives.

Since the relationship between practices can be cooperative and competitive, we tested the impact of competition on practice quality. Competition between practices is promoted by the link between their revenue and number of patients. Because in England patients face a zero price to access healthcare, we expected competition to raise quality. An increase in competition, proxied by the number of GPs in nearby practices, has a positive impact on practices quality. EAPMC policy also had a positive impact on quality by giving incentives to “under-doctored” PCTs to attract more GP practices. So we hope, that health authorities will focus on attracting more health care professionals to increase the quality of their primary care services.

Since competition will only have an impact on quality if the patient’s choice of GP practice is influenced by quality, we tested to see if quality had an impact on the choice of practice for patients that switched GP practices but did not change address. We anticipate that these patients will be better informed about the characteristics of the local practices. If they are not responsive to quality then it is unlikely that competition amongst practices will have an effect on quality. We found that practice quality and number of GPs are the main factors that attract patients to join or to leave a practice.

Quality is multi-dimensional and often difficult to measure, but it is also the most important factor for patients in the English NHS. Clinical quality and patient access determine ACSCs emergency admissions and GP practices compete and cooperate on quality. It is by increasing quality that practices can attract patients and therefore increase their revenue. The findings reported in this thesis suggest that there are no panaceas, although increasing staffing (GPs), targeting policy at peer group leaders, and increasing competition will all improve quality, the effects are modest. The decision to improve the access of patients to quality indicators of the practices nearby will influence patient choice and likely promote an increase in the quality of the services. It was not possible in this study to understand the movement of patients across practices, as we did not have the information on inter-practice transfers (the number who leave a practice j and then join practice k). This data would be important to understand if the movement of patients was due to factors that are not quality, for example, the movement of their GP or provision of extended access.

The results of these five chapters shed new light on the factors and mechanisms that explain the variation in quality across GP practices. Over and above the GPs, patient and catchment area characteristics, the competitive environment and its peers influence practices quality.

This thesis started by identifying for the first time the spatial pattern of ACSCs emergency admissions, revealing a dual and stable spatial pattern with some practices in spatial clusters of high indirect standardised ACSCs emergency admissions for more than five years. We then explored the factors that influence the number of ACSCs emergency admissions at GP practice. Using a rich panel dataset with GP, patient and catchment area characteristics and by analysing a subset of ACSCs that were incentivised by the QOF and a subset of ACSCs that were not, we can report that practice quality and FTE GPs were the factors with higher impact, especially in more deprived areas. Since there are health care market mechanisms that can explain the duality of the stable spatial pattern, we investigated peer effects and competition between GP practices. In Chapter 3, we investigated the re-organisation of PCTs which created exogenous peer groups of practices, to test for peer effects between GP practices. The results show positive peer effects, although when the quality of the largest practice in each peer group is increased, the effect is small. Another positive but small effect is reported in Chapter 4 regarding competition. Using the number of GPs in rival practices as our competition measure, we found that practices in a more competitive environment have higher quality. Using the equitable access to primary medical care policy as a natural experience, we found that areas affected by the policy, had a greater increase in quality, once competition increased after the policy. Since practices will compete in quality to attract patients, we tested whether patients' choice for practice is influence by practice quality, and this is discussed in the last chapter. Linking a unique dataset of the number of patients that join or left the practice without changing address to the characteristics of the practices and the characteristics of the nearby practices, we found that patients choose practices that have higher quality and more GPs.

There are some limitations to the studies presented in this thesis. For example, we use a balanced panel model to estimate the peer effect model. Although it is known that exits and entries of practices in the market are rather small, allowing for a balanced panel might be restrictive. An unbalanced spatial panel model was not feasible due to the size of the sample since with a different peer group matrix for every year, this would not permit me to use the Kronecker product to lighten the computation.

Moreover, although we have shown evidence of a positive effect of competition and peer cooperation on quality of care this does not answer the normative question of whether welfare is unambiguously increased by greater competition or cooperation.

In future, we will extend the work reported in this thesis by drawing on additional datasets. We plan to apply a peer effect model to GPs within the same practice using the Clinical Practice Research Datalink (CPRD) that has data on interactions between individual patients and GPs. We also plan to apply a peer effects model to the national prescription data. While CPRD facilitates use of more detailed information within a GP practice, it will not permit adding GP practice characteristics, such as location, which might undermine the results. The prescription data will allow us to test peer effects across GP practices regarding new guidelines and understand the impact of peer effect on guidelines spillovers. We will also investigate whether it is feasible to examine and explain variation across GP practices using other outcomes, such as avoidable A&E attendances (from Hospital Episodes Statistics) and healthcare access, by linking the English Longitudinal Study of Ageing (ELSA) survey to GP practice characteristics. To disentangle the substitution and complementary effects amongst different types of staff within practices and between GP practices and hospitals would allow a better understanding of the health costs that low quality practices have to their patients and to the NHS as a whole. The importance of skill mix within GP practices has been increasing in recent years. The health professionals within a GP practice have extended from GPs and nurses to include, for example, pharmacists, physician associates and paramedics. The impact that these professionals will bring to the quality of the practices, and the ability of practices to avoid ACSCs emergency admissions needs to be investigated. Unfortunately data on that set of health professionals within a GP practice is only available from 2015 (only detailed information on nurses was available from 2013).

To understand the relationships between GP practices and Hospital Trust, we can identify the informal multispecialty physician networks using health administrative data to exploit natural linkages among patients, physicians and hospitals based on existing patient flow, and understand if networks could foster accountability for efficient, integrated care through care management tools and quality improvement. Consequently, GP practices within networks might be able to provide better healthcare and avoid ACSCs emergency admissions.

Appendices

Appendix 1.

Appendix 1.1. International literature review

The Dartmouth atlas reports the geographical variation of ACSCs across the US (http://www.dartmouthatlas.org/data/map.aspx?ind=198), showing a decrease of ACSCs discharges from east to west. Some US studies (e.g. Ajmera, Wilkins, & Findley, 2012; Dresden, Feinglass, Kang, & Adams, 2016; Finegan, Gao, Pasquale, & Campbell, 2010; Mobley, Root, Anselin, Lozano-Gracia, & Koschinsky, 2006; Pines, Mutter, & Zocchi, 2013; Williams, 2012) report that variation on ACSCs admissions is associated with variation in socioeconomic deprivation, travel time, multimorbidity, insurance, social capital and inpatient beds. However, even after controlling for patient and clinical characteristics, Abualenain et al. (2013) reports a 2.3-fold variation in emergency physician level adjusted admission rates and 1.7-fold variation at the hospital level.

In Scotland, two studies looked in the variation of all emergency admissions. Blatchford, Capewell, Murray, and Blatchford (1999) found that in Glasgow emergency admission rates from deprived areas were twice as high as those from affluent areas, after controlling for other factors, while Duffy, Neville, and Staines (2002) found that in Dundee, after correcting for age and deprivation, there was a 1.2-fold variation in general practices' emergency medical admission rates. More recently Van der Pol et al. (2016) reported that higher achievement in clinical quality of primary care and better access to care are associated with reduced admissions for ACSCs, but these effects are small and inconsistent to the expected since different access indicators have opposite effects on specific ACSCs.

In Canada, using a restricted set of ACSCs Sanchez, Vellanky Smitha , Herring , Liang, and Hui (2008) report variation of age-adjusted ACSCs admissions across the country and across an income gradient. Their finding of higher ACSCs age-adjusted admission for a more income deprived population is corroborated by Walker, Chen, and McAlister (2013) , Balogh, Lake, and Lin (2014) and Roos, Walld, Uhanova, and Bond (2005). Walker et al. (2013) analysed the geographic variations in the rate of hospitalizations for uncomplicated hypertension in four provinces and describe a large disparity among the provinces. The risk-adjusted rate of uncomplicated hypertension (an ACSC) was lowest among those in an urban setting, in the highest income quintile and with no comorbidities. Roos et al. (2005) describe a socioeconomics gradient for twelve ACSCs admissions and Balogh et al. (2014) find the inequity in admissions across areas for ACSCs, for individuals with intellectual disability, with respect to rurality, income and proportion who are First Nations.

Australian studies highlight socioeconomic status and remoteness as major causes of variation. Page, Ambrose, Glover, and Hetzel (2007) report the spatial pattern of indirect age standardised admission rates by health region for ACSCs disease group admissions. The admissions rates are much higher in very remote areas. Ansari, Haider, and Ansari (2012) also conclude that patients who are more socioeconomically deprived and live in more remote areas are more likely to have an ACSCs admission. Falster et al. (2015) report that personal sociodemographic and health characteristics, rather than GP supply, are major drivers of preventable hospitalization. A qualitative study by Longman, Passey, Singer, and Morgan (2013) reinforces those findings by identifying social isolation (patients living alone, not socialising and/or being isolated from family) as an important contributory factor in frequent and/or avoidable admission. On the other hand, Chen and Tescher (2010) suggest the effect of remoteness is due to the large geographic catchment areas, the lack of speciality staff and government funding and the stress and pressure of Australian rural emergency departments (EDs).

When analysing ACSC admission rates in four Italian cities Agabiti et al. (2009) also found a socioeconomic gradient, with higher admission rates for poorer, female and older patients. While Magan, Otero, Alberquilla, and Ribera (2008) found a centripetal pattern for Madrid, with lower rates in the districts in the centre of Madrid, even after adjusting for age and gender.
In Brazil, Macinko et al. (2010) found that higher enrolment in community based primary health care programmes reduced the number of preventable admissions.

Sarmento, Alves, and Oliveira (2015) report the spatial pattern of ACSCs standardised admission rates across Portuguese local authorities for two definitions of ACSCs. On both definitions the northeast and centre of Portugal have the highest rates. Dantas, Santana, Sarmento, and Aguiar (2016) highlight the importance of patient chronic conditions on ACSCs admissions in Portugal. Neither of these studies explored socioeconomic gradients.

In Denmark, Davydow et al. (2015) report an increased risk of ACSCs admissions for individuals with depression, and once discharged they are at elevated risk of readmissions within 30 days for ACSCs.

In Germany, Sundmacher et al. (2015) report significant regional variation of age-standardised rates of ACSC admissions for men and women at the district level in 2012 with higher rates in rural areas of the former East Germany, North Rhine, Saarland and northern and eastern Bavaria.

Niti and Ng (2003) find a gender and ethnic gradient on ACSCs admissions along a decreasing trend in ACSCs admissions in Singapore.

In France, Weeks, Ventelou, and Paraponaris (2016) report a regional spatial pattern of ACSCs (chronic, acute, vaccination preventable, alcohol-related and other) admission rates in 2010. The authors find a different spatial pattern for each ACSCs definition: higher rates chronic ACSCs are found on France northeast, while southeast France has relatively higher rates of admission for acute and other ACSCs, and northwest France has relatively higher rates of admission for alcohol-related ACSCs. Overall, the highest ACSC admission rates generally occurred in the young and the old and were associated with lower incomes.

In Lithuania, Jureviciute and Kalediene (2016) describe the geographical variation of age standardised ACSCs admission rates between administrative area units. They highlight the regional inequality of ACSCs admissions and the urban /rural gradient of those admissions.

In Mexico, Lugo-Palacios and Cairns (2015) explore the ACSCs admission rate across the 188 health jurisdictions. The ACSCs increased in Mexico by 50% between 2001 and 2011, but the trend and magnitude varied across the health jurisdictions. They also found that socioeconomic conditions, health care supply and health insurance coverage were associated with higher rates of ACSCs admissions.

Appendix 1.2. Ambulatory Care Sensitive Conditions diagnosis codes by definition

Table A. 1: Incentivised and Non-incentivised ACSCs

Incentivised
Angina
I20-Angina pectoris
I24.0-Coronary thrombosis not resulting in myocardial infarction
I24.8-Other forms of acute ischaemic heart disease
I24.9-Acute ischaemic heart disease, unspecified
Asthma
J45-Asthma
J46-Status asthmaticus
Cardiovascular diseases
I13.0-Hypertensive heart and renal disease with (congestive) heart failure
I25-Chronic ischaemic heart disease
Chronic obstructive pulmonary disease
J20-Acute bronchitis
J41-Simple and mucopurulent chronic bronchitis
J42-Unspecified chronic bronchitis
J43-Emphysema
J44-Other chronic obstructive pulmonary disease
J47-Bronchiectasis
Congestive heart failure
I11.0-Hypertensive heart disease with (congestive) heart failure
I50-Heart failure
J81-Pulmonary oedema
Convulsions and epilepsy
G40-Epilepsy
G41-Status epilepticus
Diabetes (hypoglycaemic)
E16.2-Hypoglycaemia, unspecified
Diabetes complications
E10.0–E10.8-Insulin-dependent diabetes mellitus
Hypertension
I10-Essential (primary) hypertension
I11.9-Hypertensive heart disease without (congestive) heart failure
Nutritional, endocrine and metabolic
E11.0–E11.8-Non-insulin-dependent diabetes mellitus
E13.0–E13.8-Other specified diabetes mellitus
E14.0–E14.8-Unspecified diabetes mellitus
Stroke
I61-Intracerebral haemorrhage
I62-Other nontraumatic intracranial haemorrhage

I63-Cerebral infarction
I64-Stroke, not specified as haemorrhage or infarction
I66-Occlusion and stenosis of cerebral arteries, not resulting in cerebral infarction
I67.2-Cerebral atherosclerosis
I69.8-Sequelae of other and unspecified cerebrovascular diseases
R47.0-Dysphasia and aphasia

Non-incentivised

Cellulitis

L03-Cellulitis
L04-Acute lymphadenitis
L08.0-Pyoderma
L08.8-Other specified local infections of skin and subcutaneous tissue
L08.9-Local infection of skin and subcutaneous tissue, unspecified
L88-Pyoderma gangrenosum
L98.0-Pyogenic granuloma

Dehydration and gastroenteritis

E86-Volume depletion
K52.2-Allergic and dietetic gastro-enteritis and colitis
K52.8-Other specified non-infective gastro-enteritis and colitis
K52.9-Non-infective gastro-enteritis and colitis, unspecified

Ear, nose and throat infections

H66-Suppurative and unspecified otitis media
H67-Otitis media in diseases classified elsewhere
J02-Acute pharyngitis
J03-Acute tonsillitis
J04-Acute laryngitis and tracheitis
J06-Acute upper respiratory infections of multiple and unspecified sites
J31.2-Chronic pharyngitis

Gangrene

R02-Gangrene, not elsewhere classified

Iron deficiency anaemia

D50.1-Sideropenic dysphagia
D50.8-Other iron deficiency anaemias
D50.9-Iron deficiency anaemia, unspecified

Nutritional deficiencies

E40-Kwashiorkor
E41-Nutritional marasmus
E42-Marasmic kwashiorkor
E43-Unspecified severe protein-energy malnutrition
E55.0-Rickets, active
E64.3-Sequelae of rickets

Other vaccine preventable

A35-Other tetanus
A36-Diphtheria
A37-Whooping cough
A80-Acute poliomyelitis
B05-Measles
B06-Rubella [German measles]

B16.1-Acute hepatitis B with delta-agent (coinfection) without hepatic coma
B16.9-Acute hepatitis B without delta-agent and without hepatic coma
B18.0-Chronic viral hepatitis B with delta-agent
B18.1-Chronic viral hepatitis B without delta-agent
B26-Mumps
G00.0-Haemophilus meningitis
M01.4-Rubella arthritis

Pelvic inflammatory disease

N70-Salpingitis and oophoritis
N73-Other female pelvic inflammatory diseases
N74-Female pelvic inflammatory disorders in diseases classified elsewhere

Perforated/bleeding ulcer

K25.0–K25.2-Gastric ulcer
K25.4–K25.6-Gastric ulcer
K26.0–K26.2-Duodenal ulcer
K26.4–K26.6-Duodenal ulcer
K27.0–K27.2-Peptic ulcer, site unspecified
K27.4–K27.6-Peptic ulcer, site unspecified
K28.0–28.2-Gastrojejunal ulcer
K28.4–K28.6-Gastrojejunal ulcer

Pyelonephritis and kidney/urinary tract infections

N10-Acute tubulo-interstitial nephritis
N11-Chronic tubulo-interstitial nephritis
N12-Tubulo-interstitial nephritis, not specified as acute or chronic
N13.6-Pyonephrosis
N30.0-Acute cystitis
N30.8-Other cystitis
N30.9-Cystitis, unspecified

Table A. 2: Chronic and Acute ACSCs

Acute
Angina
I24.0-Coronary thrombosis not resulting in myocardial infarction
I24.8-Other forms of acute ischaemic heart disease
I24.9-Acute ischaemic heart disease, unspecified
Cellulitis
I89.1-Lymphangitis
L01-Impetigo
L02-Cutaneous abscess, furuncle and carbuncle
L03-Cellulitis
L04-Acute lymphadenitis
L08.0-Pyoderma
L08.8-Other specified local infections of skin and subcutaneous tissue
L08.9-Local infection of skin and subcutaneous tissue, unspecified
L88-Pyoderma gangrenosum
L98.0-Pyogenic granuloma
Convulsions and epilepsy
R56-Convulsions, not elsewhere classified
Dehydration and gastroenteritis
E86-Volume depletion
Ear, nose and throat infections
H66-Suppurative and unspecified otitis media
H67-Otitis media in diseases classified elsewhere
J02-Acute pharyngitis
J03-Acute tonsillitis
J04-Acute laryngitis and tracheitis
J06-Acute upper respiratory infections of multiple and unspecified sites
J31.2-Chronic pharyngitis
Influenza and pneumonia
J10-Influenza due to identified influenza virus
J11-Influenza, virus not identified
J13X-Pneumonia due to Streptococcus pneumoniae
J14-Pneumonia due to Haemophilus influenzae
J15.3-Pneumonia due to streptococcus, group B
J15.4-Pneumonia due to other streptococci
J15.7-Pneumonia due to Mycoplasma pneumoniae
J15.9-Bacterial pneumonia, unspecified
J16.8-Pneumonia due to other specified infectious organisms
J18.1-Lobar pneumonia, unspecified
J18.8-Other pneumonia, organism unspecified
Other vaccine preventable
A36-Diphtheria
A37-Whooping cough
B05-Measles
B06-Rubella [German measles]
B16.1-Acute hepatitis B with delta-agent (coinfection) without hepatic coma

B16.9-Acute hepatitis B without delta-agent and without hepatic coma
M01.4-Rubella arthritis
Perforated/bleeding ulcer
K20-Oesophagitis
K21-Gastro-oesophageal reflux disease
K25.0–K25.2-Gastric ulcer
K25.4–K25.6-Gastric ulcer
K26.0–K26.2-Duodenal ulcer
K26.4–K26.6-Duodenal ulcer
K27.0–K27.2-Peptic ulcer, site unspecified
K27.4–K27.6-Peptic ulcer, site unspecified
K28.0–28.2-Gastrojejunal ulcer
K28.4–K28.6-Gastrojejunal ulcer
Pyelonephritis and kidney/urinary tract infections
N10-Acute tubulo-interstitial nephritis
N11-Chronic tubulo-interstitial nephritis
N12-Tubulo-interstitial nephritis, not specified as acute or chronic
N13.6-Pyonephrosis
N15.9-Renal tubulo-interstitial disease, unspecified
N30.0-Acute cystitis
N30.8-Other cystitis
N30.9-Cystitis, unspecified
N39.0-Urinary tract infection, site not specified

Chronic

Angina
I20-Angina pectoris
Asthma
J45-Asthma
J46-Status asthmaticus
Cardiovascular diseases
I13.0-Hypertensive heart and renal disease with (congestive) heart failure
I25-Chronic ischaemic heart disease
I48X-Atrial fibrillation and flutter
Chronic obstructive pulmonary disease
J20-Acute bronchitis
J41-Simple and mucopurulent chronic bronchitis
J42-Unspecified chronic bronchitis
J43-Emphysema
J44-Other chronic obstructive pulmonary disease
J47-Bronchiectasis
Congestive heart failure
I11.0-Hypertensive heart disease with (congestive) heart failure
J81-Pulmonary oedema
Convulsions and epilepsy
G40-Epilepsy
G41-Status epilepticus
Diabetes complications
E10.0–E10.8-Insulin-dependent diabetes mellitus

Diseases of the blood

D51-Vitamin B12 deficiency anaemia

D52-Folate deficiency anaemia

Hypertension

I10-Essential (primary) hypertension

I11.9-Hypertensive heart disease without (congestive) heart failure

Iron deficiency anaemia

D50.1-Sideropenic dysphagia

D50.8-Other iron deficiency anaemias

D50.9-Iron deficiency anaemia, unspecified

Mental and behavioural disorders

F00-Dementia in Alzheimer's disease

F01-Vascular dementia

F02-Dementia in other diseases classified elsewhere

F03-Unspecified dementia

Nutritional, endocrine and metabolic

E11.0–E11.8-Non-insulin-dependent diabetes mellitus

E12-Malnutrition-related diabetes mellitus

E13.0–E13.8-Other specified diabetes mellitus

E14.0–E14.8-Unspecified diabetes mellitus

Other vaccine preventable

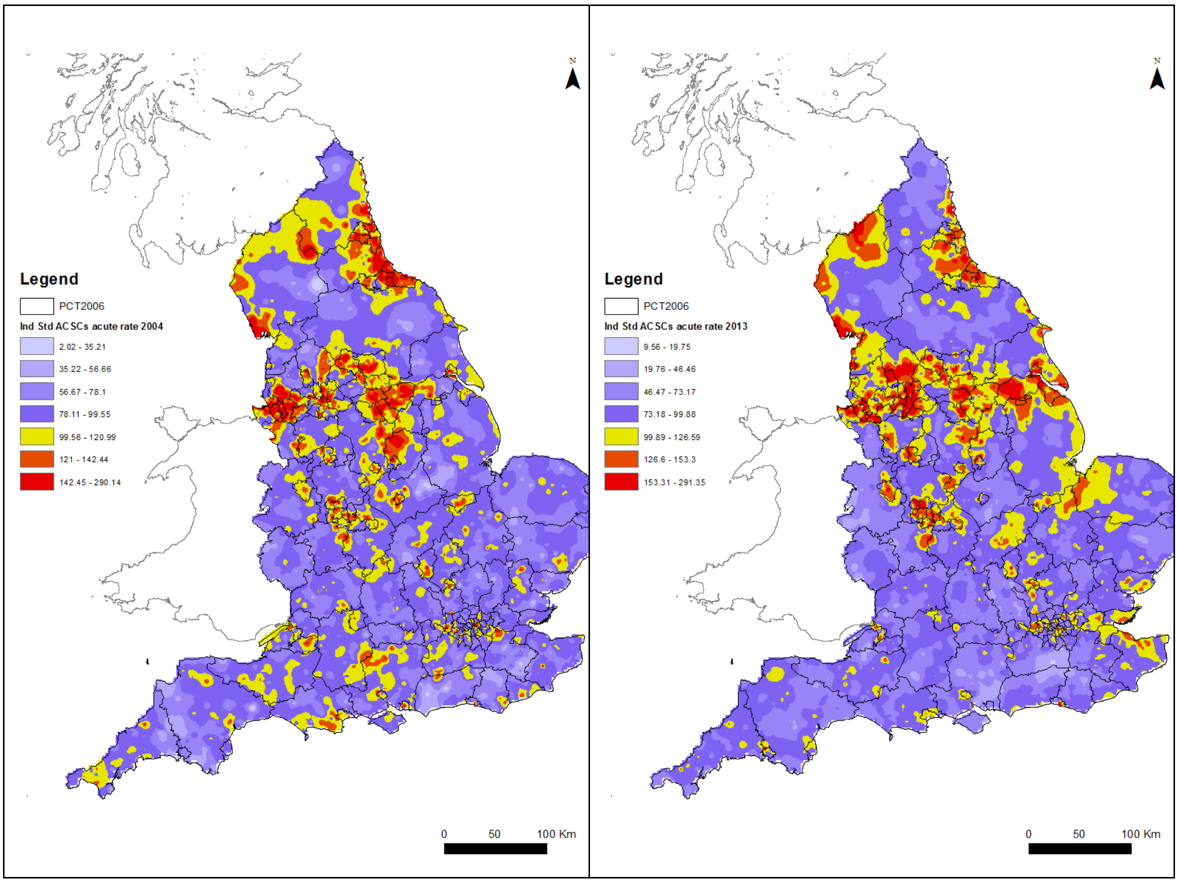
B18.0-Chronic viral hepatitis B with delta-agent

B18.1-Chronic viral hepatitis B without delta-agent

Appendix 1.3. Heat maps of indirect STD ACSCs emerg. adm.: acute versus chronic

The indirect STD Acute ACSCs emergency admission rate increased between 2004 and 2013 (reported in Table 1-2) and the maps in Figure A. 1 show that the spatial patterns for 2013 although similar to the 2004, present wider variation, with more areas represented in red (more than 2 SD from the mean ACSCs emergency admission indirect STD rate), i.e. areas with higher Acute ACSCs emergency admission indirect STD rate.

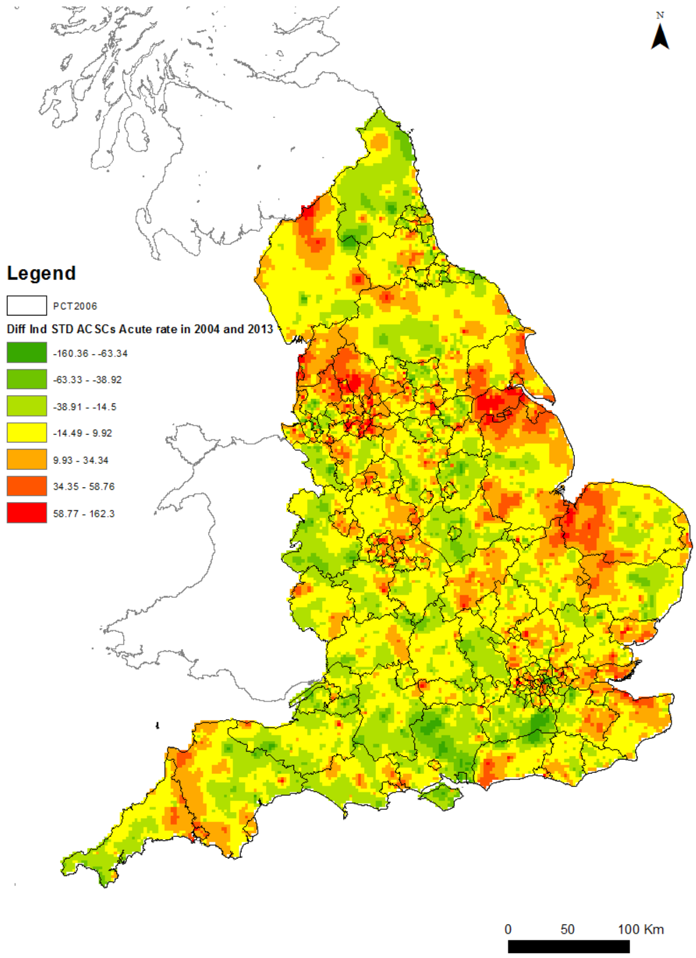
Figure A. 1- Indirect Standardised Acute ACSCs emergency admissions in 2004 and 2013



The areas within Nottinghamshire 2006 PCT improved, especially on the towns surrounding Mansfield. On the other hand, the areas within Eastern and Coastal Kent 2006 PCT had an increase in the ACSCs emergency admission indirect STD rate. Those areas had in 2004 ACSCs emergency admission indirect STD rates one to two SDs lower than the mean, but in 2013, the areas around Whitstable town had ACSCs indirect STD rates one to two SD over the mean.

