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Abstract
Provider competition is a currently popular healthcare reform model. A necessary condition for greater competition to improve quality is that providers will face higher demand if they improve their quality. In this paper we test this crucial assumption in an important part of the health care market by examining whether quality affects the choice of family doctor. We use data on the choices made by 3.4 million English patients from amongst nearly 1000 family doctor practices to estimate the determinants of choice and, in particular, whether quality affects choice. The English setting is a particularly useful test bed since all individuals are entitled to register with a family physician and generally cannot access non-emergency hospital care without doing so. All care is free, so choice of family doctor is not affected by price. Moreover, measures of clinical quality are publicly available. We find that patients do respond to quality and are willing to travel further to higher quality practices. Our estimates suggest that a one standard deviation increase in the publicly available measure of quality would increase the number of patients a practice would attract by around 15% of the practice patient list.

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Keywords: Quality; demand; healthcare; choice; competition; family practice

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1 Introduction

Governments facing fiscal pressure have increasingly turned to proposals to create or enhance consumer choice for public services e.g. Besley and Ghatak (2003), Hoxby (2003), LeGrand (2003). In health care, choice is a popular reform model adopted by administrations of different political orientations in many countries, including the US, the UK, Denmark, Italy (Lombardy), the Netherlands, Germany and Sweden. The belief is that by increasing choice for patients, providers of care will become more responsive to patient demand which, in turn, will drive greater efficiency in the delivery and funding of health care. But such reforms have been controversial and whether enhanced patient choice will make care providers more responsive to quality is not well established. Consumers may lack information about medical care providers, and measures of quality may be noisy and difficult for them to interpret.

More generally, a necessary condition for greater competition to improve quality is that a provider will face higher demand if they improve their quality. Thus one approach to the issue of whether competition promotes quality is to test the crucial assumption that quality affects demand. This is what we do in this paper. We examine whether healthcare consumers in England respond to differences in quality when they make their choice of family doctor. England is an excellent "test bed". First, all individuals in the UK are entitled to choose a family doctor practice and need to do so, as family doctors both provide almost all primary care and are also the gatekeepers for any specialist or hospital care the individual may need. Second, care is tax funded and free at point of use, so price plays no role in choice. Third, an important major strand in government policy in England has been the promotion of competition both amongst hospitals and family doctors and to make this policy work the government has actively promoted the provision of information on the performance of medical providers to the public. Fourth, the UK has been a world leader in the development of quality indicators for primary care which are both publicly available and are salient to family doctors as their performance on these indicators is used in pay-for- performance contracts that accounts for over 20% of their average total remuneration.

Despite the fact that a patient's choice of their doctor could be critical to their health and wellbeing, there are few studies of the effects of quality on patient choice of family doctors. One reason for this is that good measures of physician quality are rarely publicly available. We exploit the availability of such data in England. We use data on the choices made by 3.4

million patients from amongst nearly 1000 family doctor practices to estimate the determinants of choice and, in particular, to test whether quality affects choice. Our data contain information on the distances from patients to potential practices and a rich set of measures of practice quality, some of which are published and observable by patients, as well as characteristics of the practice which have been shown to influence choice of patients, including age and gender of the family doctors in the practice, their country of qualification, and the type of contract the practice has with the NHS.[1]

We find that patients are more likely to choose practices which are of higher quality as measured by the publicly available data on practice performance. The positive effect of clinical quality on choice is robust across patient age and gender groups, to patient socioeconomic characteristics, to allowing for unobserved heterogeneity in patient preferences, and to the potential endogeneity of the clinical quality measure. In addition, patient choice is more responsive to published than unpublished measures of quality. We also find, as expected given that most primary healthcare requires patients to attend their practice, that patients' valuation of practices decreases with distance from their home. Patients are also likely to choose practices which have a higher proportion of GPs qualified in Europe, a higher proportion of female GPs, and a lower average GP age.