The difference in indirect standardised Acute ACSCs emergency admission rates between 2013 and 2014 is shows in Figure A. 2.Once more, the areas highlighted in orange and red are those that suffered an increase and the green areas are those where GP practices had an improvement on the Acute ACSCs emergency admission indirect STD emergency admissions. The spatial pattern of Figure A. 2 is very similar to the spatial pattern observed in Figure 4, also showing that some areas with persistently high ACSCs had improvement, such as Liverpool and Hull, while others did not, such as Newcastle and Greater Manchester. However, some areas showed an improvement in Acute ACSCs emergency admission only but not in all the ACSCs, such as those in Sunderland Teaching 2006 PCT.

Figure A. 2- Difference in Indirect Standardised Acute ACSCs rate between 2013 and 2004



The spatial pattern for the indirect standardised Chronic ACSCs emergency admission in 2004 and 2013 is displayed in Figure A. 3. The areas in yellow are areas within 1 SD of the mean Chronic ACSCs emergency admissions indirect STD rate. The rate exhibits more variation in 2013 than in 2004, with light red areas in 2013 being two to three SDs of the mean and dark red areas three to four SDs of the mean, while in 2004 there are only light red areas representing areas two to three SDs of the mean. Two of the areas that in 2013 are three to four SD from the mean are located within the Cumbria 2006 PCT. This PCT has two areas of high Chronic ACSCs emergency admissions, around Carlisle city and around Barrow-in-Furness town. While the Carlisle city area was already highlighted in Figure 4 and Figure A. 2 by the increase in the ACSCs emergency admission indirect STD rate, Barrow-in-Furness areas were not since the ACSCs indirect STD rate, although high, is very similar in 2004 and 2013.

Figure A. 3 - Indirect Standardised Chronic ACSCs in 2004 and 2013

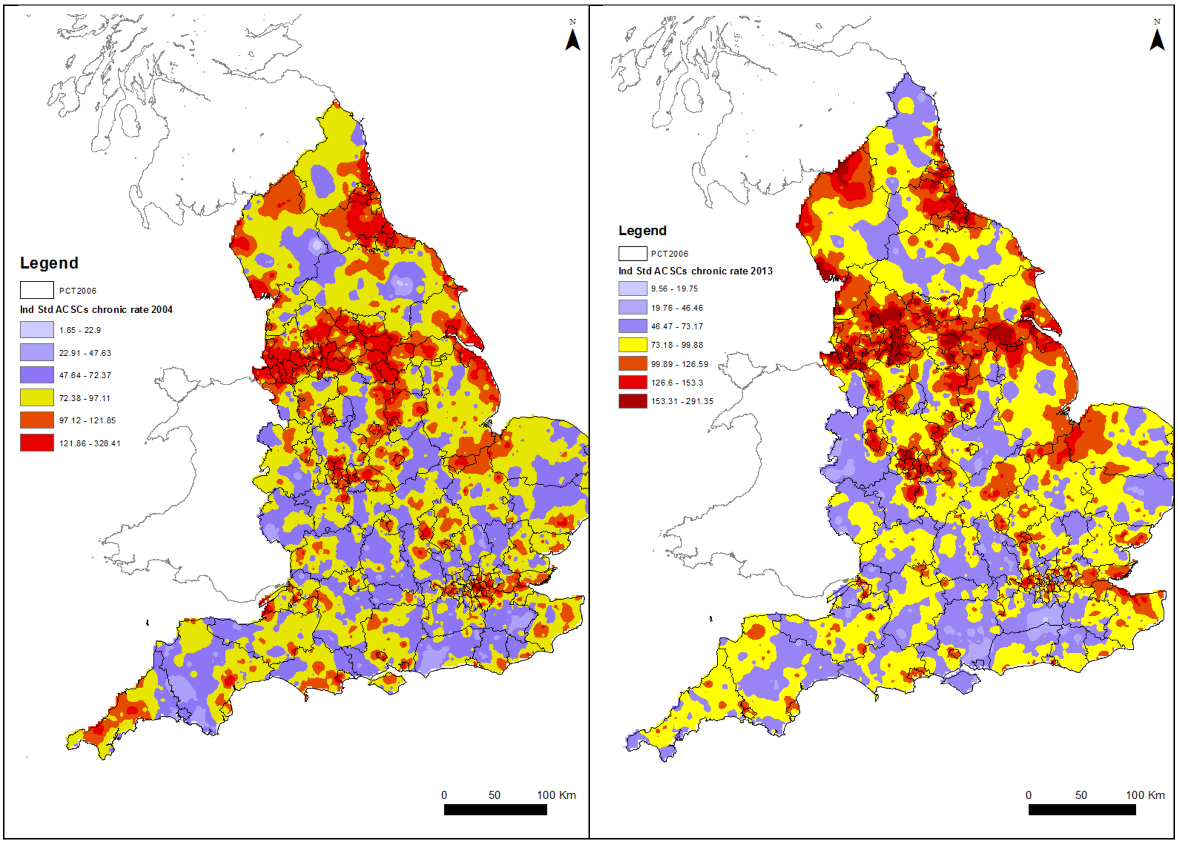
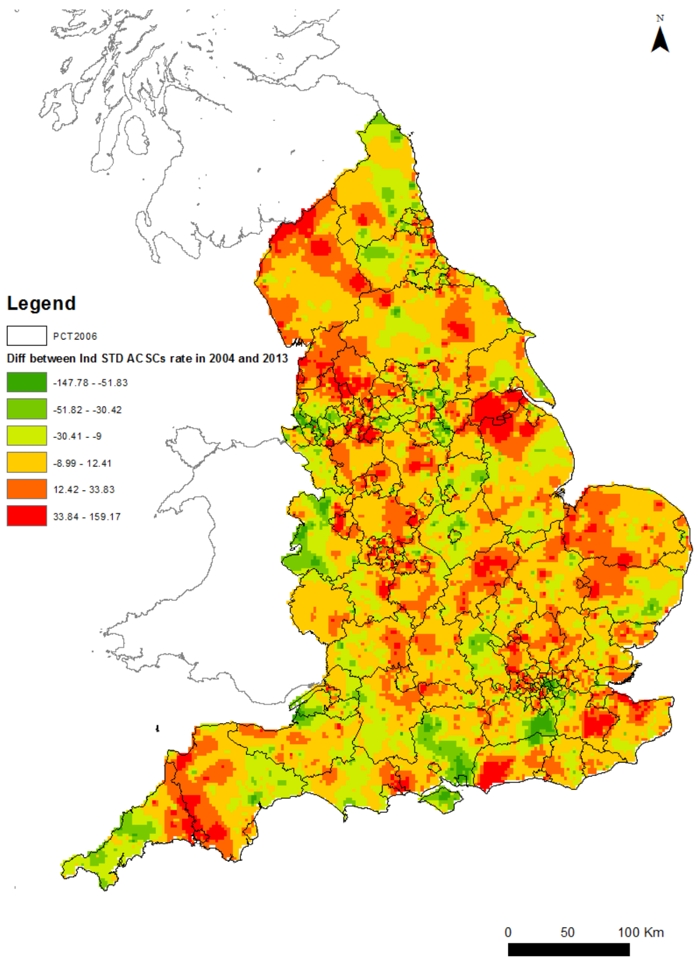


Figure A. 4 highlights the differences between the ACSCs Chronic emergency admission indirect standardised rates in 2004 and 2013. The Hull and Liverpool areas show a reduction in ACSCs Chronic emergency admission indirect STD rate, which means that it was not just the reduction in the ACSCs Acute emergency admissions that influence the overall reduction as previously reported in Figure 4, while York, Plymouth and Lancashire areas show an increase in Chronic ACSCs emergency admissions indirect STD rate. There is also an increase in the North Lincolnshire 2006 PCT, around the city of Scunthorpe, which spreads to Lincolnshire 2006 PCT, almost until Lincoln city.

Figure A. 4- Difference in the Indirect Standardised Chronic ACSCs in 2004 and 2013



Appendix 1.4. Heat maps of indirect standardised ACSCs emergency admission rate by age, gender and deprivation

Figure A. 5 shows the difference between the indirect standardised ACSCs rate including and excluding deprivation. Yorkshire and the Humber, Cumbria, Lancashire and middle southern England are the areas which GP practices have higher ACSCs emergency admissions indirect STD rate once deprivation is included in the standardisation, while in Hull, Manchester and Birmingham areas they have a smaller indirect standardised ACSCs rate with deprivation in the standardisation than without.

Figure A. 5 - Difference between Indirect standardised ACSCs emergency admission in 2013 with and without deprivation

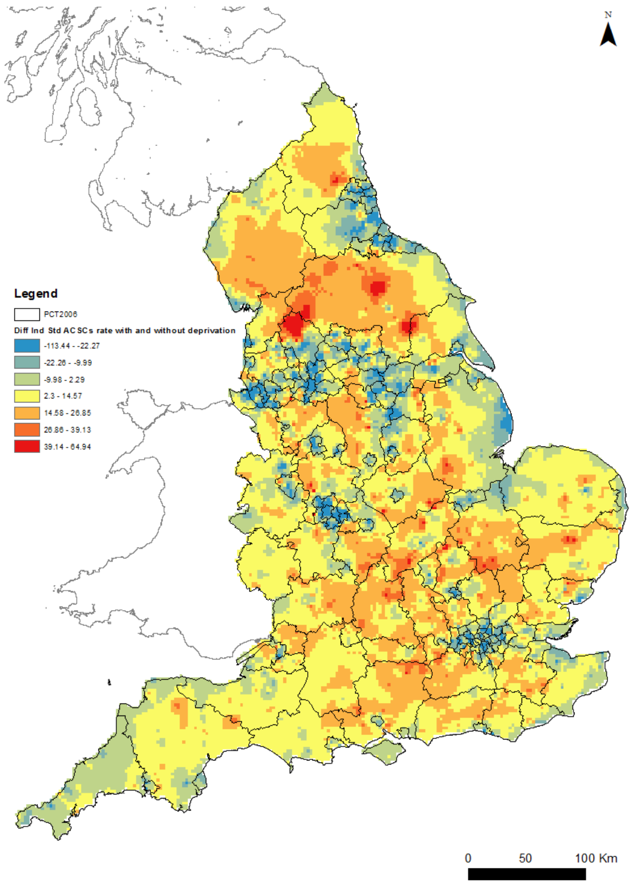
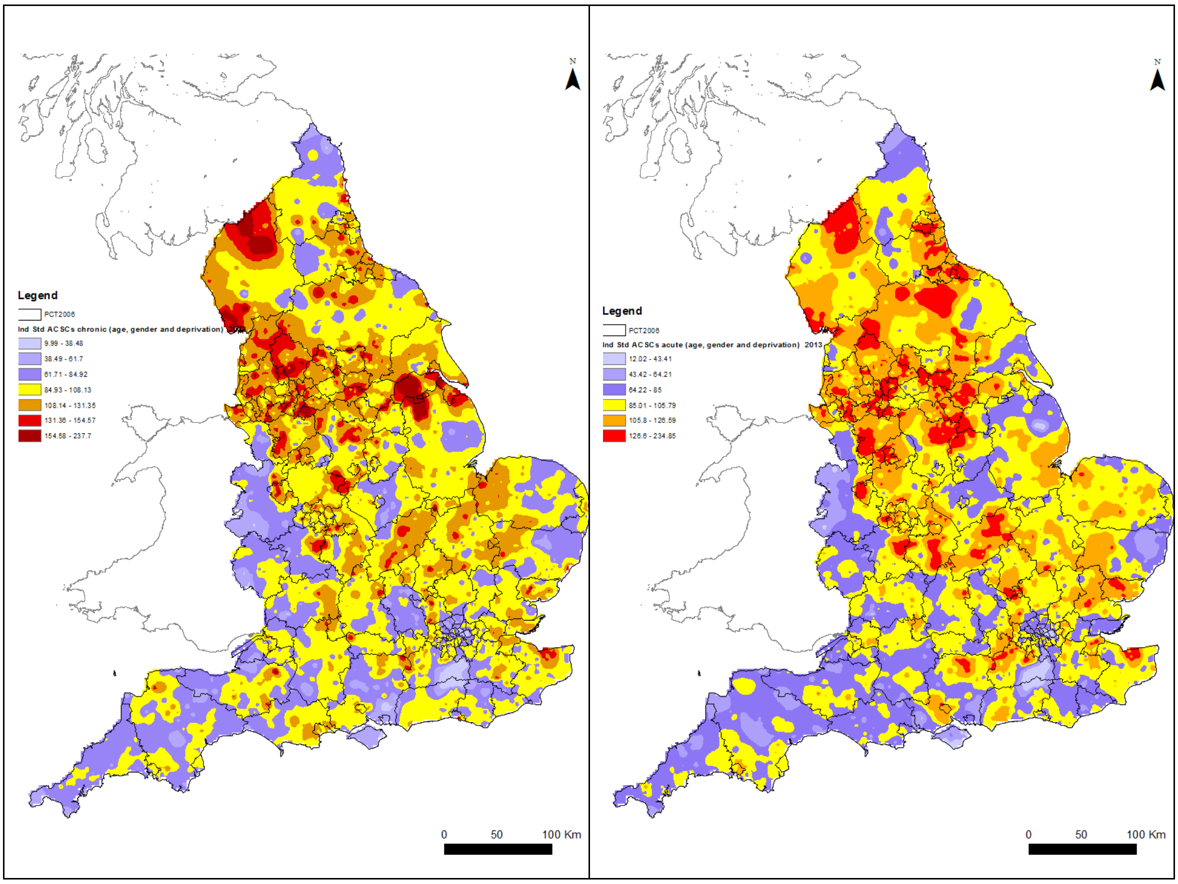


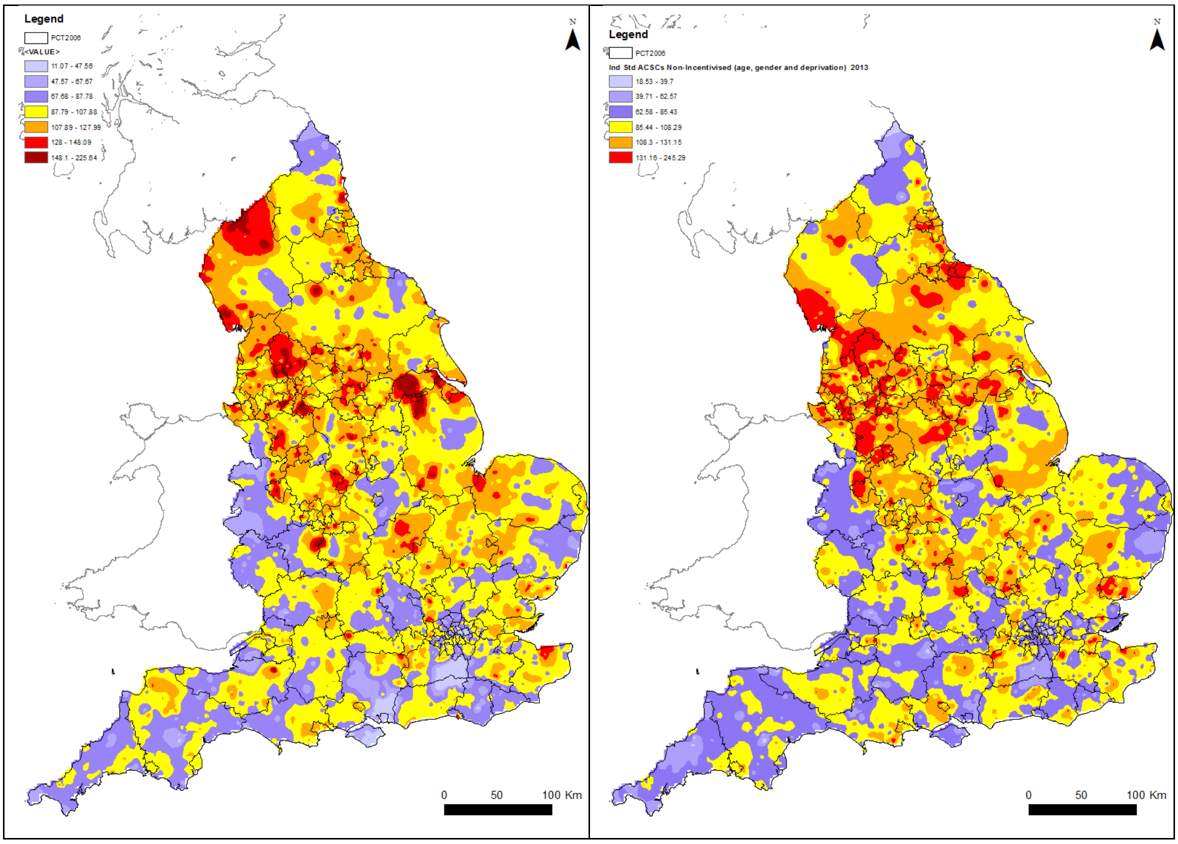
Figure A. 6 reports the Acute and Chronic ACSCs emergency admissions indirect STD by age, gender and deprivation for 2013. The spread of yellow areas shows that most areas are within one SD of the mean. The orange and light red areas are within two to three SDs and dark red areas observed in the spatial distribution of Chronic ACSCs emergency admission indirect STD rate have three to four SDs higher rates than the mean. The red areas (two to three SDs from the mean) of Northumberland, Durham and the corridor between Liverpool and Hull that were highlighted in Figure A. 3 for the 2013 Chronic ACSCs emergency admission indirect STD rate are now mostly reported in orange, because including deprivation in the standardisation implied that they are closer to the mean Chronic ACSCs emergency admission indirect STD rate, i.e., the expected Chronic ACSCs emergency admission rate for a GP practice with a given practice list age, gender and deprivation. The spatial pattern of Acute ACSCs emergency admission indirect STD rate by age, gender and deprivation highlight red areas as in Yorkshire, where the deprivation is low but the acute ACSCs emergency admissions are high.

Figure A. 6 - Indirect standardised ACSCs Chronic and Acute emergency admissions by age, gender and deprivation in 2013



The spatial pattern presented in Figure A. 7 shows that once we take into account deprivation in the standardisation more areas are highlighted in yellow, i.e., the GP practices in those areas have the expected ACSCs emergency admissions, being the indirect STD rate within 1SD of the mean. The variation is wider for indirect STD ACSCs Incentivised emergency admission rate, with some areas, demarked at dark red, having a three to four SD higher indirect STD rate. One of these areas is in North and Lincolnshire 2006 PCT, surrounding the city of Scunthorpe. This area was already highlighted in Figure 5, given the increase in the indirect STD ACSCs incentivised emergency admission rate. It seems that the deprivation did not explain the high rates of ACSCs incentivised emergency admissions observed in this area. The north eastern areas of Yorkshire are highlighted by a high indirect STD ACSCs Non-incentivised emergency admission. The Yorkshire 2006 PCTs of Redcar and Cleveland, and Middlesbrough and the Durham 2006 PCT of North Tees have high (three to four SDs from the mean) rates of non-incentivised but not of incentivised ACSCs emergency admissions. These areas were already discussed since they were highlighted in Figure 7.

Figure A. 7- Indirect standardised ACSCs Incentivised and Non-incentivised emergency admissions by age, gender and deprivation in 2013



Appendix 1.5. Spatial Correlation: Global and Local spatial autocorrelation for chronic, acute, incentivised and non-incentivised indirect STD ACSCs emergency admissions rate

The spatial pattern of Acute ACSCs emergency admissions indirect STD rate is not random. It is characterised by high and low value spatial clusters of GP practices, with 595 GP practices in a spatial cluster of high Acute ACSCs rates and 226 in a spatial cluster of low Acute ACSCs rates in 2004 and 623 and 408 in 2013, respectively (in Table A. 3). The variation in Acute ACSCs indirect standardised rates is, as in all the ACSCs, wider among the GP practices in the spatial cluster of high values (with a SD higher than 30) than among those in the spatial cluster of low values (with a SD lower than 15).

Table A. 3: Moran's I LISA 2004 - 2013 for Acute ACSCs emergency admissions indirect standardised rate

Year	**Spatial clusters**				**Acute ACSCs emergency admissions Indirect STD**		
		Frequency	Percentage	Mean	min	max	SD
2004	HH	595	7.22%	202.02	124.46	786.02	45.23
2004	LL	226	2.74%	38.40	0	69.40	14.68
2004	not significant	7415	90.03%	98.64	0	362.87	32.84
2005	HH	588	7.19%	202.64	127.57	1455.15	68.76
2005	LL	236	2.89%	36.41	0	75.28	15.06
2005	not significant	7353	89.92%	99.19	0	310.26	31.37
2006	HH	634	7.78%	202.73	119.51	1179.42	57.72
2006	LL	304	3.73%	37.80	0	70.10	15.03
2006	not significant	7215	88.50%	99.60	0	262.15	30.86
2007	HH	653	8.06%	207.09	122.94	529.89	39.92
2007	LL	488	6.02%	36.83	0	75.69	13.81
2007	not significant	6963	85.92%	100.37	0	261.40	31.66
2008	HH	711	8.83%	206.82	126.86	704.76	40.80
2008	LL	509	6.32%	33.73	0	71.87	13.85
2008	not significant	6836	84.86%	100.60	0	304.88	31.15
2009	HH	673	8.43%	205.29	125.04	867.65	46.39
2009	LL	536	6.71%	32.15	0	76.50	15.02
2009	not significant	6774	84.86%	101.03	0	343.46	30.10
2010	HH	730	9.26%	204.50	121.66	417.28	34.69
2010	LL	535	6.78%	32.55	0	74.14	14.31
2010	not significant	6622	83.96%	99.86	0	444.67	29.50
2011	HH	747	9.54%	201.27	118.27	526.31	34.39
2011	LL	450	5.75%	35.95	0	75.00	13.67
2011	not significant	6632	84.71%	99.82	15.03	273.36	28.96
2012	HH	693	8.84%	205.19	134.63	490.47	48.91
2012	LL	429	5.47%	35.96	0	65.72	12.75
2012	not significant	6714	85.68%	100.30	8.08	458.44	36.65
2013	HH	623	8.01%	203.99	129.02	502.94	50.73
2013	LL	408	5.24%	36.66	0	66.95	13.33
2013	not significant	6750	86.75%	101.09	11.63	315.19	36.86

There are more dynamics in the transitional matrix, reflecting less spatial cluster stability for Acute ACSCs emergency admission indirect STD rate. Only 61.58% of GP practices that were in the high values spatial cluster in 2004 remained in 2013. The value is smaller for GP practices that were in the low values spatial cluster in 2004, with only 57.69% remaining in the cluster in 2013.

Table A. 4: Transition probabilities across significant spatial cluster between 2004 and 2013 for Acute ACSCs emergency admissions indirect STD

	LL	not significant	HH	Total
LL	61.58	38.42	0	100
not significant	2.62	93.25	4.13	100
HH	0.07	42.24	57.69	100
Total	5.44	86.21	8.36	100

The maps in Figure A. 8show the Moran's I LISA spatial clusters areas for Acute ACSCs emergency admissions indirect STD rate in 2004 and 2013. The differences between 2004 and 2013 spatial clusters reflect Table A. 4 since they can be summarised by the disappearance and appearance of high and low value spatial clusters. The North East, Liverpool and Barrow-in-Furness high value spatial clusters disappeared, while some high value clusters appeared in Greater Manchester, East Lancashire and North Lincolnshire (specifically in the areas surrounding Scunthorpe). The low value clusters have a similar dynamic, disappearing from North Yorkshire, Cumbria, Cornwall and Lincolnshire and appearing in Sussex, Hampshire, and Shropshire.

Figure A. 8 - Moran's I LISA significant spatial clusters for Acute ACSCs emerg. adm ind. STD rate for 2004 and 2013

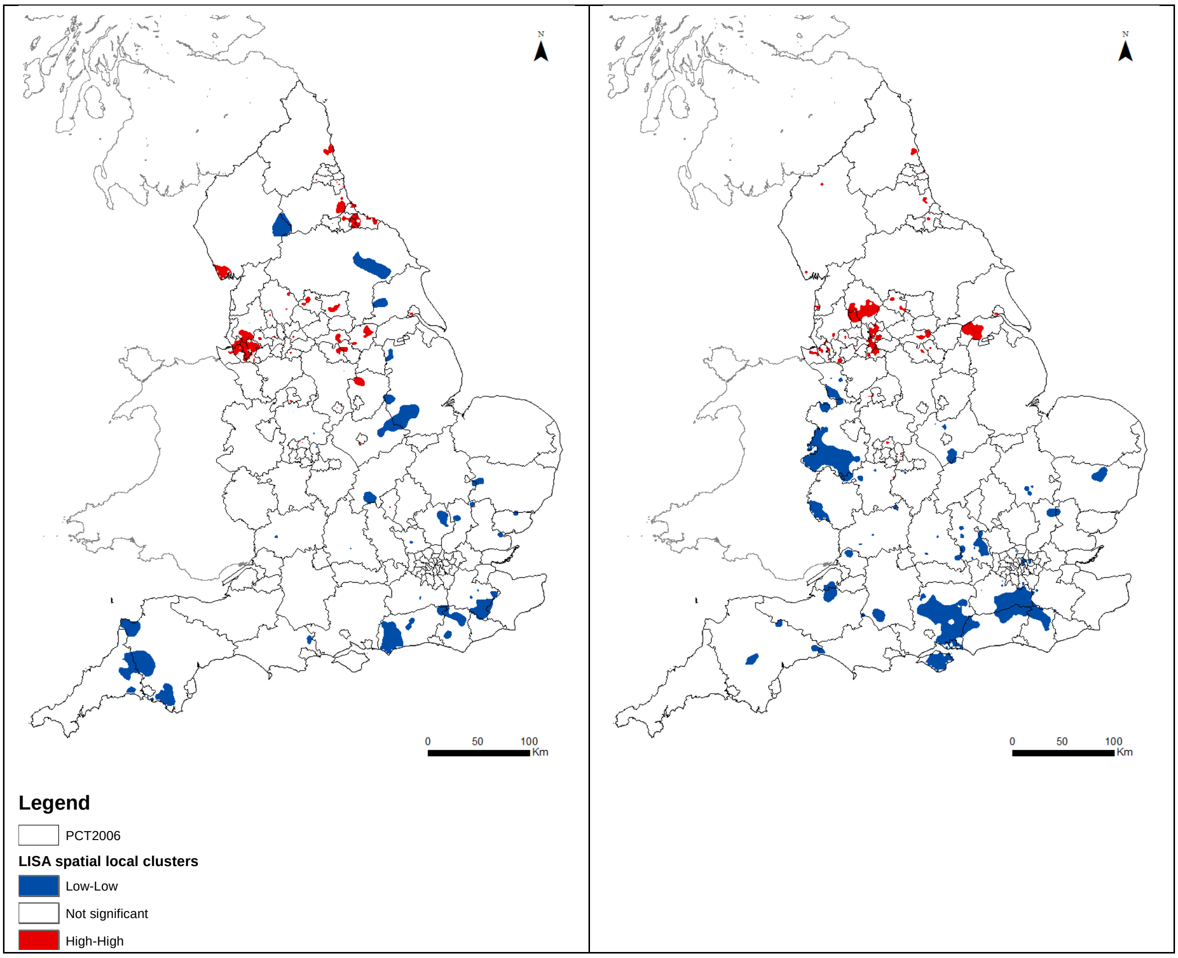


Figure A. 9 reflects the observed transitional dynamics but also adds information on the time frame of the transition. The areas that we have highlighted above, Liverpool (Merseyside), Greater Manchester and North East (including Durham and Tyne and Wear) have areas in the high-value spatial cluster for at least 5 years, which means that those areas only had a non-significant spatial cluster within the last 4 years. South Yorkshire is also highlighted in Figure A. 9 since it has several areas in a high value spatial cluster for at least two years. The time dynamics of the low value spatial clusters is similar. The low value spatial clusters highlighted in the 2013 map in Figure A. 7are in light blue since GP practices are in those spatial clusters for less than 2 years.

Figure A. 9 - Overlay of significant spatial cluster for Acute ACSCs emergency admissions indirect STD rate from 2004 to 2013

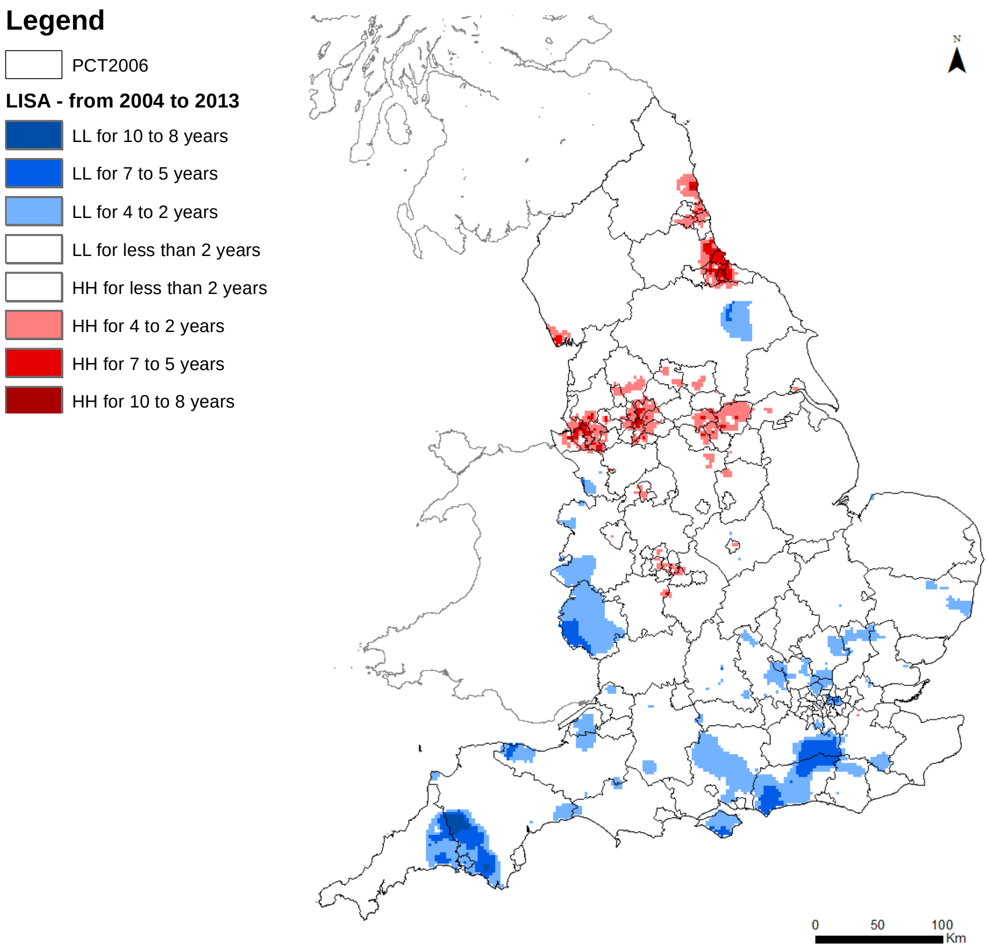


Table A.5 reports the number of GP practices in each significant spatial clusters and the Chronic ACSCs indirect standardised rate range for each type of cluster. The number of GP practices in a spatial cluster of high Chronic ACSCs rates decreased from 700 to 623 between 2004 and 2013, while the number of GP practices in a spatial cluster of low Chronic ACSCs rates increased from 281 to 408. The variation on Chronic ACSCs indirect standardised rate is wider among the GP practices in the spatial cluster of high values (with a SD higher than 45) than among those in the spatial cluster of low values (with a SD lower than 15).

Table A. 5: Moran's I LISA 2004 - 2013 for Chronic ACSCs emergency admissions indirect standardised rate

Year	Spatial clusters				Chronic ACSCs emergency admissions Indirect STD		
		Frequency	Percentage	Mean	min	max	SD
2004	HH	700	8.50%	184.52	125.95	607.54	49.08
2004	LL	281	3.41%	43.53	0	64.35	12.82
2004	not significant	7255	88.09%	98.59	0	418.06	36.59
2005	HH	677	8.28%	184.69	131.05	573.13	48.55
2005	LL	305	3.73%	38.66	0	65.16	12.42
2005	not significant	7195	87.99%	98.67	0	442.36	36.34
2006	HH	651	7.98%	185.99	128.72	468.70	46.27
2006	LL	346	4.24%	40.65	0	66.02	12.18
2006	not significant	7156	87.77%	98.44	0	341.53	36.80
2007	HH	679	8.38%	184.57	128.52	507.16	51.32
2007	LL	446	5.50%	42.85	0	64.23	12.23
2007	not significant	6979	86.12%	99.67	0	309.55	37.04
2008	HH	729	9.05%	179.92	129.64	451.04	47.89
2008	LL	516	6.41%	37.09	0	68.04	12.82
2008	not significant	6811	84.55%	99.35	0	351.92	37.03
2009	HH	714	8.94%	180.36	132.27	577.95	47.60
2009	LL	520	6.51%	37.18	0	67.65	12.80
2009	not significant	6749	84.54%	100.59	0	314.47	36.33
2010	HH	736	9.33%	178.67	126.05	518.94	47.93
2010	LL	505	6.40%	41.02	0	64.47	13.39
2010	not significant	6646	84.27%	99.66	7.25	319.86	36.11
2011	HH	699	8.93%	176.56	134.42	469.81	47.90
2011	LL	454	5.80%	43.07	0	65.92	13.22
2011	not significant	6676	85.27%	98.63	11.52	346.52	35.87
2012	HH	693	8.84%	205.19	134.63	490.47	48.91
2012	LL	429	5.47%	35.96	0	65.72	12.75
2012	not significant	6714	85.68%	100.30	8.08	458.44	36.65
2013	HH	623	8.01%	203.99	129.02	502.94	50.73
2013	LL	408	5.24%	36.66	0	66.95	13.33
2013	not significant	6750	86.75%	101.09	11.63	315.19	36.86

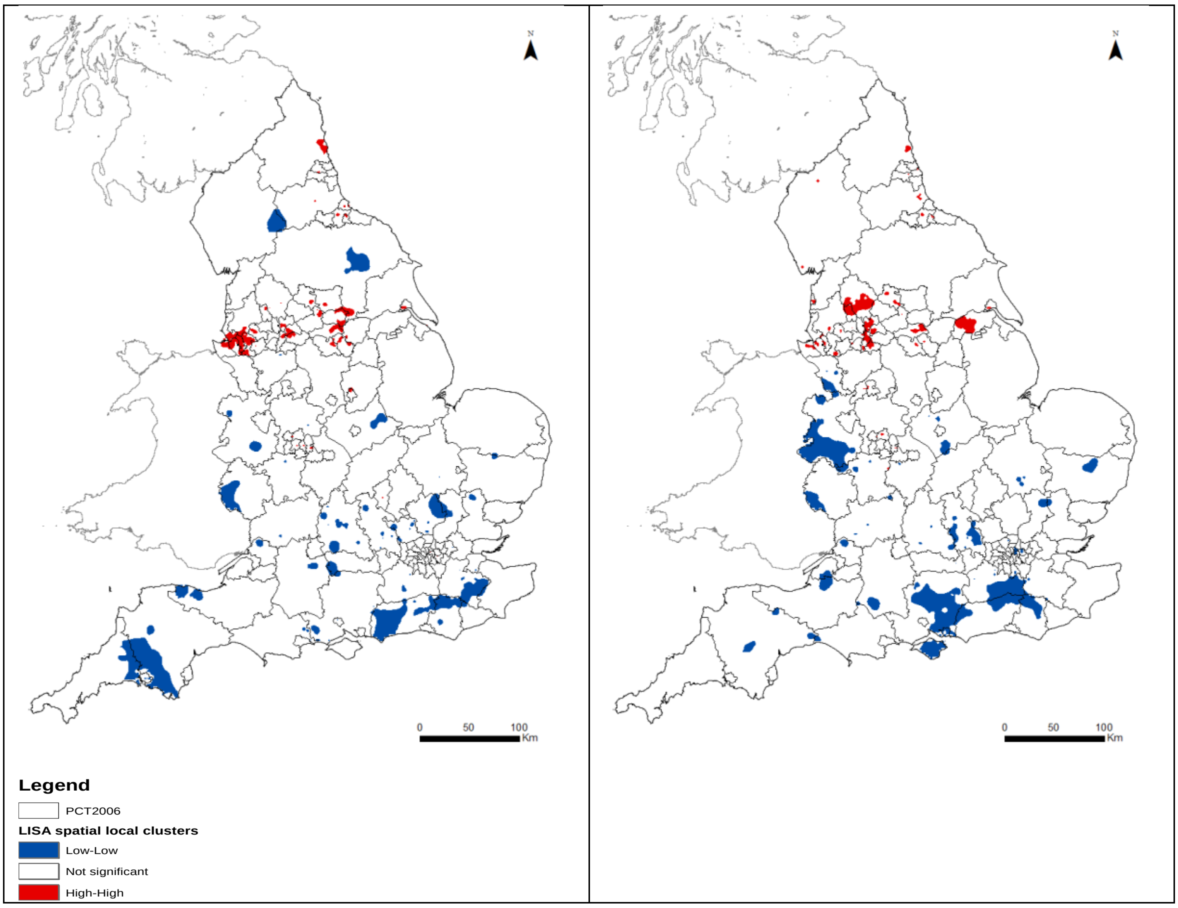
The transitional probabilities for GP practices, reported in Table A. 6, in the low and high spatial cluster is almost the same, 64%, which is smaller than those reported for all ACSCs and higher than those reported for Acute ACSCs.

Table A. 6: Transition probabilities across significant spatial cluster between 2004 and 2013 for Chronic ACSCs emergency admissions indirect STD

	LL	not significant	HH	Total
LL	64.79	35.21	0	100
not significant	2.4	94.07	3.53	100
HH	0.07	35.84	64.1	100
Total	5.48	85.95	8.56	100

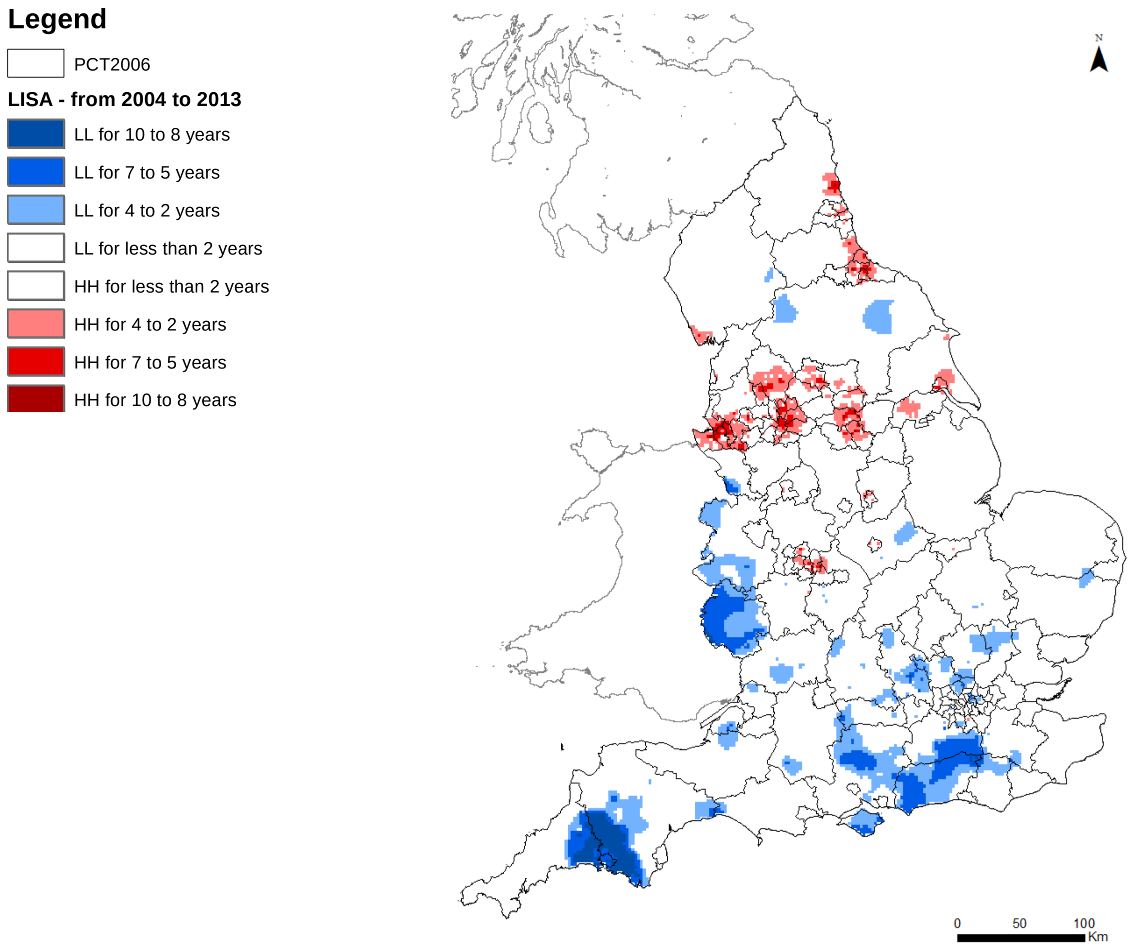
The spatial clusters observed in Figure A. 10are similar to the ones observed in Figure A. 8, however, the 2004 high-value spatial clusters for Chronic ACSCs are more concentrated in Liverpool (Merseyside) and Greater Manchester, without expression in Barrow-in-Furness or Durham and Tyne and Wear. There is also a low value spatial cluster of Chronic ACSCs indirect STD rate in 2004 in Herefordshire that was not observed for Acute ACSCs indirect STD rate in 2004. The 2013 Chronic and Acute ACSCs emergency admissions STD rate spatial clusters are quite similar. Suggesting that areas affected by high (low) values of Acute ACSCs emergency admissions are also affected by high (low) values of Chronic ACSCs emergency admissions.

Figure A. 10- Moran's I LISA significant spatial clusters for Chronic ACSCs emerg. adm. ind STD rate for 2004 and 2013



The time-space dynamics observed for Chronic ACSCs emergency admissions indirect STD in Figure A. 11reveals a spatial pattern similar to the observed for Acute ACSCs emergency admissions indirect STD. However, the Chronic ACSCs high value spatial clusters spread to East Lancashire 2006 PCT and do not have an expression in Doncaster 2006 PCT. The low Chronic ACSCs emergency admissions indirect STD spatial clusters are wider in Hampshire and Herefordshire 2006 PCTs and were significant in at least 8 of the 10 years of analysis in the counties of Cornwall and Devon.

Figure A. 11 - Overlay of significant spatial cluster for Chronic ACSCs emergency admissions indirect STD rate from 2004 to 2013



As reported in Table 1-3, the spatial pattern of Incentivised ACSCs emergency admissions indirect STD rate is not random. It is characterised by high and low value spatial clusters of GP practices, with 702 GP practices in a spatial cluster of high Incentivised ACSCs rates and 293 in a spatial cluster of low Incentivised ACSCs rates in 2004 and 629 and 444 in 2013, respectively (in Table A. 7The variation in Incentivised ACSCs indirect standardised rate is, as in the all the ACSCs, wider among the GP practices in the spatial cluster of high values (with a SD higher than 40) than among those in the spatial cluster of low values (with a SD lower than 15).

Table A. 7: Moran's I LISA 2004 - 2013 for Incentivised ACSCs emergency admissions indirect standardised rate

Year	Spatial clusters				Incentivised ACSCs emergency admissions Indirect STD		
		Frequency	Percentage	Mean	min	max	SD
2004	HH	702	8.52%	192.45	119.30	571.09	43.60
2004	LL	293	3.56%	44.47	0	68.13	12.70
2004	not significant	7241	87.92%	99.29	0	329.67	33.57
2005	HH	676	8.27%	192.78	125.12	517.09	42.84
2005	LL	329	4.02%	40.44	0	70.99	13.43
2005	not significant	7172	87.71%	100.30	0	391.33	33.22
2006	HH	692	8.49%	191.58	124.44	448.29	41.11
2006	LL	373	4.58%	40.89	0	70.85	13.16
2006	not significant	7088	86.94%	100.24	0	331.42	33.48
2007	HH	701	8.65%	196.23	126.95	476.84	44.19
2007	LL	478	5.90%	39.48	0	75.43	12.77
2007	not significant	6925	85.45%	101.22	0	294.22	34.19
2008	HH	724	8.99%	197.35	126.45	455.34	42.89
2008	LL	561	6.96%	35.56	0	67.11	13.44
2008	not significant	6771	84.05%	101.78	0	364.11	33.52
2009	HH	715	8.96%	194.77	127.39	529.54	42.49
2009	LL	548	6.86%	35.02	0	70.22	13.56
2009	not significant	6720	84.18%	102.19	0	281.89	32.90
2010	HH	745	9.45%	192.85	132.87	460.19	41.61
2010	LL	544	6.90%	37.06	0	67.49	13.95
2010	not significant	6598	83.66%	101.11	17.10	290.15	32.28
2011	HH	685	8.75%	191.16	125.55	442.06	42.38
2011	LL	492	6.28%	40.02	0	70.14	14.08
2011	not significant	6652	84.97%	101.12	0	308.59	31.89
2012	HH	670	8.55%	195.10	132.25	486.14	44.88
2012	LL	452	5.77%	39.21	3.95	73.24	13.61
2012	not significant	6714	85.68%	101.67	7.21	445.02	33.02
2013	HH	629	8.08%	192.99	125.52	483.77	45.82
2013	LL	444	5.71%	40.43	0	76.81	14.38
2013	not significant	6708	86.21%	102.10	11.82	280.58	32.50

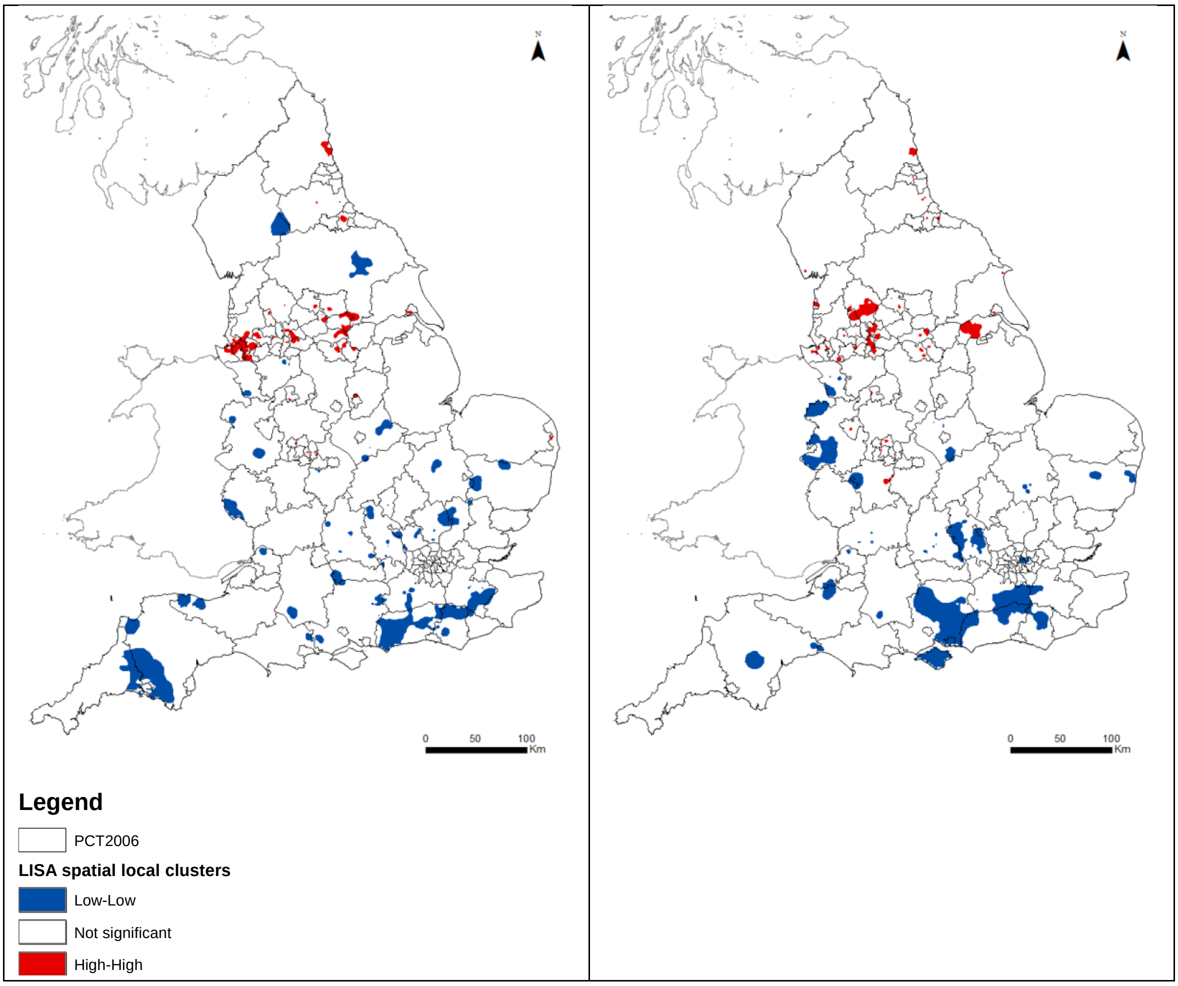
The transitional dynamics between the spatial clusters reported in Table A. 8 show that more than 30% of the GP practices were dropped from a significant high or low value spatial cluster between 2004 and 2013. This indicates that although the spatial pattern is stable overall, there are some time dynamics dimensions in the spatial clusters.

Table A. 8: Transition probabilities across significant spatial cluster between 2004 and 2013 for Incenvised ACSCs emergency admissions indirect STD

	LL	not significant	HH	Total
LL	68.24	31.76	0	100
not significant	2.38	94.06	3.56	100
HH	0.1	35.81	64.1	100
Total	5.89	85.5	8.61	100

Figure A. 12 is quite similar to Figure A. 10because most of the chronic conditions have been incentivised (with just 6% being non-incentivised or excluded). In 2013 the Greater Manchester area, East Lancashire 2006 PCT and North Lincolnshire 2006 PCT have the wider areas of high value spatial clusters, while the 2004 high value spatial clusters around Liverpool are not significant. From 2004 to 2013, the low-value spatial clusters spread in Hampshire, Sussex, Surrey and Kent in the South of England and in Shropshire 2006 PCT on the border with Wales. The 2004 low value clusters from North Yorkshire, Cumbria and Cornwall were not significant in 2013.

Figure A. 12- Moran's I LISA sign spatial clusters for Incentivised ACSCs emerg. adm. ind. STD rate for 2004 and 2013



When we overlay the Incentivised ACSCs emergency admissions indirect STD spatial clusters from 2004 to 2013 we observe that the time-dynamics of Incentivised ACSCs are quite different from what we have observed for Acute or Chronic ACSCs. Figure A. 13 shows that the spatial clusters that remained the same for at least 5 years are much more localised not showing wide areas of high or low value spatial clusters. This spread of localised spatial clusters shows that despite the time-space dynamics some areas had high-values of Incentivised ACSCs emergency admissions indirect STD rate for more than 5 years, in the North East, Liverpool, Greater Manchester, South Yorkshire and the West Midlands. The South East coast, London, the West Midlands and the South West have several small areas of GP practices in low-value spatial clusters for at least 5 years.

Figure A. 13 - Overlay of significant spatial cluster for Incentivised ACSCs emergency admissions indirect STD rate from 2004 to 2013

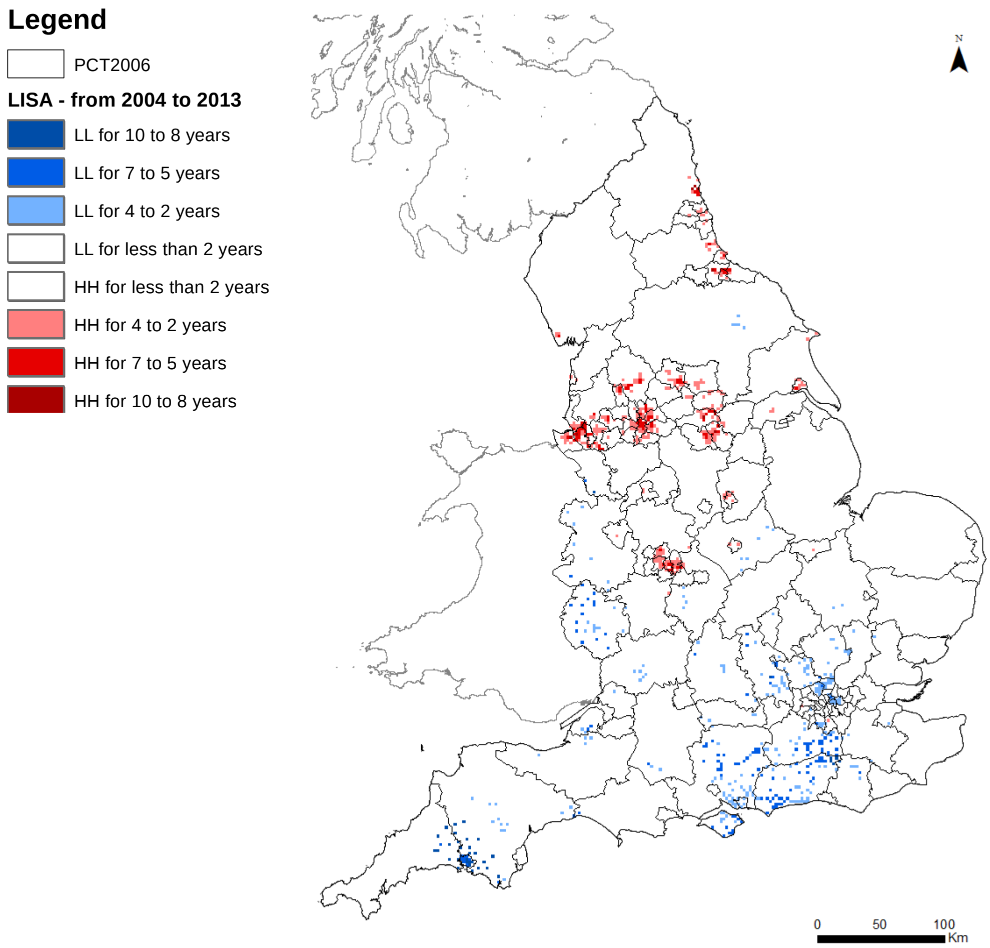


Table A. 9 reports the number of GP practices in each significant spatial cluster and the Non-incentivised ACSCs indirect standardised rate range for each type of cluster. There are 524 GP practices in a spatial cluster of high ACSCs rates and 212 in a spatial cluster of low ACSCs rates in 2004 and 625 and 421 in 2013, respectively. The variation in Non-incentivised ACSCs indirect standardised rate is, as for all other ACSCs definitions, wider among the GP practices in the spatial cluster of high values (with a SD higher than 30) than among those in the spatial cluster of low values (with a SD lower than 15). The SD for non-incentivised ACSCs emergency admissions indirect STD rate within the spatial cluster of high values decreases across the years, being 55.76 in 2005 and 35.12 in 2013.