This responsiveness of choice to practice quality is economically meaningful as well as statistically significant. Using our most conservative estimates of the effect of quality on choice, the average marginal effect of an increase of one standard deviation in measured quality is to increase the probability of a practice being chosen by a patient by 0.0083. In terms of the metric of distance, the average patient would be willing travel an additional 125 metres to join a practice with one standard deviation higher clinical quality. These results might appear to suggest a small influence of quality on the choices of individual patients. However, the relevant effect for assessing the potential incentive for practices to improve quality is the increase in the number of patients who wish to join a practice when its quality increases. This depends on the effect of quality on the probability that a patient will choose a practice *and* on the number of patients who would consider choosing the practice. In our data

[1] Our measures of practice quality are discussed in detail in Section 3.3, but include summary measures derived from the Quality and Outcomes Framework (QOF) which records and rewards practice performance on a large set of clinical and administrative quality indicators, the rate of emergency admissions for ambulatory care sensitive conditions, and average patient satisfaction with the practice.

set there are on average over 25,000 potential patients within 2km of a practice. We estimate that an increase of one standard deviation in clinical quality will increase the number of patients over the age of 24 choosing a practice by just over 1000, an increase of around 15 percent.

Our results contribute to the literature on choice and competition in health care. The theoretical literature is generally supportive of the proposition that greater competition improves quality if prices are regulated (Gaynor, 2006).[2] Most empirical studies find that when providers face fixed prices greater competition is associated with higher quality (see Gaynor and Town (2012) and Gravelle et al (2012) for reviews. For England, Cooper et al, (2011) and Gaynor et al, (forthcoming) provide evidence for a positive impact of the pro-competitive policy that operated post-2006 for hospitals. Studies of patient choice of hospital in the US (Burns and Wholey, 1992; Cutler et al, 2004; Ho, 2006; Howard, 2005; Luft et al, 1990; Pope, 2009; Tay, 2003), the Netherlands (Varkevisser et al, 2012), Italy (Moscone et al, 2012), and in England (Beckert et al, 2012; Gaynor et al, 2012; Sivey, 2011) find that higher hospital quality increases demand. But there are very few studies of the determinants of quality on patient choice of family doctors. This is primarily because measures of quality are rarely publicly available. Research to date has tended to focus on other attributes of care or proxies for quality. For example, studies have shown the importance of distance (for the UK, Salisbury, 1989; Billinghurst and Whitfield, 1993; Dixon et al, 1997; McLean and Sutton, 2005; for Norway, Godager, 2009), other aspects of accessibility such as opening hours) (e.g. Dixon et al, 1997) and attributes of the doctor such as age, gender and ethnicity (e.g. Godager 2009).[3] In the absence of any measures of clinical quality such attributes may be used by consumers as signals of a better match and so higher quality. Stated preference studies have shown that, hypothetically, patients are willing to trade-off measures of consultation quality, thoroughness of physical examinations and the GP's knowledge of the patient against the accessibility of the consultation and waiting times for appointments (Cheraghi-Sohi, 2008; Scott and Vick, 1999; Vick and Scott, 1998). Revealed preference

[2] There are caveats about the role of imperfect information and the required assumptions about provider cost functions and patient prefrences (Brekke, et al, 2010; Gravelle, 1999; Gravelle and Masiero, 2000; Karlsson, 2007; Gravelle et 2012; Halonen and Propper, 2012).

[3] Studies of Australian GPs, where GPs are paid by fee for service and GPs' prices for consultations are not regulated, find that GPs in areas with less competition (whether measured by distance to other GPs or by GPs per capita) charge higher prices (Gravelle et al, 2013; McCrae, 2009; Richardson et al, 2006; Savage and Jones, 2004).

evidence on the relationship between choice of practice and proxies for quality is more mixed (e.g McLean and Sutton, 2005), though recent studies following the introduction of a list system in Norway have found evidence of small positive responses to factors such as practice mortality rates and the volume of services provided (Iversen and Luras 2011, Biorn and Godager 2010). Finally, Pike (2010) examines the cross sectional association between competition between general practices and quality and finds that practices with more rivals within 500m have higher quality (as measured by patient satisfaction and a measure of clinical care).