Table A. 9: Moran's I LISA 2004 - 2013 for Non-incentivised ACSCs emergency admissions indirect standardised rate

Year	Spatial clusters				Non-incentivised ACSCs emergency admissions Indirect STD		
		Frequency	Percentage	Mean	min	max	SD
2004	HH	524	6.36%	192.55	116.70	532.35	45.81
2004	LL	212	2.57%	36.49	0	65.35	15.14
2004	not significant	7500	91.06%	98.68	0	418.88	37.49
2005	HH	574	7.02%	192.28	123.56	1025.74	55.76
2005	LL	229	2.80%	36.35	0	66.52	14.35
2005	not significant	7374	90.18%	98.06	0	301.46	35.21
2006	HH	555	6.81%	196.14	122.93	766.75	54.03
2006	LL	253	3.10%	37.13	0	67.39	14.11
2006	not significant	7345	90.09%	98.27	0	366.80	35.53
2007	HH	603	7.44%	194.30	128.76	402.17	44.46
2007	LL	351	4.33%	37.78	0	69.72	14.28
2007	not significant	7150	88.23%	98.48	0	320.09	35.40
2008	HH	597	7.41%	192.80	121.86	478.52	43.27
2008	LL	463	5.75%	35.18	0	69.38	13.98
2008	not significant	6996	86.84%	98.93	0	308.03	35.31
2009	HH	573	7.18%	190.99	119.99	533.08	43.03
2009	LL	465	5.82%	35.72	0	72.99	14.69
2009	not significant	6945	87.00%	99.70	0	326.16	33.94
2010	HH	678	8.60%	182.35	126.87	418.63	36.19
2010	LL	442	5.60%	36.78	0	71.59	15.37
2010	not significant	6767	85.80%	98.47	0	330.26	32.97
2011	HH	574	7.33%	182.90	123.86	411.75	36.78
2011	LL	438	5.59%	39.43	0	70.04	15.00
2011	not significant	6817	87.07%	99.34	0	317.40	32.96
2012	HH	638	8.14%	178.88	121.63	453.47	35.40
2012	LL	444	5.67%	40.85	0	71.92	13.53
2012	not significant	6754	86.19%	98.84	11.06	453.57	31.81
2013	HH	651	8.37%	178.66	122.71	319.40	35.12
2013	LL	421	5.41%	39.04	0	71.42	14.77
2013	not significant	6709	86.22%	98.60	10.35	411.82	31.47

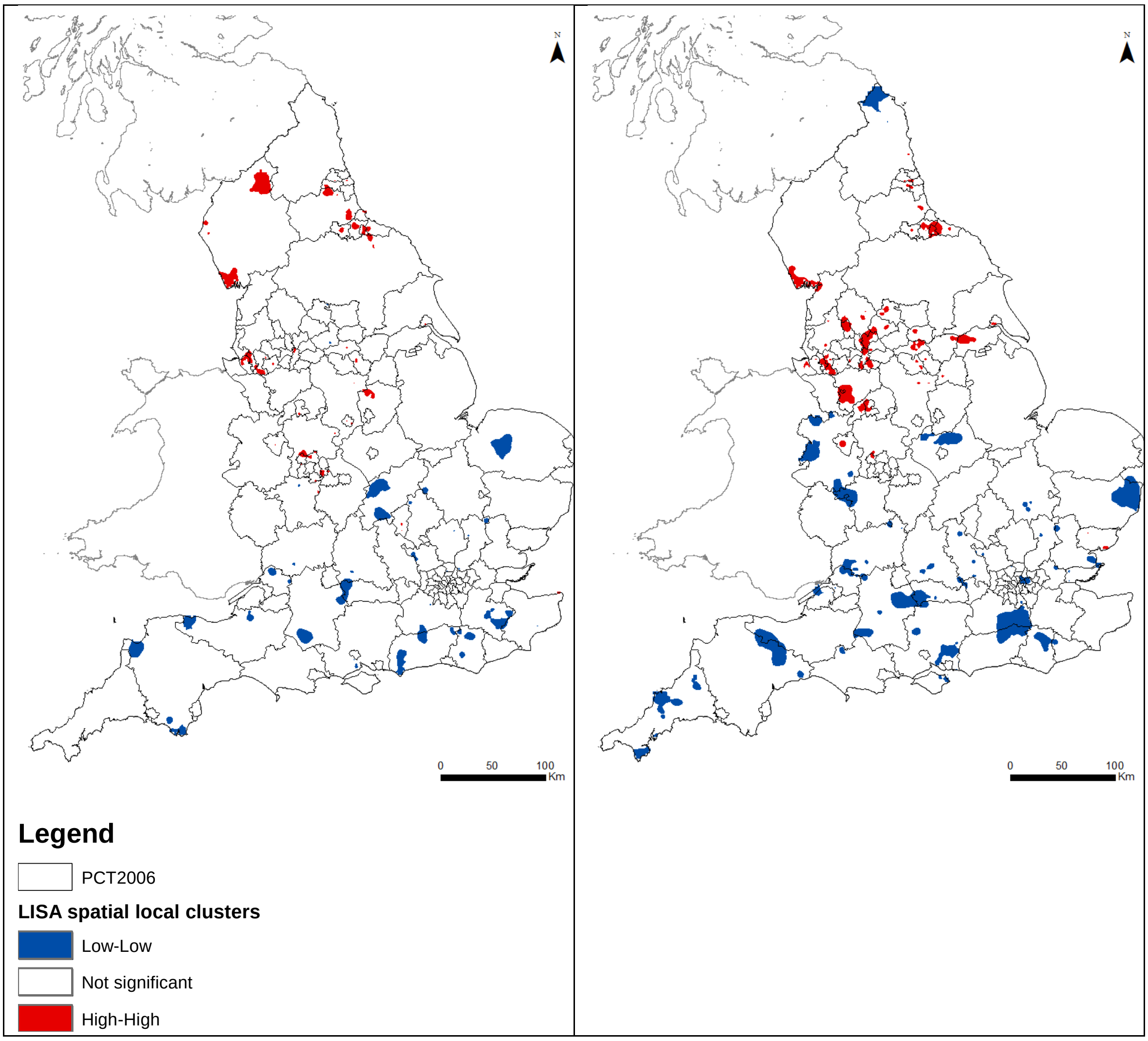
The transition probabilities from a spatial cluster to a not significant cluster reported in Table A. 10 for non-incentivised ACSCs emergency admissions indirect STD rate are the highest. This implies that the space-time dynamics were higher for this ACSCs definition.

Table A. 10: Transition probabilities across significant spatial clusters between 2004 and 2013 for Non-incenvised ACSCs emergency admissions indirect STD rate

	LL	not significant	HH	Total
LL	55.41	44.59	0	100
not significant	2.68	93.05	4.27	100
HH	0.04	48.57	51.39	100
Total	4.89	87.59	7.52	100

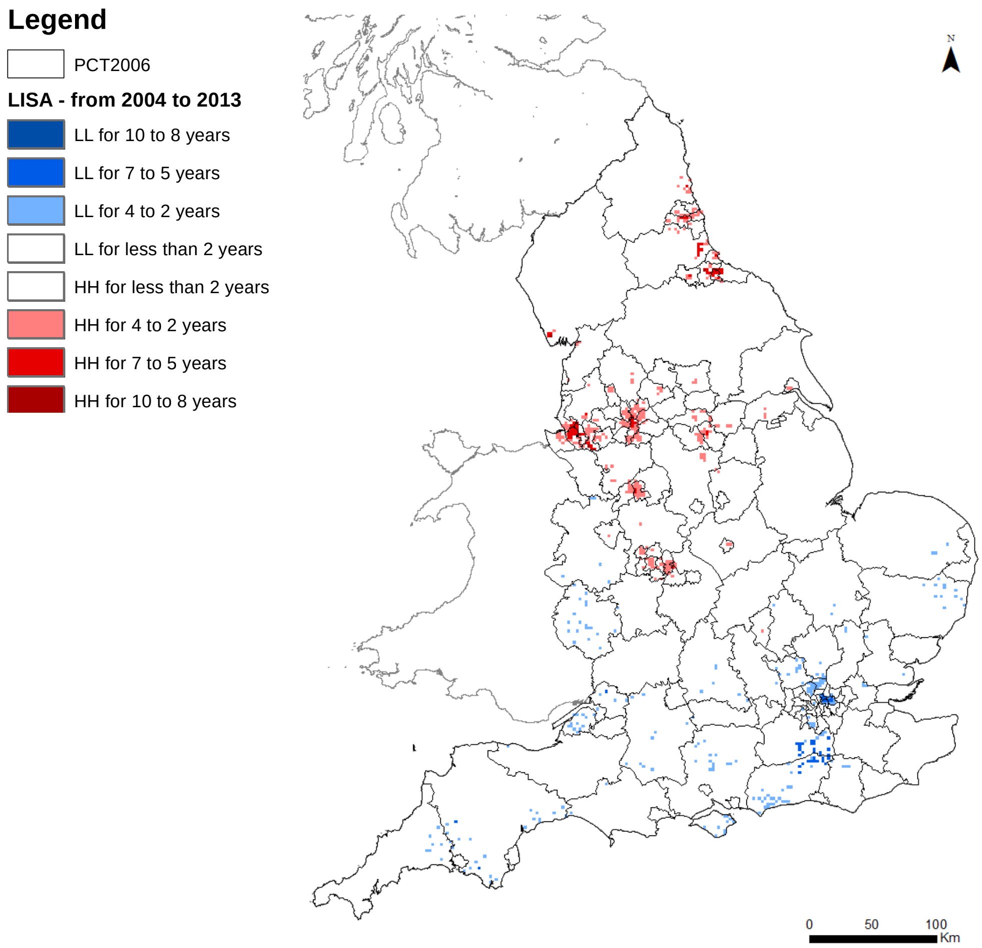
The space-time dynamic is also highlighted in Figure A. 14, with high-value spatial clusters appearing in Greater Manchester, Cheshire and Middlesbrough in 2013 and disappearing from Cumbria. The low-value spatial clusters also changed from 2004 to 2013, with more expression in Shropshire, Sussex, Surrey, Suffolk and in the South West.

Figure A. 14 - Moran's I LISA significant spatial clusters for Non-incentivised ACSCs emergency admissions indirect STD rate for 2004 and 2013



We observe in Figure A. 15 that the high-value spatial clusters identified earlier included GP practices for at least 5 years, in Liverpool, Greater Manchester, Middlesbrough, Newcastle, Birmingham and Stoke on Trent. The sparse areas are due to the high transition probabilities between spatial clusters and non-significant clusters but they still clearly highlight the areas with GP practices in high or low value clusters for at least 5 years.

Figure A. 15 - Overlay of significant spatial clusters for Non-incentivised ACSCs emergency admissions indirect STD rate from 2004 to 2013



Appendix 2.

Appendix 2.1. Population achievement

The population achievement is a weighted average of the achievement on each clinical indicator in all the disease domains.

Let N_{itgk} denote the number of patients from GP practice i that have met the indicator g from the clinical areas k at time t, D_{itgk} the number of patients from GP practice for which the indicator g from the clinical areas k at time t was considered appropriate and E_{itgk} the number of patients exception reported for indicator g from the clinical areas k at time t.

The proportion of patients from GP practice i that have achieved indicator g from the disease domain k at time t will be denoted by α_{itgk} :

$$\alpha_{itgk} = \frac{N_{itgk}}{D_{itgk} + E_{itgk}}$$

The population achievement is set as:

$$PA_{it} = \sum_k \sum_g w_{gkt} \alpha_{itgk}$$

Where w_{itgk} is the weight of each indicator g from the clinical areas k at time t. This weight is set as the proportion of the maximum possible points on indicator g of the clinical areas k at time t $\left(\pi_{gkt}^{\max}\right)$ from the maximum possible points on all indicators in all the diseases domains at time t $\left(\sum_k \sum_g \pi_{gkt}^{\max}\right)$, i.e. :

$$w_{gkt} = \frac{\pi_{gkt}^{\max}}{\sum_k \sum_g \pi_{gkt}^{\max}}$$

The maximum possible PA_{it} is 1 but this is very unlikely to be achieved by a GP practice since it would have to have zero exceptions on all indicators and to successfully achieve the indicator for all eligible patients.

Appendix 2.2. General Practice Patient Survey – data collection dates

GPPS is a survey run every year by IPOS MORIS. We have attributed the patients reported quality measures to the financial years using the fieldwork dates.

Table A. 11: GPPS dates

Financial year	Survey published date	Fieldwork
2006/7	June-2007	Jan-Mar 2007
2007/8	June-2008	Jan-Mar 2008
2008/9	June-2009	Jan-Mar 2009
2009/10	June-2010	Apr-Jun 2009, Jul-Sep 2009, Oct-Dec 2009, Jan-Mar 2010
2010/11	June-2011	Apr-Jun 2010, Jul-Sep 2010, Oct-Dec 2010 and Jan-Mar 2011
2011/12	June-2012	Jul-Sep 2011 and Jan-Mar 2012
2012/13	June-2013	Jul-Sep 2012 and Jan-Mar 2013

Appendix 2.3. Attribution of Index of Multiple Deprivation to GP practices

We use the NHS Attribution Data Set (ADS) to attribute the Population rate claiming incapacity benefit and severe disability allowance and the Education and skills Deprivation score to GP practices.
The ADS includes the number of patients registered per GP practice by Lower Super Output Area (LSOA), while the neighbourhood statistics includes, for example, the population rate claiming incapacity benefit and severe disability allowance per LSOA.
Let P_{ait} denote the number of GP practice *i* patients that reside in LSOA *a* at time *t* and P_{it} the total GP practice $_i$ patient list at time *t*.

$w_{ait} = \frac{p_{ait}}{P_{it}}$ is the proportion of GP practice i patients that reside in LSOA a at time t.

Given a neighbourhood characteristic *k* at time *t* for LSOA *a* , we attribute to the GP practice a weighted average of the LSOA *a* characteristic *k* at time *t* using as a weight the proportion of patients residing in LSOA *a* registered with GP practice *i* for each period *t*, assuming that GP practices catchment area compromise *A* LSOAs:

$$k_{it} = \sum_{a=1}^{A} w_{ai} k_a$$

IMD was published at the 30th September of 2004, 2007 and 2010, using mainly data of 2001, 2005 and 2008 respectively. On the other hand, ADS is collected every year at April. Therefore, for example, we attribute the 2004 IMD and 2006 ADS to have a GP practice IMD 2006 based on its patient list Education, skills and training deprivation
The table below shows how we have attributed the IMD using ADS to GP practice for each financial year.

Table A. 12: IMD dates

GP practice Financial year	ADS dates	IMD dates	Year of data used for calculate the IMD
2006	2006 (April)	2004 (September)	Mainly 2001
2007	2007 (April)	2007 (September)	Mainly 2005
2008	2008 (April)	2007 (September)	Mainly 2005
2009	2009 (April)	2007 (September)	Mainly 2005
2010	2010 (April)	2010 (September)	Mainly 2008
2011	2011 (April)	2010 (September)	Mainly 2008
2012	2012 (April)	2010 (September)	Mainly 2008

Appendix 2.4. Further Results

Table A. 13: Descriptive statistics

Variables	Average	Median	SD	2006	2011	G. rate
GP practice demographic factors (number of patients in 1000s)						
under 4 years old	0.390	0.342	0.246	0.363	0.416	14.60%
between 5 and 14 years old	0.774	0.686	0.468	0.785	0.779	-0.75%
between 15 and 44 years old	2.854	2.456	1.868	2.834	2.870	1.27%
between 45 and 64 years old	1.708	1.478	1.077	1.636	1.785	9.10%
between 65 and 74 years old	0.557	0.462	0.393	0.531	0.594	11.70%
over 75 years old	0.509	0.411	0.385	0.492	0.532	8.09%
Male patients	3.389	2.986	1.988	3.317	3.475	4.75%
Total practice list	6.793	5.999	4.026	6.642	6.976	5.03%
GP practice geographical factors						
Average distance from GP practice surgeries to nearest AED	0.041	0.028	0.040	0.041	0.041	0.41%
Weighted distance of patients neighbourhood (LSOAs) and the nearest GP practice surgery	0.953	0.726	0.711	0.951	0.955	0.40%
Proportion of GP practices in a:						
Town or fringe (less sparse) area	0.123	0	0.329	0.122	0.124	1.48%
Town or fringe (sparse) area	0.010	0	0.098	0.010	0.010	-2.56%
Urban (less sparse)	0.853	1	0.354	0.853	0.852	-0.22%
Urban (sparse)	0.002	0	0.044	0.002	0.002	-2.57%
Village or Hamlet (less sparse)	0.067	0	0.250	0.068	0.068	0.13%
Village or Hamlet (sparse)	0.009	0	0.095	0.009	0.009	-1.17%
GP practice Socioeconomic factors:						
Incapacity benefits	0.052	0.047	0.025	0.057	0.047	-17.71%
Nursing home patients	0.036	0.021	0.046	0.037	0.036	-2.73%
Education, skills & training deprivation score	22.741	19.89	14.023	22.801	22.630	-0.75%
GP practice Registers - per 1000 patients						
CHD	0.236	0.196	0.165	0.236	0.238	0.83%
Stroke	0.115	0.094	0.085	0.108	0.123	13.93%
Hypertension	0.901	0.773	0.577	0.836	0.961	15.06%
COPD	0.106	0.087	0.080	0.095	0.119	25.16%
Hypothyroidism	0.196	0.165	0.137	0.171	0.220	28.77%
Cancer	0.092	0.073	0.073	0.061	0.125	105.05%
Mental Health	0.052	0.043	0.037	0.047	0.057	20.81%
Asthma	0.401	0.346	0.258	0.386	0.417	8.17%
Heart Failure	0.050	0.041	0.038	0.052	0.050	-4.13%
Palliative Care	0.009	0.006	0.012	0.006	0.014	127.50%
Dementia	0.031	0.023	0.028	0.027	0.037	40.37%
Atrial Fibrillation	0.094	0.076	0.075	0.087	0.105	21.10%
Diabetes mellitus	0.284	0.248	0.178	0.244	0.325	33.36%
Epilepsy	0.041	0.035	0.028	0.040	0.043	8.04%
Chronic Kidney Disease (CKD)	0.213	0.161	0.189	0.161	0.238	48.31%
Obesity	0.556	0.472	0.363	0.493	0.613	24.28%

Learning disabilities	0.021	0.015	0.020	0.017	0.025	44.95%
Note: Descriptive statistics for the 7982 GP practices 46314 observations.						

Table A. 14: Poisson panel data models for ACSCs emergency admissions

	Fixed Effects		Random Effects		Mundlak	
FTE GPs	-0.0024*	(0.001)	-0.0019	(0.001)	-0.00243*	(0.001)
Proportion of female GPs	0.0043	(0.011)	-0.0028	(0.01)	0.00434	(0.012)
Average GP age	-0.0027	(0.003)	-0.0031	(0.003)	-0.00269	(0.003)
Proportion of EU GPs	-0.005	(0.022)	-0.0025	(0.018)	-0.00564	(0.022)
Proportion of Non-EU GPs	0.0179	(0.013)	0.012	(0.01)	0.0180	(0.013)
Proportion of salaried GPs	0.005	(0.01)	-0.00052	(0.009)	0.00540	(0.01)
Practice list	-0.117***	(0.023)	-0.083***	(0.019)	-0.117***	(0.023)
Population achievement	-0.0007**	(0.000)	-0.00065**	(0.000)	-0.000695**	(0.000)
Urgent appointments	-0.110***	(0.018)	-0.096***	(0.017)	-0.111***	(0.018)
Advance appointments	-0.0245*	(0.013)	-0.038**	(0.012)	-0.0246*	(0.013)
AIC	309213		405728		404819	
BIC	309589		406174		405597	
Hausman test:	Chi2(38)=1010.15		(0.000)			

Note: The Poisson panel data models also include the GP practice demographic variables, workforce factors, socioeconomic factors and disease registers, the weighted distance of patients' neighbourhood and the nearest GP practice surgery, year dummies and practice list exposure list. There were 46314 observations of the 7982 GP practices between 2006 and 2011. Standard errors in parentheses. * p<0.10, **p<0.05 and *** p<0.001.

Table XX – All emergency admissions and non-ACSCs emergency admissions

	All emergency admissions		Non- ACSCs emergency admissions	
FTE GPs	-0.000682	(0.00089)	-0.000455	(0.00092)
Proportion of female GPs	0.00701	(0.00828)	0.00845	(0.00840)
Average GP age	0.000795	(0.00220)	0.00125	(0.00223)
Proportion of EU GPs	0.000363	(0.01608)	0.00346	(0.01661)
Proportion of Non-EU GPs	0.00977	(0.00914)	0.00753	(0.00925)
Proportion of salaried GPs	-0.000674	(0.00690)	-0.00165	(0.00703)
Population achievement	-0.0561***	(0.01505)	-0.0528***	(0.01536)
Urgent appointments	-0.0766***	(0.01290)	-0.0715***	(0.01308)
Advance appointments	-0.0272**	(0.00912)	-0.0283**	(0.00927)
AIC	558899		503852	
BIC	559275		504228	

Appendix 3.

Appendix 3.1. Information on the reorganisation of Primary Care Trusts in 2006

Table A. 15: 2006 PCTs resulting from a merge of two or more 2002 PCTs

PCT 2002 code	PCT 2002 name	PCT 2006 code	PCT 2006 name
5AN	North East Lincolnshire	5AN	North East Lincolnshire
5D2	West Lincolnshire	5AN	North East Lincolnshire
5AT	Hillingdon	5AT	Hillingdon
5G4	Chiltern and South Bucks	5AT	Hillingdon
5C1	Enfield	5C1	Enfield
5GG	Welwyn Hatfield	5C1	Enfield
5EM	Nottingham City	5EM	Nottingham City
5EV	Broxtowe & Hucknall	5EM	Nottingham City
5FA	Ashfield	5EM	Nottingham City
5FC	Rushcliffe	5EM	Nottingham City
5CV	South Hams and West Devon	5F1	Plymouth Teaching
5F1	Plymouth Teaching	5F1	Plymouth Teaching
5FD	East Hampshire	5FE	Portsmouth City Teaching
5FE	Portsmouth City Teaching	5FE	Portsmouth City Teaching
5LX	Fareham and Gosport	5FE	Portsmouth City Teaching
5FL	Bath and North East Somerset	5FL	Bath and North East Somerset
5FX	Mendip	5FL	Bath and North East Somerset
5EQ	South East Sheffield	5H8	Rotherham
5H8	Rotherham	5H8	Rotherham
5HE	Fylde	5HP	Blackpool
5HP	Blackpool	5HP	Blackpool
5HY	Hounslow	5HY	Hounslow
5L6	North Surrey	5HY	Hounslow
5J9	Darlington	5J9	Darlington
5KE	Sedgefield	5J9	Darlington
5F4	Heywood and Middleton	5JX	Bury
5JX	Bury	5JX	Bury
5CP	Hertsmere	5K6	Harrow
5K6	Harrow	5K6	Harrow
5K9	Croydon	5K9	Croydon
5KQ	East Surrey	5K9	Croydon
5KA	Derwentside	5KF	Gateshead
5KF	Gateshead	5KF	Gateshead
5KC	Durham and Chester-le-Street	5KL	Sunderland Teaching
5KD	Easington	5KL	Sunderland Teaching
5KL	Sunderland Teaching	5KL	Sunderland Teaching
5A1	New Forest	5L1	Southampton City
5L1	Southampton City	5L1	Southampton City
5LY	Eastleigh and Test Valley South	5L1	Southampton City
5L3	Medway	5L3	Medway
5L4	Swale	5L3	Medway

5FK	Mid-Sussex	5LQ	Brighton and Hove City
5L8	Adur, Arun and Worthing	5LQ	Brighton and Hove City
5LQ	Brighton and Hove City	5LQ	Brighton and Hove City
5M1	South Birmingham	5M1	South Birmingham
5MR	Redditch and Bromsgrove	5M1	South Birmingham
5DQ	Burntwood, Lichfield and Tamworth	5M3	Walsall Teaching
5M3	Walsall Teaching	5M3	Walsall Teaching
5M9	Rugby	5MD	Coventry Teaching
5MD	Coventry Teaching	5MD	Coventry Teaching
5MP	North Warwickshire	5MD	Coventry Teaching
5HH	Leeds West	5N1	Leeds
5HJ	Leeds North East	5N1	Leeds
5HK	East Leeds	5N1	Leeds
5HL	South Leeds	5N1	Leeds
5HM	Leeds North West	5N1	Leeds
5J7	North Kirklees	5N2	Kirklees
5LJ	Huddersfield Central	5N2	Kirklees
5LK	South Huddersfield	5N2	Kirklees
5E7	Eastern Wakefield	5N3	Wakefield District
5E8	Wakefield West	5N3	Wakefield District
5EE	North Sheffield	5N4	Sheffield
5EN	Sheffield West	5N4	Sheffield
5EP	Sheffield South West	5N4	Sheffield
5CK	Doncaster Central	5N5	Doncaster
5EK	Doncaster East	5N5	Doncaster
5EL	Doncaster West	5N5	Doncaster
5EA	Chesterfield	5N6	Derbyshire County
5EG	North Eastern Derbyshire	5N6	Derbyshire County
5H7	Derbyshire Dales and South Derbyshire	5N6	Derbyshire County
5HN	High Peak and Dales	5N6	Derbyshire County
5AL	Central Derby	5N7	Derby City
5ED	Amber Valley	5N7	Derby City
5ER	Erewash	5N7	Derby City
5EX	Greater Derby	5N7	Derby City
5AM	Mansfield District	5N8	Nottinghamshire County
5AP	Newark and Sherwood	5N8	Nottinghamshire County
5EC	Gedling	5N8	Nottinghamshire County
5D3	Lincolnshire South West Teaching	5N9	Lincolnshire
5H9	East Lincolnshire	5N9	Lincolnshire
5AJ	Epping Forest	5NA	Redbridge
5NA	Redbridge	5NA	Redbridge
5J8	Durham Dales	5ND	County Durham
5D4	Carlisle and District	5NE	Cumbria
5D5	Eden Valley	5NE	Cumbria
5D6	West Cumbria	5NE	Cumbria
5DD	Morecambe Bay	5NF	North Lancashire
5HF	Wyre	5NF	North Lancashire
5F2	Chorley and South Ribble	5NG	Central Lancashire

5HD	Preston	5NG	Central Lancashire
5G7	Hyndburn and Ribble Valley	5NH	East Lancashire
5G8	Burnley, Pendle and Rossendale	5NH	East Lancashire
5F3	West Lancashire	5NJ	Sefton
5F9	Southport and Formby	5NJ	Sefton
5G9	North Liverpool	5NJ	Sefton
5M5	South Sefton	5NJ	Sefton
5F8	Bebington and West Wirral	5NK	Wirral
5H2	Birkenhead and Wallasey	5NK	Wirral
5H6	Ellesmere Port and Neston	5NK	Wirral
5HA	Central Liverpool	5NL	Liverpool
5HC	South Liverpool	5NL	Liverpool
5J1	Halton	5NM	Halton and St Helens
5J3	St Helens	5NM	Halton and St Helens
5H3	Cheshire West	5NN	Western Cheshire
5H4	Central Cheshire	5NP	Central and Eastern Cheshire
5H5	Eastern Cheshire	5NP	Central and Eastern Cheshire
5JY	Rochdale	5NQ	Heywood, Middleton and Rochdale
5CX	Trafford South	5NR	Trafford
5F6	Trafford North	5NR	Trafford
5AA	South Manchester	5NT	Manchester
5CL	Central Manchester	5NT	Manchester
5CR	North Manchester	5NT	Manchester
5E2	Selby and York	5NV	North Yorkshire and York
5KH	Hambleton and Richmondshire	5NV	North Yorkshire and York
5KJ	Craven, Harrogate and Rural District	5NV	North Yorkshire and York
5E3	East Yorkshire	5NW	East Riding of Yorkshire
5E4	Yorkshire Wolds and Coast	5NX	Hull
5E5	Eastern Hull	5NX	Hull
5E6	West Hull	5NX	Hull
5AW	Airedale	5NY	Bradford and Airedale
5CF	Bradford City Teaching	5NY	Bradford and Airedale
5CG	Bradford South and West	5NY	Bradford and Airedale
5CH	North Bradford	5NY	Bradford and Airedale
5AK	Southend on Sea	5P1	South East Essex
5JP	Castle Point and Rochford	5P1	South East Essex
5GD	Bedford	5P2	Bedfordshire
5GE	Bedfordshire Heartlands	5P2	Bedfordshire
5GH	North Hertfordshire and Stevenage	5P3	East and North Hertfordshire
5GJ	South East Hertfordshire	5P3	East and North Hertfordshire
5GV	Watford and Three Rivers	5P4	West Hertfordshire
5GW	Dacorum	5P4	West Hertfordshire
5GX	St. Albans and Harpenden	5P4	West Hertfordshire
5KP	East Elmbridge and Mid Surrey	5P5	Surrey
5L5	Guildford and Waverley	5P5	Surrey
5L7	Surrey Heath and Woking	5P5	Surrey
5MA	Crawley	5P5	Surrey
5L9	Western Sussex	5P6	West Sussex

5MC	Horsham and Chanctonbury	5P6	West Sussex
5LR	Eastbourne Downs	5P7	East Sussex Downs and Weald
5LT	Sussex Downs and Weald	5P7	East Sussex Downs and Weald
5FH	Bexhill and Rother	5P8	Hastings and Rother
5FJ	Hastings and St Leonards	5P8	Hastings and Rother
5FF	South West Kent	5P9	West Kent
5L2	Maidstone Weald	5P9	West Kent
5EH	Melton, Rutland and Harborough	5PA	Leicestershire County and Rutland
5JC	Charnwood and North West Leicestershire	5PA	Leicestershire County and Rutland
5EJ	Leicester City West	5PC	Leicester City
5EY	Eastern Leicester	5PC	Leicester City
5JA	Hinckley and Bosworth	5PC	Leicester City
5JD	South Leicestershire	5PC	Leicester City
5AC	Daventry and South Northamptonshire	5PD	Northamptonshire
5LV	Northamptonshire Heartlands	5PD	Northamptonshire
5LW	Northampton	5PD	Northamptonshire
5DR	Wyre Forest	5PE	Dudley
5HT	Dudley South	5PE	Dudley
5HV	Dudley Beacon and Castle	5PE	Dudley
5MG	Oldbury and Smethwick	5PF	Sandwell
5MH	Rowley Regis and Tipton	5PF	Sandwell
5MJ	Wednesbury and West Bromwich	5PF	Sandwell
5MW	North Birmingham	5PG	Birmingham East and North
5MY	Eastern Birmingham	5PG	Birmingham East and North
5HR	Staffordshire Moorlands	5PH	North Staffordshire
5HW	Newcastle-under-Lyme	5PJ	Stoke on Trent
5ME	North Stoke	5PJ	Stoke on Trent
5MF	South Stoke	5PJ	Stoke on Trent
5ML	East Staffordshire	5PK	South Staffordshire
5MM	Cannock Chase	5PK	South Staffordshire
5MN	South Western Staffordshire	5PK	South Staffordshire
5MT	South Worcestershire	5PL	Worcestershire
5MQ	South Warwickshire	5PM	Warwickshire
5AF	North Peterborough	5PN	Peterborough
5AG	South Peterborough	5PN	Peterborough
5GF	Huntingdonshire	5PP	Cambridgeshire
5JH	Cambridge City	5PP	Cambridgeshire
5JJ	South Cambridgeshire	5PP	Cambridgeshire
5JK	East Cambridgeshire and Fenland	5PP	Cambridgeshire
5CY	West Norfolk	5PQ	Norfolk
5G1	Southern Norfolk	5PQ	Norfolk
5JL	Broadland	5PQ	Norfolk
5JM	North Norfolk	5PQ	Norfolk
5A2	Norwich	5PR	Great Yarmouth and Waveney
5GT	Great Yarmouth	5PR	Great Yarmouth and Waveney
5JR	Suffolk Coastal	5PR	Great Yarmouth and Waveney
5JV	Waveney	5PR	Great Yarmouth and Waveney
5JQ	Ipswich	5PT	Suffolk

5JT	Central Suffolk	5PT	Suffolk
5JW	Suffolk West	5PT	Suffolk
5DC	Harlow	5PV	West Essex
5GK	Royston, Buntingford and Bishop's Stortford	5PV	West Essex
5GN	Uttlesford	5PV	West Essex
5AH	Tendring	5PW	North East Essex
5GM	Colchester	5PW	North East Essex
5GL	Maldon and South Chelmsford	5PX	Mid Essex
5JN	Chelmsford	5PX	Mid Essex
TAG	Witham, Braintree and Halstead	5PX	Mid Essex
5GP	Billericay, Brentwood and Wickford	5PY	South West Essex
5GQ	Thurrock	5PY	South West Essex
5GR	Basildon	5PY	South West Essex
5LL	Ashford	5QA	Eastern and Coastal Kent
5LM	Canterbury and Coastal	5QA	Eastern and Coastal Kent
5LN	East Kent Coastal	5QA	Eastern and Coastal Kent
5LP	Shepway	5QA	Eastern and Coastal Kent
5E9	Mid-Hampshire	5QC	Hampshire
5DP	Vale of Aylesbury	5QD	Buckinghamshire
5DT	North East Oxfordshire	5QE	Oxfordshire
5DV	Cherwell Vale	5QE	Oxfordshire
5DW	Oxford City	5QE	Oxfordshire
5DY	South West Oxfordshire	5QE	Oxfordshire
5DF	North Hampshire	5QF	Berkshire West
5DK	Newbury and Community	5QF	Berkshire West
5DL	Reading	5QF	Berkshire West
5DX	South East Oxfordshire	5QF	Berkshire West
5DM	Slough	5QG	Berkshire East
5DN	Wokingham	5QG	Berkshire East
5G2	Bracknell Forest	5QG	Berkshire East
5G3	Windsor, Ascot and Maidenhead	5QG	Berkshire East
5G5	Wycombe	5QG	Berkshire East
5G6	Blackwater Valley and Hart	5QG	Berkshire East
5KW	Cheltenham and Tewkesbury	5QH	Gloucestershire
5KX	West Gloucestershire	5QH	Gloucestershire
5KY	Cotswold and Vale	5QH	Gloucestershire
5JF	Bristol North	5QJ	Bristol
5JG	Bristol South and West	5QJ	Bristol
5DH	West Wiltshire	5QK	Wiltshire
5DJ	South Wiltshire	5QK	Wiltshire
5K4	Kennet and North Wiltshire	5QK	Wiltshire
5FW	Somerset Coast	5QL	Somerset
5K1	South Somerset	5QL	Somerset
5K2	Taunton Deane	5QL	Somerset
5CD	North Dorset	5QM	Dorset
5FP	South West Dorset	5QM	Dorset
5CE	Bournemouth Teaching	5QN	Bournemouth and Poole
5FN	South and East Dorset	5QN	Bournemouth and Poole

5KV	Poole	5QN	Bournemouth and Poole
5FM	West of Cornwall	5QP	Cornwall and Isles of Scilly
5KR	North and East Cornwall	5QP	Cornwall and Isles of Scilly
5KT	Central Cornwall	5QP	Cornwall and Isles of Scilly
5FQ	North Devon	5QQ	Devon
5FR	Exeter	5QQ	Devon
5FV	Mid Devon	5QQ	Devon
5KK	Scarborough, Whitby and Ryedale	5QR	Redcar and Cleveland
5KN	Langbaurgh	5QR	Redcar and Cleveland
5DG	Isle of Wight	5QT	Isle of Wight National Health Service
5CM	Dartford, Gravesham and Swanley	TAK	Bexley
TAK	Bexley	TAK	Bexley
5FT	East Devon	TAL	Torbay
5FY	Teignbridge	TAL	Torbay
TAL	Torbay Care Trust	TAL	Torbay
5D1	Solihull	TAM	Solihull Care Trust

Table A. 16: LAs that were divided by more than one 2006 PCT

LA code	LA name	PCT 2006 code	PCT 2006 name
E06000013	North Lincolnshire	5N9	Lincolnshire
E06000013	North Lincolnshire	5EF	North Lincolnshire
E06000013	North Lincolnshire	5AN	North East Lincolnshire
E06000049	Cheshire East	5NN	Western Cheshire
E06000049	Cheshire East	5NP	Central and Eastern Cheshire
E06000050	Cheshire West and Chester	5NP	Central and Eastern Cheshire
E06000050	Cheshire West and Chester	5NN	Western Cheshire
E07000004	Aylesbury Vale	5QD	Buckinghamshire
E07000004	Aylesbury Vale	5CQ	Milton Keynes
E07000037	High Peak	5LH	Tameside and Glossop
E07000037	High Peak	5N6	Derbyshire County
E07000065	Wealden	5P8	Hastings and Rother
E07000065	Wealden	5P7	East Sussex Downs and Weald
E07000067	Braintree	5PX	Mid Essex
E07000067	Braintree	5PV	West Essex
E07000179	South Oxfordshire	5QD	Buckinghamshire
E07000179	South Oxfordshire	5QE	Oxfordshire
E07000180	Vale of White Horse	5K3	Swindon
E07000180	Vale of White Horse	5QE	Oxfordshire
E07000198	Staffordshire Moorlands	5PJ	Stoke on Trent
E07000198	Staffordshire Moorlands	5PH	North Staffordshire
E07000212	Runnymede	5P5	Surrey
E07000212	Runnymede	5QG	Berkshire East
E08000025	Birmingham	5M1	South Birmingham
E08000025	Birmingham	5PG	Birmingham East and North
E08000025	Birmingham	5MX	Heart of Birmingham Teaching

Appendix 3.2. Patient experience domain in QOF

Table A. 17: The QOF indicators for Patient Experience Domain from 2006/07 to 2011/12

Indicator code	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	Indicator
PE1	33	33	33	33	33	33	The length of routine booked appointments in the practice is not less than 10 minutes. (If the practice routinely sees extras during booked surgeries, then the average booked consultation length should allow for the average number of extras seen in a surgery session. If the extras are seen at the end, then it is not necessary to make this adjustment.) For practices with only an open surgery system, the average face-to-face time spent by the GP with the patient is at least 8 minutes. Practices that routinely operate a mixed economy of booked and open surgeries should report on both criteria.
PE2	25	25	25	–	–	–	The practice will have undertaken an approved patient survey each year.
PE3	–	–	–	–	–	–	The practice will have undertaken a patient survey each year, will have reflected on the results, and have proposed changes if appropriate.
PE4	–	–	–	–	–	–	The practice will have undertaken a patient survey each year and discussed the results as a team and with either a patient group or non-executive director of the primary care organisation (PCO). Appropriate changes will have been proposed with some evidence that the changes have been enacted.
PE5	20	20	–	–	–	–	The practice will have undertaken a patient survey each year and, having reflected on the results, will produce an action plan that:
							summarises the findings of the survey;
							summarises the findings of the previous year's survey; and
							reports on the activities undertaken in the past year to address patient experience issues.

PE6	30	30	30	–	–	–	The practice will have undertaken a patient survey and, having reflected on the results, will produce an action plan that:
							sets priorities for the next 2 years;
							describes how the practice will report the findings to patients (for example, posters in the practice, a meeting with a patient practice group or a PCO-approved patient representative);
							describes the plans for achieving the priorities, including indicating the lead person in the practice; and
							considers the case for collecting additional information on patient experience, for example through surveys of patients with specific illnesses, or consultation with a patient group.
PE7	–	–	23.5	23.5	23.5	–	The percentage of patients who, using an approved survey, indicate that they were able to obtain a consultation with a GP (in England) or appropriate health care professional (in Scotland, Wales and NI) within 2 working days (In Wales this will be within 24 hours).
PE8	–	–	35	35	35	–	The percentage of patients who, using an approved survey, indicate that they were able to book an appointment with a GP more than 2 days ahead.

Appendix 3.3. Descriptive statistics of practices' patient list by gender and age band

Table A. 18: Descriptive statistics for patient list by gender and age band

	Overall	**STD**			**Percentile**		**Average**		**Growth Rate ***
Patients in 1000s	Average	Overall	Between	Within	5	95	2006	2011	
Practice list	7.089	3.995	3.969	0.459	2.270	14.278	6.916	7.244	4.7%
N patients 0to4yrs	0.407	0.245	0.241	0.044	0.113	0.850	0.379	0.432	13.9%
N patients 5to14yrs	0.808	0.466	0.462	0.058	0.237	1.648	0.818	0.809	-1.1%
N patients 15to44yrs	2.974	1.851	1.836	0.231	0.940	6.087	2.947	2.975	0.9%
N patients 45to64yrs	1.784	1.073	1.066	0.121	0.513	3.735	1.705	1.856	8.9%
N patients 65to74yrs	0.582	0.394	0.391	0.049	0.134	1.325	0.554	0.618	11.6%
N patients 75plus yrs	0.533	0.388	0.386	0.038	0.099	1.245	0.513	0.555	8.0%
N male patients	3.534	1.975	1.962	0.232	1.167	7.074	3.450	3.607	4.5%
N female patients	3.554	2.029	2.016	0.231	1.098	7.214	3.465	3.637	5.0%

Note: These descriptive statistics include all 7062 GP practices in the 6 years panel, so 42372 (7062*6) observation. *Growth rate from 2006 to 2011s

Appendix 3.4. Peer effects model estimated using a Spatial Durbin Model with the peer group weight matrix with influence weighted by FTE GPs

Table A. 19: Spatial Durbin Model with the peer group weight matrix with influence weighted by FTE GPs

	Total QOF points	Proportion of ACSCs emergency admissions (in 1000s of patients)	Population achievement	Urgent appointment	Advance appointment
Peer effect	0.395***	0.686***	0.454***	0.431***	0.367***
	(0.015)	(0.007)	(0.011)	(0.013)	(0.014)
GP practice own characteristics					
FTE GPs per 1000 patients	0.000768	0.000338***	-0.000133	0.0000249***	0.0000146***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
N patients 0to4yrs (in 1000s)	-33.68***	0.987*	-2.549***	-0.114***	-0.0834***
	(5.797)	(0.416)	(0.760)	(0.011)	(0.015)
N patients 5to14yrs (in 1000s)	22.67***	-1.060***	6.169***	-0.00781	-0.0570***
	(4.431)	(0.319)	(0.581)	(0.008)	(0.012)
N patients 45to64yrs (in 1000s)	-12.95***	-0.211	-0.607	-0.0134*	0.0200*
	(3.007)	(0.216)	(0.394)	(0.006)	(0.008)
N patients 65to74yrs (in 1000s)	-14.43**	-0.679	-1.490*	-0.0726***	0.0324*
	(5.587)	(0.401)	(0.733)	(0.010)	(0.015)
N patients 75plus yrs (in 1000s)	-6.648	2.478***	0.439	-0.0293*	-0.0217
	(6.930)	(0.498)	(0.909)	(0.013)	(0.018)
N Male patient (in 1000s)	-1.425	-1.040***	-0.921***	0.0126***	-0.000807
	(1.764)	(0.127)	(0.231)	(0.003)	(0.005)
PMS contract	-9.795***	-0.0952	-0.789***	0.00252	0.00997*
	(1.503)	(0.108)	(0.197)	(0.003)	(0.004)
Population rate claiming incapacity benefit and severe disability allowance	42.45	22.27***	-38.60***	-0.141	0.193
	(83.144)	(5.982)	(10.901)	(0.156)	(0.216)
Prop of Patients residing in a Nursing Home	-3.988	1.429	3.036	0.0692**	0.0643
	(14.267)	(1.024)	(1.871)	(0.027)	(0.037)
Education Skills and Training deprivation score	-0.0839	0.0423***	-0.0130	-0.000492	-0.000686
	(0.172)	(0.012)	(0.023)	(0.000)	(0.000)

Average GP Age	-0.0686	-0.0562*	-0.125*	-0.000558	0.00183
	(0.396)	(0.028)	(0.052)	(0.001)	(0.001)
Average GP Age Squared	-0.00814*	0.000502	0.000272	0.00000963	-0.0000132
	(0.004)	(0.000)	(0.001)	(0.000)	(0.000)
Proportion of Female GPs	2.337	0.152	-0.182	-0.0109***	-0.0219***
	(1.388)	(0.100)	(0.182)	(0.003)	(0.004)
Proportion of GPs qualified in Europe	-5.634*	-0.412*	-0.262	-0.00224	0.000820
	(2.740)	(0.197)	(0.359)	(0.005)	(0.007)
Proportion of GPs qualified outside Europe	4.732**	0.0852	0.393	-0.00239	0.00331
	(1.564)	(0.112)	(0.205)	(0.003)	(0.004)
Proportion of salaried GPs	-5.686***	0.100	-0.500**	-0.00295	-0.00230
	(1.273)	(0.091)	(0.167)	(0.002)	(0.003)
Urgent appointment	53.40***	-0.923***	0.142		
	(2.628)	(0.189)	(0.345)		
Advance appointment	25.33***	-0.372**	1.769***		
	(1.890)	(0.136)	(0.248)		
Population Achievement		-0.00622*		0.0000972	0.000699***
		(0.003)		(0.000)	(0.000)
QOF disease registers (in 100s)					
Coronary Heart Disease (CHD)	-26.62*	3.008***	-14.85***	-0.0194	-0.174***
	(12.137)	(0.872)	(1.591)	(0.023)	(0.032)
Stroke and transient ischaemic attack	38.79	6.525***	6.021*	0.0674	-0.0841
	(20.264)	(1.455)	(2.657)	(0.038)	(0.053)
Hypertension	9.825**	-0.502	0.226	-0.0168*	-0.0252*
	(3.809)	(0.273)	(0.499)	(0.007)	(0.010)
Chronic obstructive pulmonary disease (COPD)	-8.711	3.310***	6.139***	0.0528*	0.00147
	(13.077)	(0.939)	(1.715)	(0.025)	(0.034)
Hypothyroidism	-13.65	-0.854	1.200	0.00643	0.0733*
	(11.502)	(0.826)	(1.508)	(0.022)	(0.030)
Cancer	-62.71***	-0.996	-9.035***	-0.167***	0.164***
	(10.924)	(0.785)	(1.432)	(0.020)	(0.028)
Mental Health	79.87***	-0.598	-8.118*	0.0280	0.263***
	(24.250)	(1.741)	(3.180)	(0.045)	(0.063)
Asthma	21.42***	-0.0550	-0.881	0.0356**	0.00276
	(6.087)	(0.437)	(0.798)	(0.011)	(0.016)
Heart Failure	81.67***	-2.530*	16.89***	-0.0560	0.0590
	(17.709)	(1.272)	(2.322)	(0.033)	(0.046)
Palliative Care	77.90***	1.609	14.65***	0.00661	0.0781
	(18.382)	(1.320)	(2.410)	(0.034)	(0.048)
Dementia	84.32***	1.774	3.479	-0.0855*	0.201***

	(22.067)	(1.584)	(2.893)	(0.041)	(0.057)
Atrial Fibrillation	-2.623	6.419***	-4.721	-0.0155	0.0789
	(19.134)	(1.374)	(2.509)	(0.036)	(0.050)
Diabetes Mellitus (over 17yrs old)	-14.99	2.432***	-2.716*	0.128***	0.0767***
	(8.502)	(0.610)	(1.115)	(0.016)	(0.022)
Epilepsy (0ver 18yrs old)	187.1***	6.558*	16.69**	-0.139	-0.333**
	(40.347)	(2.897)	(5.290)	(0.076)	(0.105)
Chronic kidney disease (over 18 yrs old)	1.852	-0.0918	-0.826*	0.0182***	-0.0225***
	(2.464)	(0.177)	(0.323)	(0.005)	(0.006)
Obesity (over 16 yrs old)	18.26***	-0.211	2.411***	0.00933**	0.0291***
	(1.797)	(0.129)	(0.236)	(0.003)	(0.005)
Learning Disabilities (over 18 yrs old)	48.71	-1.249	-7.440*	0.0922	0.171*
	(25.552)	(1.835)	(3.350)	(0.048)	(0.066)
year2007	8.393***	-0.196***	1.230***	0.00877***	0.00899***
	(0.581)	(0.042)	(0.076)	(0.001)	(0.002)
year2008	3.086***	-0.0150	1.653***	-0.00352**	-0.00775***
	(0.710)	(0.052)	(0.094)	(0.001)	(0.002)
year2009	0.243	-0.0449	-2.148***	-0.0181***	-0.0297***
	(1.069)	(0.080)	(0.179)	(0.002)	(0.003)
year2010	5.240***	-0.00949	0.838***	-0.0165***	-0.0394***
	(1.166)	(0.082)	(0.150)	(0.002)	(0.003)
year2011	13.85***	-0.0808	0.422*	0.0171***	-0.0197***
	(1.292)	(0.092)	(0.169)	(0.002)	(0.003)
Contextual Effects					
FTE GPs per 1000 patients	0.00186	-0.000810***	-0.000473	0.00000274	0.0000156*
	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)
N patients 0to4yrs (in 1000s)	-7.627	1.538	4.182**	-0.0836***	-0.0517
	(12.104)	(0.869)	(1.586)	(0.023)	(0.031)
N patients 5to14yrs (in 1000s)	2.631	0.266	3.333**	0.00524	-0.0781**
	(9.183)	(0.662)	(1.206)	(0.017)	(0.024)
N patients 45to64yrs (in 1000s)	0.985	-0.754	-0.436	-0.0244*	0.0217
	(6.243)	(0.448)	(0.818)	(0.012)	(0.016)
N patients 65to74yrs (in 1000s)	0.833	1.882**	0.545	-0.0444*	0.0292
	(9.470)	(0.680)	(1.242)	(0.018)	(0.025)
N patients 75plus yrs (in 1000s)	-13.25	0.810	1.171	-0.0302	-0.200***
	(13.190)	(0.947)	(1.729)	(0.025)	(0.034)
N Male patient (in 1000s)	1.224	0.0399	-1.303*	0.0363***	0.0288**
	(4.128)	(0.296)	(0.542)	(0.008)	(0.011)
PMS contract	-0.643	0.232	0.443	-0.000112	-0.0327***

	(3.243)	(0.233)	(0.425)	(0.006)	(0.008)
Population rate claiming incapacity benefit and severe disability allowance	246.2*	-15.36*	5.479	0.583**	0.0952
	(97.931)	(7.043)	(12.859)	(0.183)	(0.254)
Prop of Patients residing in a Nursing Home	21.01	-2.014	-0.225	-0.111*	-0.155*
	(26.307)	(1.889)	(3.449)	(0.049)	(0.068)
Education Skills and Training deprivation score	-0.0134	-0.0483**	0.0809*	-0.00142**	0.000455
	(0.242)	(0.017)	(0.032)	(0.000)	(0.001)
Average GP Age	-1.703	0.0532	-0.110	-0.00539**	0.00146
	(1.043)	(0.075)	(0.137)	(0.002)	(0.003)
Average GP Age Squared	0.0204	-0.000758	0.00122	0.0000537**	-0.0000141
	(0.011)	(0.001)	(0.001)	(0.000)	(0.000)
Proportion of Female GPs	0.0444	0.0650	-0.360	-0.00173	0.0333***
	(3.476)	(0.250)	(0.456)	(0.007)	(0.009)
Proportion of GPs qualified in Europe	10.37	0.505	0.867	0.00229	0.0547**
	(6.823)	(0.490)	(0.895)	(0.013)	(0.018)
Proportion of GPs qualified outside Europe	0.388	0.617*	0.0136	-0.0212**	0.0245*
	(3.862)	(0.277)	(0.507)	(0.007)	(0.010)
Proportion of salaried GPs	4.917	-0.408	0.853*	0.00224	-0.00778
	(2.919)	(0.210)	(0.383)	(0.005)	(0.008)
Urgent appointment	6.355	0.222	-0.904		
	(5.531)	(0.396)	(0.725)		
Advance appointment	5.366	-0.0118	0.604		
	(3.761)	(0.271)	(0.493)		
Population Achievement		0.00403		-0.0000400	0.000127
		(0.005)		(0.000)	(0.000)
QOF disease registers (in 100s)					
Coronary Heart Disease (CHD)	-40.48	-2.546	2.472	-0.0207	-0.0317
	(23.837)	(1.712)	(3.126)	(0.045)	(0.062)
Stroke and transient ischaemic attack	-2.544	2.297	-6.449	0.0201	0.336***
	(38.465)	(2.762)	(5.043)	(0.072)	(0.100)
Hypertension	-3.045	-0.180	-0.512	0.0409**	-0.0242
	(7.511)	(0.539)	(0.985)	(0.014)	(0.020)
Chronic obstructive pulmonary disease (COPD)	50.64*	3.767*	7.851*	0.0474	0.0893
	(25.156)	(1.807)	(3.298)	(0.047)	(0.065)
Hypothyroidism	-2.661	-2.830*	-0.723	-0.0310	0.0179

	(18.768)	(1.347)	(2.461)	(0.035)	(0.049)
Cancer	0.0530	-0.301	0.659	-0.0944*	0.0506
	(19.628)	(1.410)	(2.574)	(0.037)	(0.051)
Mental Health	-113.5*	-4.002	0.127	0.0830	0.107
	(56.489)	(4.056)	(7.408)	(0.106)	(0.147)
Asthma	12.39	1.640	-0.431	-0.0222	-0.0338
	(12.219)	(0.877)	(1.602)	(0.023)	(0.032)
Heart Failure	5.160	-1.786	2.916	0.0227	-0.0831
	(32.153)	(2.312)	(4.218)	(0.060)	(0.084)
Palliative Care	31.31	-0.469	-5.767	-0.137*	0.0330
	(31.999)	(2.299)	(4.196)	(0.060)	(0.083)
Dementia	39.89	-1.727	9.457	-0.0351	0.0380
	(42.714)	(3.066)	(5.600)	(0.080)	(0.111)
Atrial Fibrillation	32.72	-3.267	-2.604	-0.133*	0.0947
	(35.511)	(2.551)	(4.658)	(0.067)	(0.092)
Diabetes Mellitus (over 17yrs old)	-28.55	-1.262	-0.936	0.0959**	-0.0920*
	(15.871)	(1.140)	(2.081)	(0.030)	(0.041)
Epilepsy (0ver 18yrs old)	178.1*	0.368	17.02	-0.480**	-0.331
	(83.961)	(6.029)	(11.009)	(0.157)	(0.218)
Chronic kidney disease (over 18 yrs old)	6.923	-0.436	-0.358	0.00376	-0.0100
	(4.074)	(0.293)	(0.534)	(0.008)	(0.011)
Obesity (over 16 yrs old)	-2.006	-0.370	-0.311	0.000466	0.00148
	(3.255)	(0.234)	(0.427)	(0.006)	(0.008)
Learning Disabilities (over 18 yrs old)	21.95	7.788*	-14.79*	0.176*	0.207
	(47.064)	(3.380)	(6.169)	(0.088)	(0.122)
Sigma squared	730.5***	3.765***	12.56***	0.00257***	0.00494***
	(5.028)	(0.026)	(0.086)	(0.000)	(0.000)
Observations	42372	42372	42372	42372	42372
AIC	399995	177463	227905	-132085	-104431
BIC	400679	178164	228589	-131418	-103764
FE	yes	yes	yes	yes	yes

*Note: Number of observations = 42372. The models use the Peer group weight matrix on which influence is weighted by number of FTE GPs. Standard errors in parentheses. *p<0.05, ** p<0.01, ***p<0.001.*

Appendix 3.5. Pseudo peer effects identification using a Spatial Error Model

Other authors (e.g. Burridge et al., 2016) have tested pseudo-peer effects , i.e., if the peer effects is among the unobservables, in the error term. We estimate the Spatial Error Model (SDEM) as shown in Section 3.3:

$$y_{it} = x_{it}\beta + \sum_j c_{ij} x_{jt}\lambda + F_i + f_i + a_t + \mu_{it}$$
$$\mu_{it} = \nu \sum_j p_{ij} u_j + \upsilon_{it} \qquad (30)$$

Table A. 20: Spatial Error Durbin Model results

	QOF total points	Proportion of ACSCs emergency admissions	Population achievement	Urgent appointment	Advance appointment
Pseudo Peer Effect	0.407***	1.318***	0.465***	0.457***	0.377***
	(0.015)	(0.008)	(0.011)	(0.013)	(0.014)
GP practice own characteristics					
FTE GPs per 1000 patients	0.00066	0.00034***	-0.00014	0.000026***	0.000016***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
PMS contract	-9.438***	-0.115	-0.681***	0.00118	0.00855*
	(1.520)	(0.108)	(0.200)	(0.003)	(0.004)
Average GP Age(Salaried + Providers)	-0.0778	-0.0633*	-0.122*	-0.000705	0.00220*
	(0.396)	(0.028)	(0.052)	(0.001)	(0.001)
Urgent appointment	54.54***	-1.007***	0.257		
	(2.623)	(0.189)	(0.345)		
Advance appointment	26.09***	-0.242	1.710***		
	(1.894)	(0.135)	(0.249)		
Population achievement		-0.0065*		0.00014*	0.00069***
		(0.003)		(0.000)	(0.000)
Contextual Effects					
FTE GPs per 1000 patients	-0.000027	0.0000702	0.000127	-0.00000297	0.00000071
	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)
PMS contract	0.594	-0.0502	0.0647	-0.000577	0.00115
	(0.628)	(0.045)	(0.082)	(0.001)	(0.002)
Average GP Age(Salaried + Providers)	-0.0763	0.00966	-0.0274	0.000272	-0.000389
	(0.166)	(0.018)	(0.022)	(0.000)	(0.001)
Urgent appointment	2.449	0.376	-0.0513		
	(3.474)	(0.249)	(0.455)		
Advance appointment	-1.184	-0.191	0.301		
	(2.139)	(0.152)	(0.280)		
Population achievement		-0.00512		-0.0000712	0.0000665
		(0.004)		(0.000)	(0.000)
Observations	42372	42372	42372	42372	42372
AIC	399998	177464	227972	-131815	-104273
BIC	400682	178165	228656	-131149	-103607
FE	Yes	Yes	Yes	Yes	Yes

Note: Number of observations = 42372. The models use the Peer group weight matrix on which influence is weighted by number of FTE GPs The models also include all the other GP practice and population characteristics and contextual characteristics presented in Table 0-5 and Table 0-6. Standard errors in parentheses. *p<0.05, ** p<0.01, ***p<0.001.