More broadly, our paper contributes to the literature on whether choice based reforms will provide incentives for firms to increase quality. There has been a great deal of interest in recent years in competition in education, both theoretically and empirically (e.g., Epple and Romano 1998; Hoxby 2000; Epple, Figlio, and Romano 2004). In this literature, as in health, the predictions from theoretical models are often ambiguous and the empirical evidence quite contested (Hoxby 2000; Rothstein 2007; Bayer and McMillan 2005; Burgess, Propper and Wilson 2005). Our results thus add to the evidence on the conditions under which gains from consumer choice in the provision of public services may be realized.

2 Institutional setting

To receive primary medical care in the British National Health Service (NHS) patients must register with a general (family) practice, which also acts as a gatekeeper for elective hospital care. The NHS is financed almost entirely from general taxation and patients face no charges for NHS health care, apart from a small charge for dispensed medicines.

General practitioners (GPs) are not employees of the NHS, apart from a small proportion directly employed by local primary care organisations (Primary Care Trusts - PCTs). GPs are organised in general practices, most of which are limited liability partnerships owned by the GPs. The NHS contracts with the general practices, not with the individual GPs. English practices have on average 4.2 general practitioners (GPs) and around 6,600 patients (Information Centre, 2011).

Practice contracts with the NHS to supply services to patients are of two types. Just over half of general practices have the General Medical Services (GMS) contract whose terms are set

by national negotiations between the NHS and the British Medical Association (the doctors' trade union). GMS practices are paid a mixture of lump sums, capitation, quality incentive payments, and items of service. Around 80% of practice revenue varies with the number of patients on the practice revenue. Most of practice revenue (over 60%) is generated by capitation payments which are determined by a national formula which takes account of the demographic mix of practice patients and local morbidity measures. Quality incentives from the Quality and Outcomes Framework (QOF) (Roland, 2004) generate over 20% of practice revenue. For a given quality level, QOF revenue increases with the number of patients. Practice payments for vaccinating and screening specified target proportions of the relevant practice population also increase with the total list. Practices are reimbursed for the costs of their premises but have to fund all other expenses, such as hiring practice nurses and clerical staff, from their revenue.

Around 48% of practices are paid under a Primary Medical Services (PMS) contract. These contracts are negotiated between the practice and their local PCT. Under the PMS contract, the practice receives a lump sum in exchange for agreeing to provide similar services to those required under the GMS contract, plus additional services for particular patient groups. The amount received is typically the amount the practice would have received under GMS, plus an addition intended to cover the cost of the extra services. PMS practices also receive QOF payments, though they are paid less than GMS practices for the same quality achievement because some of the QOF payments relate to activities which are also paid for directly under PMS contracts. As under GMS, the practice has to meet its expenses from its revenue.

One of the strands in policy in the English National Health Service (NHS) in recent years has been the promotion of competition amongst hospitals in the secondary care sector and amongst general practices in primary medical care. In general practice the national body which controlled entry of new practices was abolished in 2002 and the Department of Health (DH) introduced a tendering process to make it easier for new practices to be established, especially in under-doctored areas (Department of Health, 2006). Patients are to be given the right to register with any practice in England (Department of Health, 2010). A website, NHS Choices, has been set up by the DH containing information on the characteristics of practices,

such as the clinics they offer and their performance under the national quality incentive (QOF) scheme and results from patient satisfaction surveys.[4]

The method of payment for practices ensures that, whether they have GMS or PMS contracts, their revenue will increase with the number of patients. The question we address is whether practices can attract more patients by improving their quality.

3 Data

We construct a rich data set on patients and practices by linking a number of NHS administrative data sets (Attribution Data Set, General Medical Statistics, Quality and Outcomes Framework, Hospital Episode Statistics) with small area census and socio-economic data from Neighbourhood Statistics. Sources are in Table A1.