Appendix 3.6. Peer effects identification with a Mundlak panel model

The use of spatial econometric models implies that we use a balanced panel, i.e., we can only include in our study GP practices that have no missing information on the quality and GP practice and population characteristics for the whole period. To understand if this strategy undermined the peer effects results we use the full unbalanced panel data and estimate the peer effect by using a strategy similar to Cornelissen et al. (2017).

In a first stage we estimate a linear panel model with time and GP practice fixed effects as below

$$y_{it} = X_{it}\beta + f_i + a_t + \varepsilon$$

Where, y_{it} is the quality of the GP practice i at time t, f_i is the GP practice fixed effect, a_t is the time effect and ε the error term.

We retrieve the GP practice fixed effects (f_i) and calculate the average fixed effect in the peer group (i.e. the 2006 PCT) without practice i *, as* $PCT\_FE_i = \frac{1}{J-1}\sum_{j=1}^{J-1} f_j, j \neq i$, where J is the total number of peer group members.

In a second stage we estimate the following Mundlak model:

$$y_{it} = X_{it}\beta + \bar{X}_i\gamma + PCT\_FE_i + a_t + \varepsilon$$

Which includes y_{it} the quality of the GP practice i at time t, the time effect a_t, the average peer group fixed effect (without $i's$ fixed effect) and the error term ε.

The descriptive statistics for quality are similar to the reported in the main text Table 3-1. The within and between variation is higher in the unbalanced panel than in the balanced panel. For example, the within variation is higher for the proportion of ACSCs emergency admissions (per 1000 patients) (17.6% of the average versus 17.2% on balanced panel) and lower for total QOF points (3.3% versus 3.12% of the average in the balanced panel). The between variation is the sum of squares of differences between the practices means and the whole-sample mean, and indicates variation across practices in quality. The between variation is also higher for ACSCs emergency admissions and lower for total QOF points (33.3% and 4% of the average, respectively).

As in the balanced panel, the average proportion of ACSCs emergency admissions was higher in 2010, the Population Achievement has its higher average in 2008 and the total QOF points and the GPPS variables had the highest averages in 2007.

Table A. 21: Descriptive statistics - quality measures

		Proportion of ACSCs emergency admissions (in 1000s patients)	Population Achievement	Total QOF points	Urgent appointment	Advance appointment
Overall	Average	12.50	79.73	959.41	83.56%	74.27%
STD	Overall	4.70	6.35	48.29	10.82%	15.81%
	Between	4.18	4.28	38.60	9.24%	13.97%
	Within	2.20	4.80	31.26	5.75%	7.43%
Percentile	5	5.31	66.64	876.77	63.00%	45.00%
	95	20.71	87.49	999.13	97.44%	96.00%
2006	Average	12.58	80.42	961.40	85.32%	74.68%
	STD	4.64	5.42	59.16	10.93%	18.97%
2007	Average	11.86	82.10	973.31	86.50%	76.94%
	STD	4.51	4.64	45.89	10.18%	17.42%
2008	Average	12.54	82.34	957.80	84.09%	75.30%
	STD	4.86	4.29	44.53	10.62%	15.19%
2009	Average	12.55	73.47	942.61	80.36%	71.26%
	STD	4.73	8.38	48.47	11.52%	15.12%
2010	Average	12.79	80.41	950.00	80.19%	71.51%
	STD	4.82	5.54	41.14	11.30%	15.03%
2011	Average	12.68	79.73	971.70	84.98%	75.96%
	STD	4.57	4.29	40.92	8.39%	11.22%

Note: These descriptive statistics include all 7954 GP practices in the 6 years unbalanced panel, so 46280 observations

The number of GP practices in each PCT varies between 9 and 140, with an average of 50.5 and a SD of 23.8 in the six years.

The descriptive statistics reported in Table 3-5 and Table 3-6 for the GP practice and population characteristics reported in Table A.18 are also similar.

In average there are less GPs per patient (615 versus 617) and less Full Time Equivalent (FTE) GPs per practice (4.2 versus 4.4). This indicates that the unbalanced panel includes smaller GP practices with less GPs (FTE) and smaller patients lists since in average a GP practice has in the unbalanced panel 6790 patients and in the balanced panel (in Table 3-6) there are 7089. The average proportion of GP salaried increased wider in the unbalanced panel between 2006 and 2011, 52% versus 45% of the balanced panel.

Table A. 22: Descriptive statistic: GP practice and population characteristics

	Overall	SD			Percentile		Average		Growth Rate from 2006 to 2011
	Average	Overall	Between	Within	5	95	2006	2011	
GP practice									
FTE GPs per 1000 patients	615.79	220.87	189.40	118.75	320.20	995.15	610.85	621.86	1.80
FTE GPs	4.24	2.94	2.85	0.72	1.00	9.76	4.14	4.38	5.86
PMS contract	0.42	0.49	0.48	0.09	0.00	1.00	0.42	0.41	-2.57
Average GP age	48.68	7.19	6.66	2.88	39.29	63.00	48.56	48.66	0.21
Proportion of Female GPs	0.39	0.27	0.25	0.10	0.00	0.80	0.36	0.41	14.06
Proportion of GPs qualified in the UK	0.69	0.38	0.37	0.09	0.00	1.00	0.69	0.69	0.30
Proportion of GPs qualified in Europe	0.05	0.13	0.13	0.05	0.00	0.33	0.05	0.05	-0.71
Proportion of GPs qualified outside Europe	0.26	0.37	0.36	0.09	0.00	1.00	0.26	0.26	-0.65
Proportion of salaried GPs	0.17	0.22	0.20	0.12	0.00	0.60	0.13	0.19	52.34
Population Characteristics									
Practice list (in 1000s)	6.790	4.026	4.012	0.390	2.030	14.030	6.642	6.964	4.86
N patients 0to4yrs (in 1000s)	0.39	0.25	0.24	0.04	0.10	0.84	0.36	0.42	14.35
N patients 5to14yrs (in 1000s)	0.77	0.47	0.47	0.05	0.20	1.63	0.78	0.78	-0.93
N patients 15to44yrs (in 1000s)	2.85	1.87	1.86	0.20	0.83	5.97	2.83	2.87	1.12
N patients 45to64yrs (in 1000s)	1.71	1.08	1.07	0.10	0.46	3.69	1.64	1.78	8.92
N patients 65to74yrs (in 1000s)	0.56	0.39	0.39	0.04	0.12	1.30	0.53	0.59	11.49
N patients 75plus yrs (in 1000s)	0.51	0.39	0.38	0.03	0.09	1.23	0.49	0.53	7.93
N male patients (in 1000s)	3.39	1.99	1.98	0.20	1.05	6.96	3.32	3.47	4.58
N female patients (in 1000s)	3.40	2.05	2.04	0.20	0.97	7.09	3.32	3.50	5.13
Prop of Patients residing in a Nursing Home	0.04	0.05	0.04	0.01	0.00	0.12	0.04	0.04	-2.96

Socioeconomic deprivation									
Population rate claiming incapacity benefit and severe disability allowance	0.05	0.02	0.02	0.01	0.02	0.10	0.06	0.05	-17.73
Education Skills and Training deprivation score	22.74	14.03	14.05	1.19	5.26	50.08	22.81	22.62	-0.83
QOF disease registers (in 100s)									
Coronary Heart Disease (CHD)	0.24	0.17	0.16	0.02	0.05	0.55	0.24	0.24	0.59
Stroke and transient ischaemic attack	0.11	0.08	0.08	0.01	0.02	0.28	0.11	0.12	13.71
Hypertension	0.90	0.58	0.57	0.08	0.23	1.98	0.84	0.96	14.83
Chronic obstructive pulmonary disease (COPD)	0.11	0.08	0.08	0.01	0.02	0.26	0.09	0.12	24.87
Hypothyroidism	0.20	0.14	0.13	0.02	0.04	0.46	0.17	0.22	28.50
Cancer	0.09	0.07	0.07	0.03	0.01	0.23	0.06	0.13	104.70
Mental Health	0.05	0.04	0.04	0.01	0.01	0.12	0.05	0.06	20.46
Asthma	0.40	0.26	0.26	0.03	0.10	0.88	0.39	0.42	7.93
Heart Failure	0.05	0.04	0.04	0.01	0.01	0.12	0.05	0.05	-4.31
Palliative Care	0.01	0.01	0.01	0.01	0.00	0.03	0.01	0.01	127.21
Dementia	0.03	0.03	0.03	0.01	0.00	0.09	0.03	0.04	40.06
Atrial Fibrillation	0.09	0.07	0.07	0.01	0.01	0.23	0.09	0.10	20.86
Diabetes Mellitus (over 17yrs old)	0.28	0.18	0.17	0.04	0.08	0.61	0.24	0.32	33.04
Epilepsy (0ver 18yrs old)	0.04	0.03	0.03	0.00	0.01	0.09	0.04	0.04	7.79
Chronic kidney disease (over 18 yrs old)	0.21	0.19	0.18	0.06	0.02	0.57	0.16	0.24	48.06
Obesity (over 16 yrs old)	0.56	0.36	0.35	0.09	0.15	1.24	0.49	0.61	23.97
Learning Disabilities (over 18 yrs old)	0.02	0.02	0.02	0.01	0.00	0.06	0.02	0.03	44.59

Note: These descriptive statistics include all 7954 GP practices in the 6 years unbalanced panel, so 46280 observations

The peer effects are positive and significant as reported in Table A.19. as in the results reported in Table 3-8, the peer effect is stronger on the proportion of ACSCs emergency admissions, however, the second stronger peer effects is not on population achievement but on the satisfaction with the ability to book an advance appointment. Other coefficients are also similar. The FTE GPs per 1000 patients are only significant on the satisfaction with the ability to book an urgent appointment and with the ability to book an advance appointment. A difference to the results of Table 3-8 is that the coefficient of the satisfaction with the ability to see an urgent appointment on the population achievement is not significant.

This specification is not entirely compatible with the proposed Bayesian social interaction game model. Instead of pure simultaneous peers effects, which we represented by $\sum_{\substack{j=1 \\ j \neq i}}^{J} p_{ij} y_j$, where J represents the total number of peer members , p_{ij} the weighted relationship between GP practice i and j and y_j the quality of GP practice j , the Mundlak model specifies the peer effects as $\sum_{\substack{j=1 \\ j \neq i}}^{J} w_{ij} f_j$ where J represents the total number of peer members , w_{ij} the peer groups membership, taking only the values 1 or 0, being 1 if GP practice i and j belong to the same peer group and f_i is the peer effect of GP practice i in the first stage. In our study we could interpret this peer measurement as the “environment” at the PCT that allowed the practices to perform better, or worst. The environment would include the promotion of meetings between GP practices senior GPs and quality comparisons. This interpretation is consistence with the literature, for example Cornelissen et al. (2017) interpreted this type of peer measurement as the skills of the workers when analysis the peer effects among wages of workers.

Table A. 23: Mundlak panel model: peer effects results

	Proportion of ACSCs emergency admissions (in 1000s patients)		Population Achievement		Total QOF points		Urgent appointment		Advance appointment	
Average Peer FE	0.502***	(0.015)	0.262***	(0.027)	0.442***	(0.032)	0.456***	(0.025)	0.483***	(0.032)
Quality :										
Population achievement	-0.0624***	(0.019)					0.0000357	(0.000)	0.000698***	(0.000)
Urgent appointment	-8.195***	(1.576)	-0.288	(0.413)	55.08***	(4.009)				
Advance appointment	-2.919**	(1.220)	1.983***	(0.282)	26.94***	(2.465)				
GP practice characteristics:										
FTE GPS per 1000 patients	-0.000758	(0.001)	-0.0000181	(0.000)	0.000375	(0.002)	0.0000234***	(0.000)	0.0000122**	(0.000)
Average GP age	-0.353*	(0.193)	-0.107	(0.071)	0.763	(0.707)	-0.00107	(0.001)	0.00189	(0.001)
Average GP age squared	0.00283	(0.002)	0.000122	(0.001)	-0.0162**	(0.007)	0.0000152	(0.000)	-0.0000144	(0.000)
Proportion of Female GPs	0.136	(0.711)	-0.232	(0.235)	3.075	(2.547)	-0.0102**	(0.004)	-0.0189***	(0.005)
Proportion of GPs qualified in Europe	-0.776	(1.379)	-0.270	(0.472)	-4.964	(5.444)	0.00206	(0.007)	0.00607	(0.010)
Proportion of GPs qualified outside Europe	1.032	(0.829)	0.295	(0.282)	4.684*	(2.794)	-0.00494	(0.004)	0.00304	(0.006)
Proportion of salaried GPs	0.128	(0.660)	-0.375*	(0.217)	-5.874**	(2.071)	-0.00301	(0.003)	-0.00421	(0.004)
Population characteristics (in 1000s):										
N patients 0to4yrs	34.15***	(4.739)	-2.449**	(1.052)	-44.06***	(7.990)	-0.136***	(0.016)	-0.103***	(0.023)
N patients 5to14yrs	2.913	(3.897)	7.699***	(0.836)	22.91***	(5.806)	-0.00616	(0.012)	-0.0740***	(0.018)
N patients 45to64yrs	5.015*	(2.811)	-0.741	(0.509)	-16.19***	(4.053)	-0.0225**	(0.008)	0.0184	(0.013)
N patients 65to74yrs	22.48***	(5.056)	-1.561*	(0.828)	-9.381	(6.381)	-0.125***	(0.014)	0.0579**	(0.023)
N patients 75plus yrs	34.00***	(6.598)	1.429	(1.463)	-11.33	(8.467)	-0.0341*	(0.018)	-0.0679**	(0.030)
N male patients	2.370	(1.441)	-1.409***	(0.306)	0.00298	(2.495)	0.0205***	(0.005)	0.00507	(0.006)
Prop of Patients residing in a Nursing Home	12.18	(12.526)	3.390	(2.207)	-5.418	(17.172)	0.0703**	(0.034)	0.0477	(0.054)

Population rate claiming incapacity benefit and severe disability allowance	-176.6***	(38.215)	-60.60***	(9.334)	180.5**	(75.500)	0.107	(0.129)	0.170	(0.201)
Education Skills and Training deprivation score	0.118	(0.074)	0.0279	(0.018)	-0.270	(0.171)	-0.00238***	(0.000)	0.000252	(0.000)
Coronary Heart Disease (CHD)	15.69	(12.578)	-14.97*	(8.784)	-31.38**	(15.917)	-0.0206	(0.028)	-0.209**	(0.065)
Stroke and transient ischaemic attack	46.77**	(17.069)	7.085	(4.586)	42.06*	(21.774)	0.0288	(0.046)	-0.0714	(0.082)
Hypertension	-2.706	(3.244)	-0.0505	(0.995)	7.364	(6.730)	-0.00750	(0.010)	-0.0378**	(0.016)
Chronic obstructive pulmonary disease (COPD)	48.80***	(11.281)	5.369**	(2.602)	-15.95	(18.861)	0.0330	(0.032)	0.0446	(0.057)
Hypothyroidism	-30.06**	(10.783)	0.599	(2.187)	-7.357	(18.166)	-0.00954	(0.027)	0.0886*	(0.048)
Cancer	17.71*	(10.141)	-9.199***	(2.472)	-65.83***	(13.171)	-0.195***	(0.026)	0.221***	(0.046)
Mental Health	-11.60	(20.131)	-6.262	(6.475)	56.87	(56.996)	0.0631	(0.084)	0.250**	(0.101)
Asthma	2.981	(4.977)	-1.164	(1.352)	23.98**	(8.594)	0.0361**	(0.015)	-0.00920	(0.025)
Heart Failure	-33.67**	(15.905)	19.72***	(3.790)	79.91***	(19.236)	-0.0557	(0.038)	0.0327	(0.076)
Palliative Care	-6.062	(15.944)	15.63***	(3.162)	89.11***	(20.608)	0.00344	(0.053)	0.0868	(0.071)
Dementia	12.53	(19.343)	4.135	(3.842)	94.27***	(27.704)	-0.0991*	(0.053)	0.294***	(0.086)
Atrial Fibrillation	75.03***	(16.488)	-6.032*	(3.300)	12.72	(22.769)	-0.0703	(0.044)	0.130*	(0.076)
Diabetes Mellitus (over 17yrs old)	21.33**	(7.598)	-2.477	(2.760)	-20.85	(24.001)	0.175***	(0.023)	0.0566	(0.035)
Epilepsy (0ver 18yrs old)	70.29**	(31.708)	20.42**	(8.788)	224.9***	(66.364)	-0.234**	(0.098)	-0.290*	(0.163)
Chronic kidney disease (over 18 yrs old)	-2.749	(2.336)	-1.257***	(0.379)	2.703	(2.806)	0.0218***	(0.006)	-0.0239**	(0.010)
Obesity (over 16 yrs old)	-3.535**	(1.509)	2.660***	(0.291)	19.49***	(2.325)	0.00843*	(0.005)	0.0330***	(0.007)
Learning Disabilities (over 18 yrs old)	23.55	(22.737)	-11.73**	(3.978)	67.64**	(30.496)	0.104*	(0.060)	0.211*	(0.111)
Average distance to nearest AE department	-9.057	(6.654)	-2.428**	(1.216)	-21.68**	(9.294)	0.0114	(0.027)	0.0302	(0.046)
Weighted average distance from patients	10.40	(13.019)	-3.182	(2.246)	-4.720	(17.751)	0.0582	(0.036)	0.0916	(0.056)

LSOA to GP practice nearest surgery										
GP practice in town less sparse area	-0.622	(0.687)	-0.253*	(0.136)	-1.319	(1.103)	0.00181	(0.003)	-0.00145	(0.005)
GP practice in town fringe sparse area	0.143	(2.135)	-0.233	(0.363)	-0.0448	(3.445)	-0.00452	(0.007)	0.0189	(0.013)
GP practice in town sparse area	-21.17**	(7.146)	-1.698**	(0.540)	2.825	(2.917)	0.0102	(0.017)	-0.0664**	(0.034)
GP practice in town hamlet less sparse area	0.863	(0.883)	0.233	(0.168)	-0.141	(1.314)	0.000756	(0.003)	0.0304***	(0.006)
GP practice in town hamlet sparse area	-1.524	(1.752)	0.0252	(0.411)	-3.081	(2.869)	-0.00331	(0.008)	0.0207*	(0.012)
Time dummies:										
2007	-5.661***	(0.281)	1.879***	(0.060)	12.42***	(0.652)	0.0135***	(0.001)	0.0177***	(0.001)
2008	-2.510***	(0.366)	2.374***	(0.085)	0.467	(0.881)	-0.00829***	(0.001)	-0.00393**	(0.002)
2009	-5.937***	(0.617)	-6.704***	(0.159)	-9.707***	(1.281)	-0.0413***	(0.002)	-0.0427***	(0.003)
2010	-5.066***	(0.658)	0.403**	(0.162)	-2.209	(1.420)	-0.0405***	(0.002)	-0.0489***	(0.003)
2011	-6.598***	(0.748)	-0.253	(0.177)	16.06***	(1.590)	0.0104***	(0.002)	-0.0110**	(0.004)
Mundlak variables										
Quality :										
Population achievement	-0.132**	(0.047)					0.00233***	(0.000)	0.00233***	(0.000)
Urgent appointments	4.576	(2.853)	4.463***	(0.742)	17.71**	(6.807)				
Advance appointment	-6.955**	(2.118)	0.477	(0.435)	21.31***	(3.584)				
GP practice characteristics:										
FTE GPS per 1000 patients	0.00587***	(0.001)	-0.000924**	(0.000)	-0.00225	(0.004)	0.0000348***	(0.000)	0.0000544***	(0.000)
Average GP age	0.311	(0.352)	0.290**	(0.116)	3.631**	(1.172)	0.00389*	(0.002)	0.000961	(0.003)
Average GP age squared	-0.00332	(0.003)	-0.00244**	(0.001)	-0.0373**	(0.012)	-0.0000284	(0.000)	0.0000105	(0.000)
Proportion of Female GPs	-0.663	(0.966)	1.214***	(0.331)	10.72**	(3.275)	-0.0144**	(0.006)	-0.0180**	(0.008)
Proportion of GPs qualified in EU	-0.253	(1.907)	-0.805	(0.608)	-6.401	(6.448)	0.00173	(0.011)	-0.0156	(0.014)

Proportion of GPs qualified outside EU	-0.794	(1.011)	0.528	(0.347)	-0.0325	(3.395)	-0.00883	(0.006)	-0.0137*	(0.008)
Proportion of salaried GPs	-0.00303	(1.189)	-1.393***	(0.356)	-6.694*	(3.420)	-0.00626	(0.006)	-0.00571	(0.009)
Population characteristics (In 1000s):										
N patients 0to4yrs	-13.44**	(6.062)	2.774**	(1.325)	62.86***	(10.486)	0.0885***	(0.023)	0.0776**	(0.035)
N patients 5to14yrs	-0.679	(4.604)	-8.403***	(0.940)	-32.75***	(6.773)	0.000983	(0.016)	-0.0196	(0.022)
N patients 45to64yrs	-7.510**	(3.191)	0.709	(0.563)	20.53***	(4.751)	0.0348***	(0.010)	0.0213	(0.016)
N patients 65to74yrs	-23.27***	(6.706)	0.109	(0.988)	-2.360	(7.655)	0.0896***	(0.020)	-0.0778**	(0.035)
N patients 75plus yrs	-5.688	(7.482)	-3.331**	(1.482)	-6.118	(8.964)	0.0642**	(0.021)	0.104**	(0.034)
N male patients	-0.333	(1.481)	0.701**	(0.329)	-6.111**	(2.913)	-0.0250***	(0.006)	0.000819	(0.007)
Prop of Patients residing in a Nursing Home	-19.57	(16.380)	-11.73***	(2.602)	-32.76	(20.707)	-0.102**	(0.048)	-0.0685	(0.078)
Population rate claiming incapacity benefit and severe disability allowance	83.25**	(41.296)	47.25***	(10.100)	-176.7**	(80.085)	-0.0144	(0.150)	-0.257	(0.206)
Education Skills and Training deprivation score	0.142*	(0.077)	-0.0348*	(0.019)	0.210	(0.185)	0.00139***	(0.000)	-0.00103**	(0.000)
Coronary Heart Disease (CHD)	86.13***	(15.363)	6.333	(8.582)	4.222	(17.912)	-0.0634*	(0.039)	0.0417	(0.075)
Stroke and transient ischaemic attack	-21.38	(22.018)	-6.667	(5.412)	-8.690	(29.454)	0.0912	(0.069)	0.275**	(0.112)
Hypertension	-5.625	(4.027)	-0.863	(1.065)	-1.019	(7.130)	-0.0180	(0.013)	-0.0172	(0.021)
Chronic obstructive pulmonary disease (COPD)	61.50***	(13.950)	-8.139**	(2.893)	-6.181	(21.902)	0.00408	(0.044)	0.00350	(0.073)
Hypothyroidism	17.96	(12.580)	3.663	(2.383)	30.95	(19.532)	0.0228	(0.036)	-0.160**	(0.064)
Cancer	-44.32**	(17.078)	15.59***	(2.888)	120.1***	(18.839)	0.305***	(0.051)	-0.0482	(0.096)
Mental Health	81.52***	(24.135)	-8.119	(6.951)	14.65	(60.394)	-0.173*	(0.100)	-0.629***	(0.132)
Asthma	6.293	(6.397)	1.673	(1.472)	-11.12	(9.648)	0.0166	(0.020)	0.136***	(0.032)
Heart Failure	-9.681	(25.074)	-19.65***	(4.551)	-75.71**	(26.620)	-0.0439	(0.071)	0.0163	(0.122)
Palliative Care	-7.304	(36.074)	1.780	(5.611)	81.70*	(47.937)	0.0898	(0.136)	-0.160	(0.245)
Dementia	-27.62	(29.598)	0.499	(5.220)	-40.31	(37.545)	0.120	(0.094)	-0.0384	(0.159)

Atrial Fibrillation	-86.70***	(24.955)	18.29***	(4.305)	52.71*	(29.386)	0.125*	(0.075)	-0.155	(0.128)
Diabetes Mellitus (over 17yrs old)	25.89**	(8.903)	5.591*	(2.922)	24.05	(25.316)	-0.292***	(0.031)	-0.374***	(0.048)
Epilepsy (0ver 18yrs old)	318.2***	(43.302)	-29.02**	(9.891)	-305.3***	(75.625)	0.280*	(0.147)	0.498**	(0.240)
Chronic kidney disease (over 18 yrs old)	-2.872	(3.584)	4.656***	(0.560)	10.76**	(3.881)	-0.00321	(0.011)	0.0628***	(0.018)
Obesity (over 16 yrs old)	2.004	(2.578)	1.262**	(0.421)	-2.606	(2.995)	0.0126	(0.008)	0.00419	(0.013)
Learning Disabilities (over 18 yrs old)	-35.94	(35.669)	25.68***	(5.119)	-2.094	(40.487)	0.125	(0.093)	-0.183	(0.172)
Average distance to nearest AE department	omitted because it does vary over time									
Weighted average distance from patients LSOA to GP practice nearest surgery	-9.029	(13.044)	2.609	(2.242)	4.070	(17.762)	-0.0443	(0.036)	-0.0672	(0.056)
GP practice in town less sparse area	omitted because it does vary over time									
GP practice in town fringe sparse area	omitted because it does vary over time									
GP practice in town sparse area	omitted because it does vary over time									
GP practice in town hamlet less sparse area	omitted because it does vary over time									
GP practice in town hamlet sparse area	omitted because it does vary over time									
Constant	28.84***	(8.300)	75.29***	(2.360)	765.6***	(23.608)	0.564***	(0.052)	0.422***	(0.069)
Observations	46280		46280		46280		46280		46280	
R2 – overall	0.862		0.315		0.227		0.235		0.233	
R2 – between	0.912		0.195		0.278		0.249		0.272	
R2 – within	0.151		0.398		0.153		0.201		0.102	