3.1 Patients

The Attribution Data Set (ADS) contains, for each administratively defined homogenous small geographical area in England (known as a Lower Super Output Area, LSOA), the number of patients by age/sex band who are registered with each general practice at 1 April 2010. There are 32,482 LSOAs in England, with a minimum population of 1000 and a mean population of 1500.[5]

To reduce computational burden we limit our analysis to the choice of practice by patients resident in one of 10 geographically defined Strategic Health Authorities (SHAs) in England. We selected the East Midlands SHA which contains 2875 LSOAs. It has a mixture of densely populated urban areas and rural areas, has an ethnically diverse population allowing investigation of the effects of ethnicity and other socio-economic characteristics on patients'

[4] http://www.nhs.uk/choiceintheNHS/Yourchoices/GPchoice/Pages/ChoosingaGP.aspx. Detailed information on performance of practices in an area under the national P4P scheme is also available via http://www.qof.ic.nhs.uk/search/ and information on patient satisfaction survey in http://www.gp-patient.co.uk/info/

[5] On average over England the population registered with general practices is about 7% greater than estimates of the population derived from the decennial population census (Ashworth et al, 2005). The difference is due to lags in the updating of patient registration data when patients die or change practice. Since general practices are paid according to their registered lists it is appropriate to model the determinants of the number of patients registered with practices as we wish to examine whether practices are paid more, via larger lists, when their quality is greater.

tastes for practice characteristics, and it is far from the English-Welsh and English-Scottish borders so that we do not have to drop any LSOAs whose patients are registered in Welsh or Scottish practices whose characteristics we do not observe.[6]

We exclude practice registrations of children because their choices are made by their parents and we cannot distinguish in our data between patients with and without children. We also exclude patients aged 18-24 because students in post-secondary education may continue to be registered at their parents' general practice despite living away from home. We therefore analyse the choice of practice by the 3.372M individuals in the East Midlands SHA who are aged 25 and over.

The ADS data contain age (in bands) and gender of each patient. We attribute socio-economic characteristics to patients by their LSOA of residence. The characteristics we include are the proportion of the LSOA who are income deprived (defined as receiving income related social security benefits), the proportion of adults with no formal educational qualifications, the proportion who report themselves as being in fair or good, rather than poor, self rated health, and the proportion who are of Asian ethnicity. We also categorise an LSOA as urban or rural. These patient and small area level variables allow us to examine whether different types of patient have different preferences over practice characteristics.

3.2 Practice characteristics

We use data from the General Medical Services census (taken on 30 September 2010 and 2009) to measure the average age of GPs, the proportion of female GPs, the proportion of GPs qualified in the UK, in Europe, in Asia, and elsewhere. We also have data on the type of practice contract (PMS or GMS), whether the practice has opted out of providing out of hours care for its patients, and whether the practice is permitted to dispense medicines as well as prescribe them. Data on the type of contract are missing for 13 practices and rather than reduce the number of practices we assumed they had GMS contracts and included a dummy variable indicating that the contract status dummy had been imputed.

[6] The ADS includes patients resident in England but registered in practices located in Wales and Scotland as well as England.

3.3 Practice quality

We have several measures of the quality of the practice. We use these to examine which aspects of quality are most salient to patients and to test the robustness of our results. Our primary measure of quality is practice performance on the Quality and Outcomes Framework (QOF). The QOF is a national pay-for-performance scheme introduced in April 2004 and whose broad structure has been maintained subsequently. From 2006/7 practices could receive up to 1000 points for achieving quality indicators grouped into four domains: clinical, organisation, patient experience, holistic care and additional services. Each point earned the practice £125.[7] As noted above, QOF payments account for around 20% of general practice gross income.[8]

As a measure of clinical quality QOF points have two potential drawbacks. Up to 665 of the 1000 QOF points are awarded for having disease registers and for the percentage of eligible patients in a disease area for whom various indicators are achieved.[9] No points were awarded for achievement less than 40% and points increased linearly with percentage achievement above 40% up to an upper threshold ranging from 60% to 90%, with no points earned for further increases in achievement. In addition, research has suggested that some practices designated patients as "exceptions" to increase their reported achievement (Gravelle et al, 2010). Thus points are an imperfect measure of actual achievement on a clinical indicator. However, performance measured by the QOF total points is readily available to the public (via the government NHS Choices website designed to help patients choose health care providers). Although it may be an imperfect measure of quality because of upper and lower thresholds and exception reporting, we use total QOF points as our main quality measure as it is most visible to patients.