Appendix 3.7. Contextual demand characteristics

Table A. 24: Contextual demand characteristics (using the 5km contextual weight matrix)

	Overall	STD			Percentile		Average	
	Average	Overall	Between	Within	5	95	2006	2011
Practice list (in 1000s)	6.77	2.82	2.81	0.22	0	11.46	6.61	6.92
N patients 0to4yrs (in 1000s)	0.39	0.16	0.16	0.03	0	0.66	0.37	0.42
N patients 5to14yrs (in 1000s)	0.77	0.33	0.33	0.03	0	1.33	0.78	0.77
N patients 15to44yrs (in 1000s)	2.90	1.19	1.18	0.10	0	4.74	2.87	2.91
N patients 45to64yrs (in 1000s)	1.67	0.78	0.78	0.07	0	3.05	1.60	1.74
N patients 65to74yrs (in 1000s)	0.54	0.29	0.29	0.03	0	1.06	0.52	0.57
N patients 75plus yrs (in 1000s)	0.50	0.29	0.29	0.02	0	1.00	0.48	0.52
N male patients (in 1000s)	3.38	1.40	1.39	0.11	0	5.68	3.30	3.45
N female patients (in 1000s)	3.39	1.43	1.42	0.11	0	5.78	3.31	3.47
Prop of Patients residing in a Nursing Home	0.04	0.03	0.03	0.01	0	0.09	0.04	0.04
Socioeconomic deprivation								
Population rate claiming incapacity benefit and severe disability allowance	0.05	0.02	0.02	0.01	0	0.09	0.06	0.05
Education Skills and Training deprivation score	22.15	12.00	11.97	0.90	0	43.46	22.31	22.02
QOF disease registers (in 100s)								
Coronary Heart Disease (CHD)	0.23	0.12	0.12	0.01	0	0.44	0.23	0.23
Stroke and transient ischaemic attack	0.11	0.06	0.06	0.01	0	0.22	0.11	0.12
Hypertension	0.89	0.42	0.41	0.05	0	1.61	0.82	0.94
Chronic obstructive pulmonary disease (COPD)	0.11	0.06	0.06	0.01	0	0.20	0.09	0.12
Hypothyroidism	0.19	0.10	0.10	0.02	0	0.37	0.17	0.21
Cancer	0.09	0.05	0.05	0.02	0	0.19	0.06	0.12
Mental Health	0.05	0.02	0.02	0.00	0	0.09	0.05	0.06
Asthma	0.40	0.19	0.18	0.02	0	0.71	0.38	0.41
Heart Failure	0.05	0.03	0.03	0.00	0	0.10	0.05	0.05
Palliative Care	0.01	0.01	0.01	0.01	0	0.02	0.01	0.01
Dementia	0.03	0.02	0.02	0.01	0	0.06	0.03	0.04
Atrial Fibrillation	0.09	0.06	0.05	0.01	0	0.19	0.08	0.10
Diabetes Mellitus (over 17yrs old)	0.28	0.12	0.12	0.03	0	0.49	0.24	0.32
Epilepsy (0ver 18yrs old)	0.04	0.02	0.02	0.00	0	0.08	0.04	0.04
Chronic kidney disease (over 18 yrs old)	0.21	0.14	0.13	0.05	0	0.45	0.16	0.23
Obesity (over 16 yrs old)	0.55	0.26	0.25	0.06	0	0.99	0.49	0.61
Learning Disabilities (over 18 yrs old)	0.02	0.01	0.01	0.00	0	0.05	0.02	0.03

Appendix 3.8. Spatial Durbin Model with wider contextual and without the 378 practices that do not have another GP practice within 5km

Table A. 25: Peer effects models - using a wider contextual effects weight matrix

	Total QOF points	Proportion of ACSCs emergency admissions (in 1000s of patients)	Population achievement	Urgent appointment	Advance appointment
Peer Effect	0.391***	0.683***	0.449***	0.420***	0.358***
	(0.015)	(0.007)	(0.011)	(0.013)	(0.014)
GP practice own characteristics					
FTE GPs per 1000 patients	0.000963	0.000361***	-0.000121	0.0000248***	0.0000149***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
PMS contract	-9.708***	-0.124	-0.755***	0.00146	0.00959*
	(1.511)	(0.108)	(0.198)	(0.003)	(0.004)
Average GP Age	-0.125	-0.0568*	-0.129*	-0.000423	0.00178
	(0.397)	(0.028)	(0.052)	(0.001)	(0.001)
Urgent appointment	53.62***	-0.945***	0.236		
	(2.631)	(0.189)	(0.345)		
Advance appointment	25.40***	-0.356**	1.741***		
	(1.895)	(0.136)	(0.248)		
Population achievement		-0.00561*		0.000133	0.000687***
		(0.003)		(0.000)	(0.000)
Contextual characteristics					
FTE GPs per 1000 patients	0.000583	-0.00170***	-0.000747	0.00000167	0.0000139
	(0.004)	(0.000)	(0.001)	(0.000)	(0.000)
PMS contract	-3.353	0.726*	0.0458	0.0111	-0.0212
	(4.699)	(0.337)	(0.616)	(0.009)	(0.012)
Average GP Age	-2.685	0.0844	-0.131	-0.00789*	0.00439
	(1.670)	(0.120)	(0.219)	(0.003)	(0.004)
Urgent appointment	5.187	0.199	-2.560*		
	(8.180)	(0.587)	(1.070)		
Adavance appointment	2.789	-0.537	0.927		
	(5.738)	(0.413)	(0.752)		
Population achievement		-0.00247		-0.000450*	0.000311
		(0.008)		(0.000)	(0.000)
Observations	42372	42372	42372	42372	42372
AIC	399993	177432	227892	-132129	-104442
BIC	400677	178133	228576	-131463	-103776
FE	Yes	Yes	Yes	Yes	Yes

Note: Number of observations = 42372. The models use the Peer group weight matrix on which influence is weighted by number of FTE GPs The models also include all the other GP practice and population characteristics and contextual characteristics presented in Table 3-5 and Table 3-6.
Standard errors in parentheses. *p<0.05, ** p<0.01, ***p<0.001.

Table A. 26: Peer effects models - dropping the 378 practices that do not have another GP practice within 5km

	Total QOF points	Prop of ACSCs emergency admissions (in 1000s)	Population achievement	Urgent appointment	Advance appointment
Peer Effect	0.386***	0.681***	0.455***	0.405***	0.356***
	(0.015)	(0.007)	(0.011)	(0.013)	(0.014)
GP practice own characteristics					
FTE GPs per 1000 patients	0.00126	0.000383***	-0.000119	0.0000248***	0.0000133***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
PMS contract	-10.01***	-0.103	-0.747***	0.00292	0.0109**
	(1.548)	(0.111)	(0.202)	(0.003)	(0.004)
Average GP Age	-0.202	-0.0413	-0.127*	-0.000510	0.00166
	(0.407)	(0.029)	(0.053)	(0.001)	(0.001)
Urgent appointment	53.78***	-0.925***	0.136		
	(2.708)	(0.193)	(0.353)		
Advance appointment	25.49***	-0.423**	1.699***		
	(1.960)	(0.140)	(0.255)		
Population achievement		-0.00686*		0.000110	0.000671***
		(0.003)		(0.000)	(0.000)
Contextual characteristics					
FTE GPs per 1000 patients	0.00196	-0.000795***	-0.000440	0.00000306	0.0000161*
	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)
PMS contract	-0.101	0.245	0.437	0.00109	-0.0332***
	(3.286)	(0.235)	(0.428)	(0.006)	(0.008)
Average GP Age	-1.673	0.0532	-0.109	-0.00511**	0.00144
	(1.056)	(0.075)	(0.138)	(0.002)	(0.003)
Urgent appointment	2.584	0.133	-0.733		
	(5.696)	(0.407)	(0.742)		
Advance appointment	4.130	-0.0221	0.669		
	(3.836)	(0.274)	(0.500)		
Population achievement		0.00237		-0.000198	0.000117
		(0.005)		(0.000)	(0.000)
Observations	40104	40104	40104	40104	40104
AIC	379596.2	168578.1	216245.1	-124159	-98494
BIC	380275.5	169274.7	216924.5	-123497	-97831.9
FE	Yes	Yes	Yes	Yes	Yes

Note: Number of observations = 42372. The models use the Peer group weight matrix on which influence is weighted by number of FTE GPs The models also include all the other public and contextual characteristics presented in Table 3-5 and Table 3-6.
Standard errors in parentheses. *p<0.05, ** p<0.01, ***p<0.001.

Appendix 3.9. Spatial Autoregressive Model

The SAR model coefficients on GP practice characteristics are also similar as reported in Table A.23

Table A. 27: Peer effect models without contextual effects - a SAR specification using a peers group weight matrix which influence power is proxied by number of FTE GPs

	Total QOF points	Proportion of ACSCs emergency admissions (in 1000s of patients)	Population achievement	Urgent appointment	Advance appointment
Peer Effect	0.398***	0.688***	0.459***	0.454***	0.378***
	(0.014)	(0.007)	(0.011)	(0.012)	(0.013)
GP practice own characteristics					
FTE GPs per 1000 patients	0.000778	0.000304***	-0.000140	0.0000257***	0.0000148***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
PMS contract	-9.880***	-0.0616	-0.748***	0.00263	0.00758*
	(1.486)	(0.107)	(0.195)	(0.003)	(0.004)
Average GP Age	-0.0511	-0.0547	-0.126*	-0.000714	0.00197
	(0.396)	(0.028)	(0.052)	(0.001)	(0.001)
Urgent appointment	53.47***	-0.908***	0.0143		
	(2.585)	(0.186)	(0.339)		
Advance appointment	25.80***	-0.370**	1.777***		
	(1.873)	(0.135)	(0.246)		
Population achievement		-0.00579*		0.0000885	0.000686***
		(0.003)		(0.000)	(0.000)
Observations	42372	42372	42372	42372	42372
AIC	399979	177486	227898	-131984	-104344
BIC	400351	177866	228270	-131620	-103980
FE	Yes	Yes	Yes	Yes	Yes

Note: Number of observations = 42372. The models also include all the other GP practice and population characteristics and contextual characteristics presented in Table 3-5 and Table 3-6.
Standard errors in parentheses. *p<0.05, ** p<0.01, ***p<0.001.

The AIC and BIC are smaller for SAR models (with the exception of the proportion of ACSCs emergency admissions model). This is likely due to the extensive number of variables in the contextual set that are not significant.

Appendix 4.

Appendix 4.1. Descriptive statistics

Table A. 28: Covariate summary statistics (2005/6-2012/13)

		Mean	SD	Min	Max	Obs
Local (MSOA) covariates						
Total population ('000s)	Overall	7.99	1.60	3.50	17.08	64676
	Between		1.57	4.70	15.81	8351
	Within		0.30	5.17	11.80	$\bar{T}$: 7.74
% of males d 0-15	Overall	9.78	2.04	1.14	19.39	64676
	Between		2.01	1.64	19.05	8351
	Within		0.37	7.40	13.31	$\bar{T}$: 7.74
% of males 16-24	Overall	6.20	2.82	2.45	35.61	64676
	Between		2.78	2.73	34.35	8351
	Within		0.44	0.88	11.82	$\bar{T}$: 7.74
% of males 50-64	Overall	8.49	1.93	1.23	14.50	64676
	Between		1.92	1.43	13.96	8351
	Within		0.28	6.74	10.57	$\bar{T}$: 7.74
% of males at least 65	Overall	6.78	2.37	0.80	20.79	64676
	Between		2.33	1.07	18.80	8351
	Within		0.41	4.38	9.06	$\bar{T}$: 7.74
% of females 0-15	Overall	9.32	1.97	0.92	19.10	64676
	Between		1.94	1.50	18.78	8351
	Within		0.35	7.17	13.21	$\bar{T}$: 7.74
% of females 16-24	Overall	6.15	2.89	2.12	42.59	64676
	Between		2.85	2.27	39.24	8351
	Within		0.43	-0.75	12.39	$\bar{T}$: 7.74
% of females 25-49	Overall	17.82	2.75	4.53	32.62	64676
	Between		2.73	5.02	31.09	8351
	Within		0.43	13.37	20.95	$\bar{T}$: 7.74
% of females 50-64	Overall	6.57	1.96	0.95	14.22	64676
	Between		1.48	1.17	10.77	8351
	Within		1.29	4.41	11.08	$\bar{T}$: 7.74
% of females at least 65	Overall	10.91	3.86	0.69	33.16	64676
	Between		3.68	1.35	31.52	8351
	Within		1.19	6.22	13.94	$\bar{T}$: 7.74
% of residents on benefits	Overall	5.16	2.46	0.28	17.76	64676
	Between		2.43	0.40	17.36	8351
	Within		0.31	3.06	9.59	$\bar{T}$: 7.74
Income IMD score	Overall	17.52	11.04	0.73	66.91	64676
	Between		10.98	1.01	60.41	8351
Practice plus 5 nearest rivals						

	Within		1.49	-0.38	32.04	$\bar{T}$: 7.74
Nursing home patients ('000s)	Overall	5.21	3.40	0.00	73.44	64676
	Between		1.84	0.00	14.79	8351
	Within		2.87	-7.60	65.60	$\bar{T}$: 7.74
CHD prevalence (%)	Overall	3.51	1.00	0.32	11.28	64676
	Between		0.69	1.28	6.31	8351
	Within		0.72	0.40	10.00	$\bar{T}$: 7.74
Stroke prevalene (%)	Overall	1.66	0.49	0.10	5.73	64676
	Between		0.34	0.65	2.75	8351
	Within		0.36	0.13	5.15	$\bar{T}$: 7.74
Hypertension prevalence (%)	Overall	13.19	2.55	1.81	43.95	64676
	Between		1.64	6.37	21.94	8351
	Within		1.95	2.77	39.99	$\bar{T}$: 7.74
Diabetes prevalence (%)	Overall	4.28	0.97	0.94	13.61	64676
	Between		0.65	2.08	7.42	8351
	Within		0.72	0.45	12.51	$\bar{T}$: 7.74
Epilepsy prevalence (%)	Overall	0.61	0.14	0.06	1.59	64676
	Between		0.10	0.28	1.19	8351
	Within		0.10	0.15	1.47	$\bar{T}$: 7.74
COPD prevalence (%)	Overall	1.59	0.62	0.06	7.24	64676
	Between		0.43	0.58	4.44	8351
	Within		0.45	-0.32	6.58	$\bar{T}$: 7.74
Hypothyroidism prevalence (%)	Overall	2.84	0.79	0.18	7.29	64676
	Between		0.54	0.91	6.06	8351
	Within		0.57	0.09	6.73	$\bar{T}$: 7.74
Cancer prevalence (%)	Overall	1.31	0.55	0.10	4.29	64676
	Between		0.45	0.35	2.79	8351
	Within		0.31	-0.50	3.40	7.744701
Mental illness prevalence (%)	Overall	0.77	0.25	0.14	2.50	64676
	Between		0.16	0.29	1.61	8351
	Within		0.20	-0.11	2.25	7.744701
Asthma prevalence (%)	Overall	5.90	0.89	0.66	13.50	64676
	Between		0.61	3.27	9.63	8351
	Within		0.65	1.32	11.96	7.744701

Notes. $\bar{T}$ average number of years of observations per practice. The MSOA is where the practice main branch located.

Appendix 4.2. Correlations between quality and competition measures

Table A. 29: Quality and competition measures: correlations 2009/12-2012/13

	PA clinical	RA clinical	QOF points	ACSCs emerg adm	Op hrs sat	Overall sat	Recommend	N rivals GPs
RA clinical	0.8270	1						
QOF points	0.6010	0.7057	1					
ACSCs Emerg adm	-0.0335	-0.0130	-0.0395	1				
Op hrs sat	0.1528	0.1483	0.2337	0.1197	1			
Overal sat	0.1499	0.1670	0.2600	0.0134	0.6631	1		
Recommend	0.1308	0.1546	0.2821	-0.0858	0.5781	0.9039	1	
N rival GPs	-0.0454	-0.0486	-0.1121	-0.0194	-0.0634	-0.1848	-0.2051	1
N rival practices	-0.0371	-0.0638	-0.1585	0.0138	-0.0940	-0.2732	-0.2943	0.8512

Notes. N rival GPs: number of full-time equivalent GPs in other practices with at least one branch within 1km of a branch of the practice. *N rival practices*: number of other practices with at least one branch within 1km of a branch of the practice.

Appendix 4.3. Baseline model – full results

Table A. 30: Full results from baseline model (Table 3, Panel D)

	PA clinical	RA clinical	QOF points	ACSCs emerg adm	Open hrs sat	Care sat	Recommend
	2005-12	2005-12	2005-12	2005-12	2006-12	2008-12	2009-12
N rival GPs	0.053***	0.028	0.011	-0.008	0.111***	0.090***	0.080**
	[0.015]	[0.016]	[0.019]	[0.012]	[0.017]	[0.018]	[0.028]
Tot Pop MSOA	-0.267*	-0.364**	-0.417***	-0.236**	0.551***	-0.481*	-0.648*
	[0.108]	[0.112]	[0.120]	[0.074]	[0.150]	[0.194]	[0.316]
Males 0-15	0.009	-0.104	-0.090	-0.003	0.193*	-0.153	-0.282
	[0.071]	[0.075]	[0.082]	[0.052]	[0.085]	[0.098]	[0.171]
Males 16-24	-0.120*	-0.112	-0.131	0.024	0.128	-0.054	-0.002
	[0.060]	[0.063]	[0.068]	[0.044]	[0.073]	[0.082]	[0.130]
Males 50-64	0.095	-0.073	0.083	-0.206**	0.337**	-0.162	-0.437*
	[0.088]	[0.094]	[0.101]	[0.063]	[0.108]	[0.117]	[0.202]
Males 65plus	-0.522***	-0.477***	-0.211*	0.123	0.219	-0.113	-0.443*
	[0.091]	[0.095]	[0.104]	[0.064]	[0.115]	[0.126]	[0.218]
Females 0-15	-0.166*	-0.161*	-0.188*	0.109*	-0.054	-0.240*	-0.373*
	[0.072]	[0.077]	[0.086]	[0.054]	[0.090]	[0.105]	[0.182]
Females 16-24	0.103	0.089	0.115	0.043	0.106	-0.108	-0.302
	[0.064]	[0.069]	[0.076]	[0.046]	[0.078]	[0.090]	[0.158]
Females 25-49	0.025	-0.009	-0.100	0.131*	0.277**	-0.079	-0.334
	[0.080]	[0.087]	[0.097]	[0.057]	[0.095]	[0.105]	[0.176]
Females 50-64	0.069	0.038	-0.346***	0.174**	0.408***	-0.190	-0.265
	[0.081]	[0.086]	[0.096]	[0.057]	[0.100]	[0.107]	[0.182]
Females 65plus	-0.098	-0.211**	-0.135	0.110*	0.448***	-0.123	-0.040
	[0.074]	[0.078]	[0.086]	[0.050]	[0.092]	[0.102]	[0.179]
Benefits MSOA	-0.382***	-0.151	-0.146	0.256***	-0.317**	-0.353**	-0.394
	[0.095]	[0.104]	[0.125]	[0.066]	[0.108]	[0.134]	[0.235]
IMD MSOA	0.013	-0.014	0.005	0.036**	-0.023	-0.047*	0.058
	[0.014]	[0.016]	[0.016]	[0.011]	[0.024]	[0.021]	[0.444]
Nursing home	0.004	0.002	0.002	-0.002	-0.003	0.002	-0.001
	[0.005]	[0.005]	[0.006]	[0.005]	[0.007]	[0.007]	[0.011]
CHDPrev	0.068	0.081*	0.040	0.004	0.011	0.069	-0.040
	[0.038]	[0.040]	[0.047]	[0.036]	[0.051]	[0.053]	[0.084]
StrokePrev	-0.018	-0.059	-0.083	0.106	-0.033	-0.070	0.108
	[0.076]	[0.080]	[0.094]	[0.074]	[0.103]	[0.104]	[0.167]
HyperPrev	-0.022	-0.036**	-0.037*	-0.000	0.026	0.005	0.021

	[0.012]	[0.013]	[0.015]	[0.011]	[0.016]	[0.017]	[0.027]
DiabetesPrev	-0.010	0.015	0.030	-0.023	-0.009	0.023	0.095
	[0.024]	[0.026]	[0.029]	[0.022]	[0.032]	[0.032]	[0.050]
EpiPrev	0.072	0.090	0.017	-0.073	0.080	-0.265	-0.186
	[0.175]	[0.184]	[0.214]	[0.167]	[0.235]	[0.238]	[0.382]
COPDPrev	-0.090*	-0.073	-0.025	-0.010	-0.001	0.004	-0.005
	[0.045]	[0.047]	[0.054]	[0.040]	[0.058]	[0.057]	[0.093]
HypoPrev	0.006	-0.014	-0.006	-0.006	-0.027	-0.011	-0.075
	[0.033]	[0.035]	[0.041]	[0.031]	[0.044]	[0.046]	[0.071]
CancerPrev	0.032	0.109	0.140	-0.022	-0.069	-0.084	-0.029
	[0.068]	[0.072]	[0.082]	[0.061]	[0.090]	[0.092]	[0.146]
MHPrev	0.041	0.057	-0.007	0.073	0.030	0.008	-0.032
	[0.069]	[0.074]	[0.087]	[0.063]	[0.091]	[0.089]	[0.145]
AsthmaPrev	0.010	-0.005	0.010	-0.018	-0.017	0.021	-0.002
	[0.022]	[0.023]	[0.026]	[0.020]	[0.028]	[0.029]	[0.046]
year2006	0.324***	1.853***	-0.816***	-0.393***			
	[0.054]	[0.058]	[0.064]	[0.045]			
year2007	1.596***	2.333***	0.431***	-0.654***	-1.811***		
	[0.066]	[0.072]	[0.074]	[0.051]	[0.049]		
year2008	1.747***	2.229***	-0.999***	-0.442***	-2.641***		
	[0.078]	[0.086]	[0.089]	[0.061]	[0.071]		
year2009	1.194***	1.660***	-2.433***	-0.524***	-2.148***	-0.436***	
	[0.090]	[0.098]	[0.105]	[0.067]	[0.094]	[0.048]	
year2010	1.670***	2.003***	-1.684***	-0.259***	-3.034***	-0.665***	-0.218**
	[0.106]	[0.115]	[0.123]	[0.078]	[0.114]	[0.073]	[0.073]
year2011	1.750***	1.855***	1.184***	-0.670***	-0.551**	-0.847***	-0.689**
	[0.157]	[0.164]	[0.188]	[0.124]	[0.196]	[0.181]	[0.249]
year2012	1.297***	1.607***	0.411*	-0.837***	-1.650***	-1.857***	-2.137***
	[0.165]	[0.174]	[0.201]	[0.131]	[0.207]	[0.192]	[0.265]
Constant	85.91***	96.13***	109.45***	7.82**	61.05***	107.47***	112.03***
	[4.189]	[4.527]	[5.091]	[2.922]	[5.102]	[5.807]	[12.518]
Observations	63,968	63,968	63,970	64,000	55,913	39,684	31,555
Practices	8,329	8,329	8,329	8,348	8,279	8,103	8,024
Within R^2	0.0485	0.0542	0.0783	0.0101	0.0822	0.0791	0.104

Notes. Competition measures: *N rival GPs*: number of full-time equivalent GPs in other practices with at least one branch within 1km of a branch of the practice. All models include practice fixed effects. Square brackets: robust SEs clustered at practice level. *** p<0.001, ** p<0.01, * p<0.05