[7] In more detail, the domains, points and indicators in 2006/7 were as follows. Clinical (80 indicators covering 19 conditions, carrying 655 points in total), organisation (43 indicators carrying 181 points for record keeping, medicines management, education and training,), patient experience (4 indicators carrying 108 points for length of consultations and having undertaken patient surveys), and additional services (8 indicators carrying 36 points for services including cervical screening, child health surveillance, maternity, and contraception). In addition there was holistic care indicator which awarded up to 20 points on the basis of performance in the 3rd worst condition in the clinical domain.

[8] The QOF data is extracted directly from patients' electronic health records for practices in the UK

[9] For example, indicator DM7 is the proportion (N/D) of eligible diabetic patients whose HbA1c was 10 or less and carried 11 points, where N is the number of patients for whom the indicator is achieved and D is the number who are declared eligible for the indicator.

Specifically, we use total QOF points for 2006/7. We choose a 4 year lagged measure (choice of practice is observed for 2010) to reduce reverse causality from patient choices to quality. However, in robustness tests we also use total points for 2009/10, the average total points from 2006/7 to 2009/10, and 2006/7 points earned on each of the domains of the QOF. We also use the raw QOF data on clinical indicators to construct measures of overall reported achievement and population achievement which are not affected by upper and lower thresholds and exception reporting.[10]

We also consider other, non-QOF, measures of quality. The first is a measure of the quality of practice disease management: the practice's total annual emergency admission rate for Ambulatory Care Sensitive Conditions (ACSCs).[11] ACSCs are conditions for which good quality management in general practice should prevent emergency admissions for complications (AHRQ, 2004; Purdy et al., 2009). ACSCs admission rates are used as measures of access to good quality primary care inside and outside the UK.

The second type of non-QOF measures are three patient satisfaction measures from the GP Patient Survey for 2009 which was sent to a 5.7M random sample of patients in all practices in England. We use the answers to three questions. The first question concerns general satisfaction ("In general, how satisfied are you with the care you get at your GP surgery or health centre?"). The second question is about satisfaction with opening hours ("How satisfied are you with the hours that your GP surgery or health centre is open?"). Patients answer both questions on a 5 points scale and we use the proportion of the practice respondents who say they were "Very satisfied" or "Fairly satisfied". The third question asks patients "Would you recommend your GP surgery or health centre to someone who has just moved to your local area?" and we use the proportion of respondents who report "Yes, would definitely recommend" or "Yes, might recommend", as opposed to "Not sure", "No, would probably not recommend", "No, would definitely not recommend" or "Don't know".

[10] Overall reported achievement is weighted average of the *reported achievement* (N/D) on the clinical indicators, where the weights are the maximum points available for the indicator. Practices can exception report patients for clinical indicators on various grounds, including the patient refusing to attend for treatment or having contra indications. We therefore also calculate overall *population achievement* as the maximum points weighted average over clinical indicators of $N/(D + E)$ where E is the number of exceptions. Further details are in Table B1.

[11] ACSCs listed in Table A2.

3.4 Distance measurement and choice sets

Figure 1 shows the practices and LSOAs in the East Midlands. Some practices have more than one surgery. In total there are 994 practices with 1232 surgeries in the choice sets of East Midlands patients. We obtained the practice branch grid references from their postcodes and calculated the straight line distance between the centroid of each LSOA and all GP surgeries within 50km of LSOAs in the East Midlands SHA. We assume that a patient considers the distance to the nearest surgery of a practice when choosing amongst practices. So we use the distance to the nearest surgery of a practice from the LSOA centroid as our measure of practice distance.

Since over 99% of the patients were registered with practice with a surgery within 10km of their LSOA centroid, we restrict the choice set for an LSOA to practices within 10km. In some urban areas there were more than 100 practices within 10km. To reduce the computation burden in these cases we further restricted the choice set to the 30 practices with the largest number of patients from the LSOA. When practices had the same number of patients from the LSOA we broke the ties by distance, taking the practices which were nearest to the LSOA centroid.

Practices are supervised by administrative bodies known as Primary Care Trusts (PCTs). Although patients are not required to register with practices located in the PCT in which they live, they may be less likely to choose practices in a different PCT because PCTs provide information about practices located within the PCT. Moreover, PCT boundaries are in part determined by physical features such as railway lines and rivers which may make it more difficult to access a practice than is suggested by the straight line distance. To allow for this, we take account of whether practices are in the same PCT as the LSOA of the patient.

3.5 Descriptive statistics

Table 1 presents the practice characteristics, distances and the small area (LSOA) characteristics. Over a third (36%) of GPs in practices are female and over a quarter (27%)

were trained outside Europe.[12] The mean distance to the nearest practice is 1.2km and the mean distance to practices within the LSOA choice set is 4.8 km. There are 22 practices on average within the choice set of each LSOA. Figure 2, panel (a) shows that the distribution of distance to nearest practice has more mass on the left hand side, but there are rural LSOAs with long distances to nearest practice in our data set. The mean distance to the chosen practice is 1.9 km. The distribution is shown in Figure 2, panel (b). This is skewed to the left as 40% of East Midlands SHA patients are registered with the nearest GP practice. This is higher than the proportion (32%) reported in Dixon et al (1997) for patients in practices in three other areas of England. Around 27% of practices in LSOA choice sets are located in a different PCT and 19% of patients choose a practice in a different PCT.

Table A3 reports the correlations amongst the quality measures. It is clear that these measures are not identical. There are reasonably high correlations amongst the QOF points measures.[13] ACSC emergency admissions are a negative measure of quality and are slightly negatively correlated with other quality indicators. Although the QOF was intended to improve care for long term conditions and to reduce hospital admissions, there is only weak negative correlation between ACSCs and QOF points. This may be because there are both negative and positive correlations between admissions for particular ACSCs and the QOF clinical indicators for management of those conditions (Bottle et al, 2008; Downing et al, 2007; Dusheiko et al, 2011; Purdy et al, 2011). The three patient reported measures are reasonably highly correlated with each other but much less well correlated with the QOF measures. Finally, the reported achievement 2009/10 and population achievement 2009/10 measures, which use more of the information used to compute QOF clinical indicators, are highly though not perfectly correlated with total 2009/10 QOF points and with each other.

4 Estimation

4.1 Model

We use McFadden's (1974; 1978) random utility choice model and estimate conditional logit models of patients' choice of practice. There are n^A LSOAs and their choice sets contain n^J

[12] We do not have data on ethnicity or first language of GPs but the majority of doctors trained outside Europe will not have English as a first language.
[13] In some cases this is due to the construction of the measures: clinical points contribute over 60% of total points, and the holistic care points are based on performance in the third worst clinical domain.

different practices in total. All n_a patients in LSOA a choose a practice from the same set C_a: $n_a = \sum_{j \in C_a} n_{aj}$, where n_{aj} is the number of LSOA a residents who choose practice j. The number of patients choosing practice j is $n_j = \sum_{a=1}^{n^A} n_{aj}$ and there are $N = \sum_{j=1}^{n^J} n_j = \sum_{a=1}^{n^A} n_a$ patients in total.

The utility for individual i living in LSOA a if she chooses practice j is

$$u_{iaj} = \mathbf{x}'_{iaj}\boldsymbol{\beta} + \varepsilon_{iaj} \quad (1)$$

$\mathbf{x}_{iaj} = (x_{1iaj}, ..., x_{Kiaj})$ is a vector of K observed variables and ε_{iaj} is random error term observed by the patient i but not the econometrician. Each patient i in LSOA a chooses the practice in their choice set C_a which yields the highest realised value of u_{iaj}.

Assuming that the ε_{iaj} errors are independently and identically distributed according to the type 1 extreme value distribution, the probability that patient i in LSOA a chooses practice j is

$$P_{iaj} = \exp(\mathbf{x}'_{iaj}\boldsymbol{\beta}) \left[\sum_{j' \in C_a} \exp(\mathbf{x}'_{iaj'}\boldsymbol{\beta}) \right]^{-1} \quad (2)$$

The log-likelihood for this conditional logit model is

$$\ln L = \sum_{a=1}^{n^A} \sum_{j' \in C_a} \sum_{i=1}^{n_a} y_{iaj} \ln \left[\frac{\exp(\mathbf{x}'_{iaj}\boldsymbol{\beta})}{\sum_{j' \in C_i} \exp(\mathbf{x}'_{iaj'})} \right] \quad (3)$$

where $y_{iaj} = 1$ when practice j is chosen by individual i in LSOA a and is zero otherwise.