Appendix 4.4. EAPMC graphs

Figure A. 16: Quality variables in EAPMC versus non-EAPMC PCTS

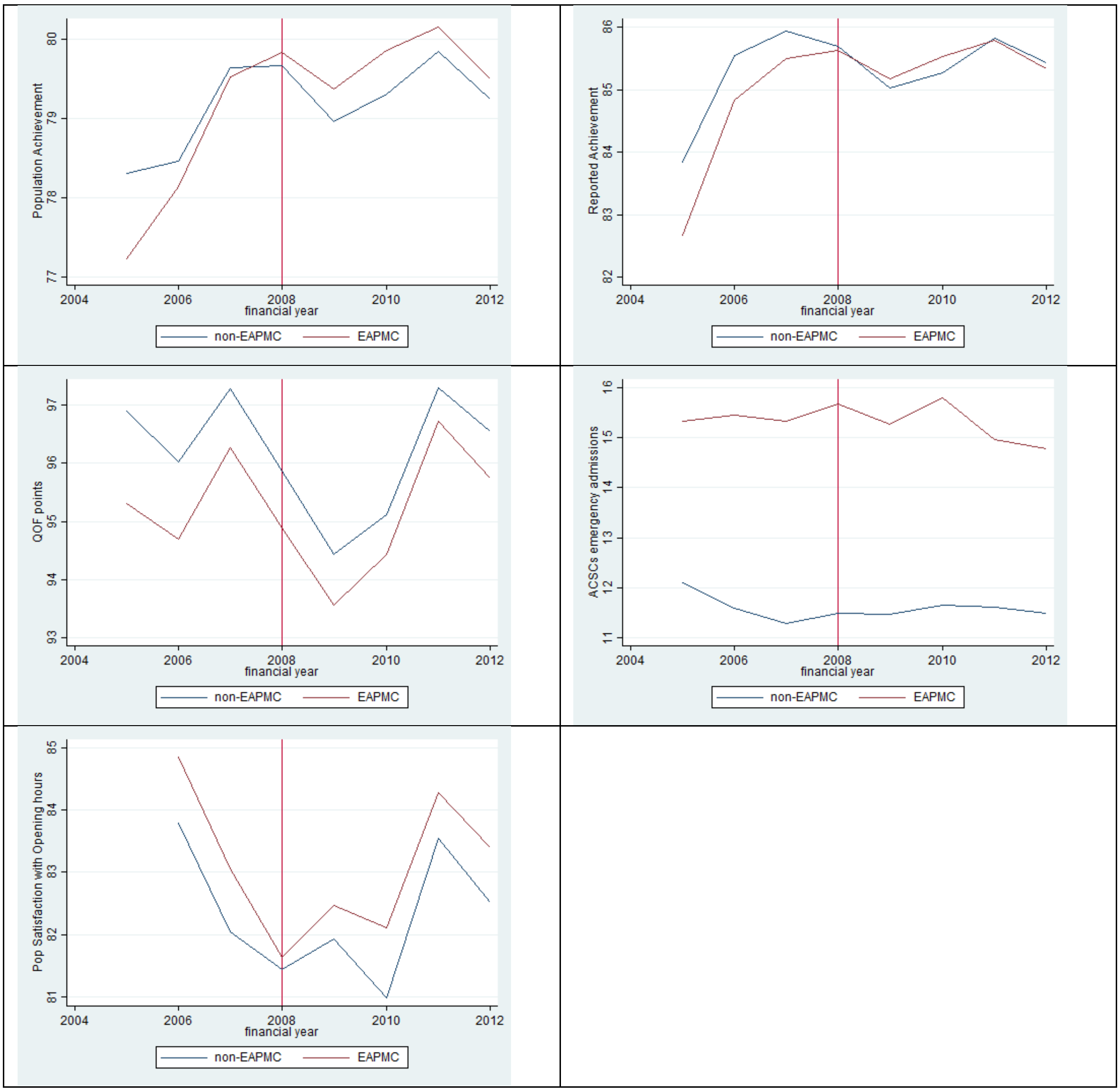
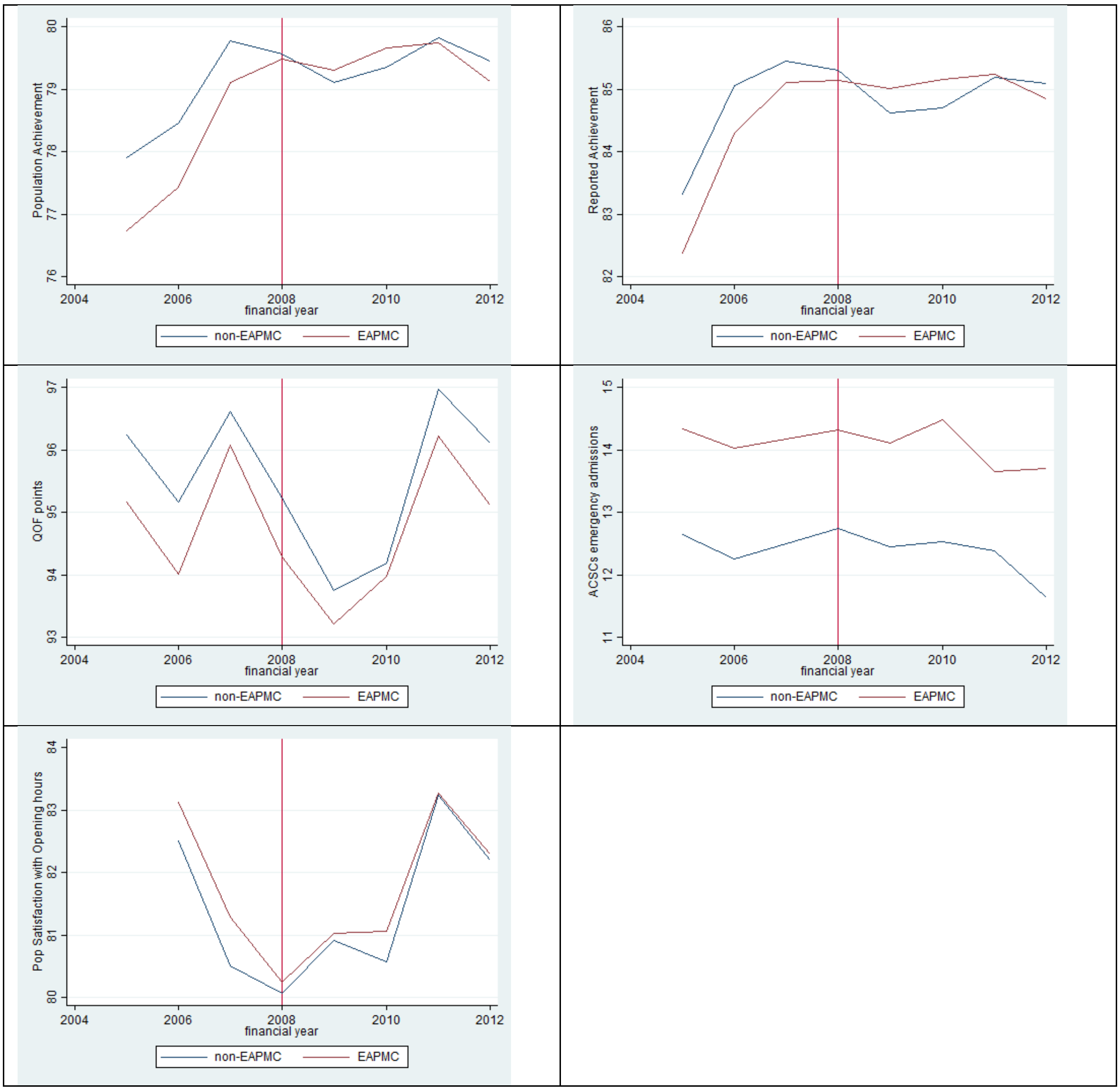


Figure A. 17: EAPMC versus non-EAPMC within 1km of an EAPMC PCT border



Appendix 4.5. Impact of EAPMC on number of FTE GPs in rival practices

Table A. 31: Changes in number of GPs in rival practices in EAPMC and non EAPMC PCTs

	N FTE GPs in rival practices
EAPMC	0.809***
	[0.118]
After	0.258**
	[0.094]
After*EAPMC	0.430*
	[0.175]
Constant	8.346***
	[0.064]
Observations	48,276
R-squared	0.003

Notes. FTE: full time equivalent. EAPMC: practice is in an EAPMC PCT. Before: 2005/6, 2006/7, 2007/8. After: 2009/10, 2010/11, 2011/12. Robust standard errors in brackets. *** p<0.001, ** p<0.01, * p<0.05

Table A. 32: Robustness test: lagged effect of competition

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	PA clinical	**RA clinical**	**QOF points**	**ACSC emerg adm**	**Open hrs sat**	**Care sat**	**Recommend**
	2006-12	2006-12	2006-12	2006-12	2006-12	2008-12	2009-12
Panel A: lagged competition							
N rival GPs lagged	0.048**	0.019	0.011	-0.003	0.041*	0.076***	0.094***
	[0.015]	[0.016]	[0.021]	[0.013]	[0.017]	[0.020]	[0.028]
Within R^2	0.0362	0.0150	0.0869	0.00716	0.0812	0.0787	0.105
Obs	55,672	55,672	55,674	55,657	55,890	39,677	31,549
Practices	8,249	8,249	8,249	8,270	8,278	8,102	8,023
Panel B: current competition							
N rival GPs	0.030*	0.014	0.011	-0.022	0.111***	0.090***	0.080**
	[0.015]	[0.017]	[0.021]	[0.013]	[0.017]	[0.018]	[0.028]
Within R^2	0.0359	0.0150	0.0869	0.00732	0.0822	0.0791	0.104
Obs	55,694	55,694	55,696	55,673	55,913	39,684	31,555
Practices	8,251	8,251	8,251	8,270	8,279	8,103	8,024

Notes: Competition measures: *N rival GPs* or *N rival GPs lagged*: number of full-time equivalent GPs in other practices with at least one branch within 1km of a branch of the practice in current or previous year. All models include practice fixed effects, year effects, local population (total population and proportions of population in age/gender groups in the MSOA in which the practice is located), local morbidity (prevalence of QOF conditions averaged across practice and its 5 nearest practices, proportion of patients in nursing homes averaged across practice and its five nearest practices, proportion of patients on invalidity or incapacity benefit in the MSOA in which the practice is located). Square brackets: robust SEs clustered at practice level. *** p<0.001, ** p<0.01, * p<0.05

Table A. 33: Robustness test: numbers of rival GPs and numbers of rival practices

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	PA clinical	**RA clinical**	**QOF points**	**ACSC emerg adm**	**Open hrs sat**	**Care sat**	**Recommend**
	2006-12	2006-12	2006-12	2006-12	2006-12	2008-12	2009-12
N rival GPs	0.057***	0.032	0.015	-0.016	0.114***	0.086***	0.080**
	[0.015]	[0.016]	[0.019]	[0.012]	[0.017]	[0.018]	[0.028]
N rival practices	-0.177*	-0.170*	-0.182*	0.307***	-0.110	0.119	0.005
	[0.076]	[0.082]	[0.091]	[0.062]	[0.089]	[0.096]	[0.150]
Within R^2	0.0487	0.0544	0.0785	0.0110	0.0822	0.0792	0.104
Obs	63,968	63,968	63,970	64,000	55,913	39,684	31,555
Practices	8,329	8,329	8,329	8,348	8,279	8,103	8,024

Notes: *N rival GPs*: number of full-time equivalent GPs in other practices with at least one branch within 1km of a branch of the practice. *N rival practices*: number of other practices with at least one branch within 1km of a branch of the practice. All models include practice fixed effects, year effects, local population (total population and proportions of population in age/gender groups in the MSOA in which the practice is located), local morbidity (prevalence of QOF conditions averaged across practice and its 5 nearest practices, proportion of patients in nursing homes averaged across practice and its five nearest practices, proportion of patients on invalidity or incapacity benefit in the MSOA in which the practice is located). Square brackets: robust SEs clustered at practice level. *** p<0.001, ** p<0.01, * p<0.05

Table A. 34: Robustness test: numbers of rival and own GPs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	PA clinical	**RA clinical**	**QOF points**	**ACSC emerg adm**	**Open hrs sat**	**Care sat**	**Recommend**
	2006-12	2006-12	2006-12	2006-12	2006-12	2008-12	2009-12
N rival GPs	0.054***	0.028	0.009	-0.006	0.109***	0.090***	0.076**
	[0.015]	[0.016]	[0.019]	[0.012]	[0.017]	[0.018]	[0.028]
N own GPs	-0.001	0.018	0.076**	-0.091***	0.073*	0.181***	0.297***
	[0.027]	[0.028]	[0.028]	[0.020]	[0.032]	[0.036]	[0.057]
Within R^2	0.0478	0.0540	0.0816	0.0106	0.0824	0.0818	0.108
Obs	0.048	0.054	0.082	0.011	0.082	0.082	0.108
Practices	8,314	8,314	8,314	8,327	8,259	8,091	8,011

Notes: *N rival GPs*: number of full-time equivalent GPs in other practices with at least one branch within 1km of a branch of the practice. *N own GPs*: number of FTE GPs in own practice. All models include practice fixed effects, year effects, local population (total population and proportions of population in age/gender groups in the MSOA in which the practice is located), local morbidity (prevalence of QOF conditions averaged across practice and its 5 nearest practices, proportion of patients in nursing homes averaged across practice and its five nearest practices, proportion of patients on invalidity or incapacity benefit in the MSOA in which the practice is located). Square brackets: robust SEs clustered at practice level. *** p<0.001, ** p<0.01, * p<0.05

Table A. 35: Robustness test: allowing for year*PCT effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	PA clinical	**RA clinical**	**QOF points**	**ACSC emerg adm**	**Open hrs sat**	**Care sat**	**Recommend**
	2005-12	2005-12	2005-12	2005-12	2006-12	2008-12	2009-12
N rival GPs	0.005	-0.008	-0.011	-0.007	0.071***	0.055**	0.040
	[0.016]	[0.018]	[0.020]	[0.012]	[0.018]	[0.019]	[0.030]
Within R^2	0.109	0.102	0.132	0.166	0.140	0.111	0.131
Obs	63,438	63,438	63,440	63,556	55,475	39,390	31,325
Practices	8,215	8,215	8,215	8,216	8,203	8,039	7,962

Notes: Competition measures: *N GPs*: number of full-time equivalent GPs in other practices with at least one branch within 1km of a branch of the practice. All models include practice fixed effects, year*PCT dummies, local population (total population and proportions of population in age/gender groups in the MSOA in which the practice is located), local morbidity (prevalence of QOF conditions averaged across practice and its 5 nearest practices, proportion of patients in nursing homes averaged across practice and its five nearest practices, proportion of patients on invalidity or incapacity benefit in the MSOA in which the practice is located). . Square brackets: robust SEs clustered at practice level. *** p<0.001, ** p<0.01, * p<0.05

Table A. 36: Comparison of EAPMC and non-EAPMC practices 2005-2007

	Non-EAPMC	**EAPMC**	**t-stat for difference in means**
N rival GPs within 1km	8.346	9.155	6.88
PA clinical	78.8	78.293	-5.51
RA clinical	85.102	84.327	-8.34
QOF points	96.73	95.424	-13.46
ACSC	11.662	15.371	46.15
Open hrs sat	82.914	83.948	7.62
urban	0.775	0.971	41.71
W income score MSOA	15.553	25.135	51.02
NH	5.145	5.389	4.67
CHDPrev	3.482	3.613	8.81
StrokePrev	1.658	1.672	1.99
HyperPrev	13.248	13.062	-4.93
DiabetesPrev	4.335	4.081	-18.07
EpiPrev	0.613	0.622	4.47
COPDPrev	1.596	1.583	-1.41
HypoPrev	2.875	2.742	-11.59
CancerPrev	1.362	1.152	-27.06
MHPrev	0.782	0.738	-11.85
AsthmaPrev	5.893	5.923	2.27

Notes: urban: dummy variable =1 if practices are in urban areas; W income score MSOA: income deprivation score in the MSOA in which the practice is located; NH: proportion of patients in nursing homes averaged across practice and its five nearest practices; prevalence of QOF conditions averaged across practice and its 5 nearest practices (CHDPrev, StrokePrev, HyperPrev, DiabetesPrev, EpiPrev, COPDPrev, HypoPrev, CancerPrev, MHPrev, AsthmaPrev).

Appendix 5.

Table A. 37: Patients leaving practice without change of address: Poisson model full results

	(1)	(2)	(3)
	FE	FE	Pooled
Period	2006/7 -2010/11	2007/8 -2010/11	2006/7 -2010/11
Current/lagged quality	Current	Lagged	Current
QOF total points (prop of available)	-0.373***	-0.328**	-0.198*
	(0.11134)	(0.11315)	(0.11355)
Clinical QOF PA (proportion)	-0.0191	-0.00188*	-0.0631
	(0.07527)	(0.00091)	(0.09368)
ACSC. Emerg adm per 1000 patients	0.00395**	0.00394**	0.0142***
	(0.00137)	(0.00147)	(0.00107)
Urgent appointment	-0.754***	-0.297***	-0.774***
	(0.06584)	(0.07000)	(0.04537)
Advance appointment	-0.261***	-0.149**	-0.298***
	(0.04677)	(0.05716)	(0.02975)
Opening hours satisfaction	-0.689***	-0.0744	-0.485***
	(0.09804)	(0.10554)	(0.08240)
GPs FTE per 1000 patients	-0.221***	-0.274***	-0.404***
	(0.03404)	(0.03974)	(0.02761)
Average GP Age	-0.000908	-0.00222	0.00246***
	(0.00116)	(0.00141)	(0.00074)
Proportion female GPs	0.0233	0.0457	-0.0719***
	(0.03080)	(0.03616)	(0.01670)
Prop EU GPs qualified	0.0639	0.152*	0.295***
	(0.06677)	(0.08381)	(0.02961)
Prop non-EU GPs qualified	0.193***	0.177***	0.340***
	(0.03441)	(0.03893)	(0.01460)
Patient to practice distance (km)	-0.580	-0.565	-0.184***
	(0.44023)	(0.40793)	(0.00913)
Number new practices within 5km	0.0211***	0.0110**	0.0204***
	(0.00438)	(0.00425)	(0.00596)
Number practices closed within 5km	0.00644	0.00953**	-0.0749***
	(0.00346)	(0.00377)	(0.00466)
QOF total points within 5km	-0.00259	-0.00352	0.333*
	(0.03326)	(0.03538)	(0.17452)
Clinical QOF PA (%) within 5km	-0.209	-0.187	-0.00867***
	(0.16258)	(0.16432)	(0.00098)
ACSC. emerg adm per 1000 patients within 5km	-0.000270	-0.00102	-0.000415***
	(0.00124)	(0.00131)	(0.00010)

Urgent appointment within 5km	0.0000359	-0.0000234	-0.132*
	(0.00009)	(0.00010)	(0.07011)
Advance appointment within 5km	-0.0311	-0.0567	-0.0347
	(0.03216)	(0.04025)	(0.04357)
Opening hrs satisfaction within 5km	0.0865	0.274**	0.186*
	(0.08321)	(0.10814)	(0.10210)
GPs FTE/1000 patients within 5km	0.0175	-0.0101	-0.0368
	(0.05999)	(0.06399)	(0.03617)
Prop pop claiming IBSD allowance	-4.746***	-5.489***	1.367***
	(1.18886)	(1.41538)	(0.25714)
Percentage of Nursing Home patients	0.0198	0.0128	0.0291***
	(0.02596)	(0.03306)	(0.00855)
ln total list	-0.0692	0.0341	-0.672***
	(0.09933)	(0.12473)	(0.01965)
Proportion male patients 0 to 4	2.413	5.708**	2.136
	(1.59280)	(1.79020)	(1.11449)
Proportion female patients 0 to 4	2.003	4.085*	-2.947*
	(1.61890)	(1.87198)	(1.14831)
Proportion male patients 5 to 14	1.139	3.639*	0.313
	(1.50423)	(1.74389)	(0.77383)
Proportion female patients 5 to 14	-0.934	-0.305	-2.889***
	(1.50732)	(1.79346)	(0.77546)
Proportion female patients 15 to 44	1.277	1.517	-3.099***
	(0.78525)	(0.90636)	(0.36343)
Proportion male patients 45 to 64	-1.191	-0.263	-0.916*
	(1.00809)	(1.14271)	(0.41787)
Proportion female patients 45 to 64	1.913	1.614	-5.651***
	(1.23384)	(1.47868)	(0.36277)
Proportion male patients 65 to 74	2.365	2.482	6.226***
	(1.82934)	(2.14720)	(1.05824)
Proportion female patients 65 to 74	6.265**	6.108*	-12.67***
	(1.99087)	(2.51030)	(1.04112)
Proportion male patients 75 plus	-0.964	1.239	2.759*
	(2.41949)	(2.85565)	(1.19760)
Proportion female patients 75 plus	-2.890	-0.754	0.196
	(1.85694)	(2.29284)	(0.71319)
CHD prevalence	-0.228	-0.352	0.618***
	(0.35710)	(0.42839)	(0.10170)
Stroke prevalence	-0.341	-0.428	-1.775***
	(0.51846)	(0.62223)	(0.21287)
Hypertension prevalence	0.315***	0.285*	0.175***
	(0.09557)	(0.11259)	(0.03237)
COPD prevalence	-0.116	0.0586	0.439***
	(0.32826)	(0.36162)	(0.12069)
Hypothyroidism prevalence	-0.143	-0.0842	0.157

	(0.26346)	(0.32233)	(0.09012)
Cancer prevalence	-0.557*	-0.656*	-1.091***
	(0.25711)	(0.29752)	(0.16767)
Mental Health prevalence	-0.391	-0.126	2.043***
	(0.51065)	(0.72782)	(0.18356)
Asthma prevalence	-0.496**	-0.427*	0.00358
	(0.15286)	(0.17178)	(0.04911)
Heart failure prevalence	-0.350	0.129	0.773***
	(0.43183)	(0.54647)	(0.22224)
Palliative care prevalence	0.0256	0.106	0.528
	(0.44962)	(0.47551)	(0.37597)
Dementia	-0.493	-0.749	-1.939***
	(0.63523)	(0.72995)	(0.28950)
Atrial fibrillation prevalence	0.414	-0.0167	-1.794***
	(0.45716)	(0.54512)	(0.22376)
Diabetes prevalence	0.314	0.469	-0.249**
	(0.25307)	(0.27108)	(0.08570)
Epilepsy prevalence	0.169	-0.277	4.429***
	(0.89625)	(1.09667)	(0.42863)
Chronic kidney disease prevalence	0.0286	0.0659	0.163***
	(0.05840)	(0.06932)	(0.03856)
Obesity prevalence	-0.00972	-0.0806	0.0129
	(0.04821)	(0.05522)	(0.02375)
Learning disability prevalence	1.032	1.471	0.852*
	(0.87564)	(0.91818)	(0.34065)
2007/8	0.0167	-0.0799***	0.0483***
	(0.00949)	(0.02379)	(0.01321)
2008/9	0.00655	-0.0409*	0.0790***
	(0.01324)	(0.01870)	(0.01379)
2009/10	0.0314	-0.0128	0.193***
	(0.02200)	(0.01097)	(0.01560)
2010/11	0.0780**		0.263***
	(0.02430)		(0.01660)
AIC	294563	214829	765490
BIC	295035	215280	765970
Observations	33636	26864	33636

Notes: Dependent variable: number of patients joining a practice without address change. Coefficients are proportionate changes from one unit increase. Robust SEs in parentheses. *: p<0.05; **: p<0.01; ***: p < 0.001

Table A. 38: Patients joining practice without change of address: Poisson model full results

	(1)	(2)	(3)
	FE	FE	Pooled
Period	2006/7 -2010/11	2007/8 -2010/11	2006/7 -2010/11
Current/lagged quality	Current	Lagged	Current
QOF total points (prop of available)	0.237*	0.265**	0.912****
	(0.12940)	(0.13097)	(0.18569)
Clinical QOF PA (proportion)	-0.153*	-0.00091	-0.784****
	-0.08152	-0.00095	-0.15798
ACSC. Emerg adm per 1000 patients	0.00563****	0.00110	-0.00324**
	(0.00150)	(0.00161)	(0.00162)
Urgent appointment	-0.0363	0.0208	-0.0647
	(0.04820)	(0.05163)	(0.04101)
Advance appointment	0.634****	0.356***	1.269****
	(0.10193)	(0.11340)	(0.12645)
Opening hours satisfaction	0.227***	0.201**	0.390****
	(0.07509)	(0.08238)	(0.06497)
GPs FTE per 1000 patients	0.0949**	0.0866**	0.0600
	(0.03716)	(0.04016)	(0.04263)
Average GP Age	-0.00770****	-0.00785****	-0.0161****
	(0.00142)	(0.00161)	(0.00117)
Proportion female GPs	-0.0817**	-0.0746*	-0.0286
	(0.03715)	(0.04112)	(0.02384)
Prop EU GPs qualified	0.0652	0.0505	0.137***
	(0.07089)	(0.08750)	(0.04684)
Prop non-EU GPs qualified	-0.0616	-0.0646	0.0311
	(0.04878)	(0.05469)	(0.02125)
Patient to practice distance (km)	-0.878	-0.751	1.084****
	(0.57391)	(0.53837)	(0.02934)
Number new practices within 5km	-0.0633****	-0.0600****	-0.193****
	(0.00553)	(0.00551)	(0.00834)
Number practices closed within 5km	0.00668	0.00390	-0.162****
	(0.00416)	(0.00452)	(0.00621)
QOF total points within 5km	0.00427	0.184	1.226****
	(0.15721)	(0.17822)	(0.29566)
Clinical QOF PA (%) within 5km	0.000998	-0.0000649	-0.0172****
	(0.00133)	(0.00138)	(0.00159)
ACSC. Emerg adm per 1000 patients within 5km	0.0000673	0.0000335	-0.000639****
	(0.00009)	(0.00010)	(0.00016)
Urgent appointment within 5km	0.0521	0.00962	-0.264**
	(0.06186)	(0.07315)	(0.11569)
Advance appointment within 5km	0.0659*	0.0117	0.235****
	(0.03721)	(0.04328)	(0.06971)
Opening hrs satisfaction within 5km	-0.157	-0.178	0.192
	(0.09613)	(0.11115)	(0.17929)
GPs FTE/1000 patients within 5km	-0.0496	-0.0195	-0.113**
	(0.03585)	(0.03817)	(0.05614)
Prop pop claiming IBSD allowance	6.813****	7.543****	-3.724****
	(1.31930)	(1.53891)	(0.40288)
Percentage of Nursing Home patients	-0.00419	-0.00562	0.186****
	(0.02398)	(0.02821)	(0.01447)
ln total list	-0.471****	-0.629****	0.503****
	(0.09823)	(0.12228)	(0.03166)

Proportion male patients 0 to 4	-2.832	-3.787*	11.48****
	(1.91803)	(2.19273)	(1.81128)
Proportion female patients 0 to 4	-1.246	-3.147	0.377
	(1.95162)	(2.21030)	(1.87803)
Proportion male patients 5 to 14	-2.138	-2.546	5.845****
	(1.65535)	(1.97315)	(1.21308)
Proportion female patients 5 to 14	-2.687	-5.334**	5.327****
	(1.78631)	(2.12179)	(1.18629)
Proportion female patients 15 to 44	4.474****	2.797***	0.345
	(0.91237)	(0.98147)	(0.50646)
Proportion male patients 45 to 64	1.439	1.445	-2.806****
	(1.23561)	(1.44447)	(0.75169)
Proportion female patients 45 to 64	2.945**	2.511	6.489****
	(1.30378)	(1.55625)	(0.59102)
Proportion male patients 65 to 74	2.281	0.0285	19.70****
	(2.21817)	(2.66435)	(2.10925)
Proportion female patients 65 to 74	-1.909	-1.136	-10.42****
	(2.18588)	(2.60054)	(1.84799)
Proportion male patients 75 plus	1.220	-1.588	6.800****
	(2.82667)	(3.41235)	(2.05232)
Proportion female patients 75 plus	-3.132	-5.043**	-2.609**
	(2.13305)	(2.47779)	(1.28010)
CHD prevalence	1.037***	0.851**	0.0732
	(0.32977)	(0.42628)	(0.15370)
Stroke prevalence	-0.341	-0.599	-0.470
	(0.45227)	(0.53825)	(0.28744)
Hypertension prevalence	0.0388	0.00954	-0.349****
	(0.09197)	(0.11489)	(0.04365)
COPD prevalence	-0.619*	-0.347	0.728****
	(0.34561)	(0.44924)	(0.15337)
Hypothyroidism prevalence	0.114	-0.202	0.763****
	(0.26323)	(0.32637)	(0.13028)
Cancer prevalence	-0.485*	-1.111****	-0.985****
	(0.24835)	(0.30499)	(0.23557)
Mental Health prevalence	0.192	0.677	-0.667**
	(0.49470)	(0.79207)	(0.27742)
Asthma prevalence	0.653****	0.721****	0.641****
	(0.13746)	(0.15579)	(0.07478)
Heart failure prevalence	-0.740**	-0.627	-0.228
	(0.36541)	(0.46560)	(0.33116)
Palliative care prevalence	-0.128	-0.539	1.059*
	(0.61203)	(0.67545)	(0.62809)
Dementia	0.915*	1.347**	-2.025****
	(0.49052)	(0.58008)	(0.41910)
Atrial fibrillation prevalence	-0.0892	0.301	2.215****
	(0.40728)	(0.48429)	(0.32235)
Diabetes prevalence	0.127	0.412	-0.483****
	(0.20565)	(0.26103)	(0.10774)
Epilepsy prevalence	3.123****	3.623****	1.394**
	(0.85059)	(1.00490)	(0.58804)
Chronic kidney disease prevalence	-0.105**	-0.143**	-0.0112
	(0.05149)	(0.06860)	(0.05332)
Obesity prevalence	0.115***	0.168***	0.249****
	(0.04366)	(0.05517)	(0.03309)
Learning disability prevalence	0.343	-0.259	2.214****
	(0.51294)	(0.63016)	(0.41224)
2007/8	0.0357****	-0.00475	0.0261
	(0.01058)	(0.02616)	(0.02071)
2008/9	0.0439***	-0.000241	0.0221

	(0.01476)	(0.02106)	(0.02300)
2009/10	-0.00271	-0.00869	-0.153****
	(0.02375)	(0.01269)	(0.02545)
2010/11	0.0223		-0.0324
	(0.02646)		(0.02641)
AIC	331907	237817	1577199
BIC	332379	238268	1577679
Observations	33631	26860	33636

Notes: Dependent variable: number of patients joining practice without address change. Exposure: number of patients leaving practices within 5km without change of address. Coefficients are proportionate changes from one unit increase. Robust SEs in parentheses.
*: p<0.05; **: p<0.01; ***: p < 0.001

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