If we assume, as in most of our models, that individuals' preferences over practice characteristics do not vary across different types of individual, only variables which vary by LSOA and practice ($\mathbf{x}_{aj}$) will affect choice probabilities and thus the probability of choice of practice j by an individual in LSOA a is the same for all individuals in LSOA a. Hence

$$P_{iaj} = \exp(\mathbf{x}'_{aj}\boldsymbol{\beta}) \left[\sum_{j' \in C_a} \exp(\mathbf{x}'_{aj'}\boldsymbol{\beta}) \right]^{-1} \quad (4)$$

and the log-likelihood is

$$\ln L = \sum_{a=1}^{n^A} \sum_{j' \in C_a} n_{aj} \ln \left[\frac{\exp(\mathbf{x}'_{aj}\boldsymbol{\beta})}{\sum_{j' \in C_a} \exp(\mathbf{x}'_{aj'}\boldsymbol{\beta})} \right] \quad (5)$$

so that the log of the choice probability for practice j in choice set C_a is weighted by the number of patients in LSOA a who choose practice j.[14]

To reduce the computational burden from assuming that patients in an LSOA can choose from amongst any of the practices in or near the East Midlands SHA, we estimate the model after imposing the restriction that the choice set for patients in an LSOA is restricted to the practices within 10 km of the LSOA centroid. McFadden (1978) has shown that maximum likelihood produces consistent estimates of the coefficients $\boldsymbol{\beta}$, which are the marginal patient utilities from practice characteristics, even with imposed choice sets which are subsets of the true choice set. (See Appendix C for a discussion.)

We examined our baseline assumption of homogeneous individual preferences in three ways. First, because we have data on the numbers of individuals in age and gender groups in each LSOA who choose each practice, we estimate versions of (5) for each age and gender group, so that n_{aj} is now the number of patients in an LSOA in a given age/gender band who choose practice j. Second, although we do not observe any other individual characteristics, we do have information on the average socio-economic characteristics of LSOAs. To investigate whether preferences about practices vary with these characteristics we stratify LSOAs separately by the proportion of the population who are income deprived, non-white, have no educational qualifications or are in fair or good self reported health. Finally, we allow the coefficients $\boldsymbol{\beta}$ in individual utility functions to vary randomly across individuals according to a normal distribution and we estimate mixed logit models of their mean and standard deviation.

4.2 Reported effects

The estimated coefficients $\hat{\boldsymbol{\beta}}$ convey information about the sign of the effect of an attribute on patient utility and on the probability of choice since $\partial \hat{P}_{aj} / \partial x_{kaj} = \hat{\beta}_k \hat{P}_{aj}(1-\hat{P}_{aj})$. The magnitudes of the marginal effects $\partial \hat{P}_{aj} / \partial x_{kaj}$ vary across practices and LSOAs. To get a more readily interpretable quantitative estimate of patient preference across practice characteristics we generally report the average of the marginal effects $\partial \hat{P}_{aj} / \partial x_{kaj}$:

[14] All models estimated using Stata 12. A subset were re-estimated using NLogit.

$$n^{-1}\sum_a \sum_{j\in C_a} n_a \hat{\beta}_k \hat{P}_{aj}\left(1-\hat{P}_{aj}\right) \qquad (6)$$

rather than the coefficients.

The estimated marginal effects of practice characteristics are typically very small. But the potential incentives for practices to increase quality to attract patients depend on the change in demand for the practice. This depends on the change in the probability that patients will wish to join the practice (i.e., the marginal effects) and on the number of patients in whose choice set the practice falls. On average there are 74,529 people aged 25 and over within 5 km of a practice and 25,070 within 2 km. Thus even small changes in the probability of an individual choosing a practice can have a non-trivial effect on demand for the practice.

We therefore also report the estimated average number of additional patients a practice would receive from a unit increase in practice characteristic x_{kj}

$$\frac{1}{n^{J*}}\sum_{j\in S^{J*}}\left(\frac{\partial \hat{n}_j}{\partial x_{kj}}\right)=\frac{1}{n^{J*}}\sum_{j\in S^{J*}}\left(\frac{\partial\left(\sum_{a\in S_j} n_a \hat{P}_{aj}\right)}{\partial x_{kj}}\right)$$

$$=\frac{1}{n^{J*}}\sum_{j\in S^{J*}}\left[\sum_{a\in S_j} n_a \hat{\beta}_k \hat{P}_{aj}\left(1-\hat{P}_{aj}\right)\right] \qquad (7)$$

$S_j = \{a \,|\, j \in C_a\}$ is the set of East Midlands LSOAs whose choice sets include practice j. S^{J*} is the set of n^{J*} (= 482) practices which draw at least 99% of their list from East Midland LSOAs.

The elasticity of demand for practice j with respect to x_{jk} is

$$\frac{\partial \hat{n}_j}{\partial x_{kj}}\frac{x_{kj}}{\hat{n}_j}=\hat{\beta}_k \frac{x_{kj}}{\hat{n}_j}\sum_{a\in S_j} n_a \hat{P}_{aj}\left(1-\hat{P}_{aj}\right) \qquad (8)$$

and we report the weighted average elasticity of demand

$$\sum_{j\in S^{J*}}\frac{\hat{n}_j}{\hat{n}}\left(\frac{\partial \hat{n}_j}{\partial x_{kj}}\frac{x_{kj}}{\hat{n}_j}\right)=\frac{1}{\hat{n}}\sum_{j\in S^{J*}}\hat{\beta}_k x_{kj}\left(\sum_{a\in S_j} n_a \hat{P}_{aj}\left(1-\hat{P}_{aj}\right)\right) \qquad (9)$$

We also calculate marginal rates of substitution between the k'th practice characteristic x_{kj} and the distance d_{aj} in kilometres between the LSOA centroid and the practice. In our

preferred model utility depends on a cubic function of distance so the marginal rate of substitution varies across practices and LSOAs:

$$MRS_{kd}^{aj} = \left.\frac{\partial x_{kj}}{\partial d_{aj}}\right|_{u} = -\frac{\partial u_{iaj} / \partial d_{aj}}{\partial u_{iaj} / \partial x_{kj}} = -\frac{\hat{\beta}_k}{\hat{\beta}_{11} + 2\hat{\beta}_{12} d_{aj} + 3\hat{\beta}_{13} d_{aj}^2} \qquad (10)$$

MRS_{kd}^{aj} is the additional distance that a patient in LSOA *a* would be willing to travel to practice *j* a practice if x_{kj} increased by one unit. To avoid the computational burden in estimating standard errors for the average of (10) across all patients we evaluate the MRS_{kd} at the mean distance to practice chosen and, using the results in Hole (2007), estimate standard errors using the delta method.

5 Results

5.1 The effect of quality, distance and practice characteristics

We begin by exploring the responsiveness of choice to our key variables of interest – practice quality and distance. Table 2 presents our baseline model. Quality is measured by four year lagged total QOF points (2006/7) and we allow for non-linearity in distance with a cubic function of distance from the LSOA centroid to the nearest surgery of the practice. Other covariates are practice characteristics: whether the practice is in the same PCT as the LSOA, mean GP age, proportion of female GPs, the proportion of GPs qualified outside Europe (where GPs qualified in Europe is the baseline), the type of contract the practice has (GMS is the baseline category), and whether the practice has opted out of providing out of hours cover for its patients.

The table reports the average marginal effects of variables on the probability that a practice is chosen. The first row shows that patients are more likely to choose a practice with higher quality. An increase of 10 QOF points increases the probability of choice of practice by 0.0013. Note the small magnitude of this estimate is in part because of the scale of the QOF measure (the mean number of QOF points is 633 with a standard deviation of 64). The second row shows that patients dislike distance and prefer practices that are closer to their homes, and the third that, conditional on distance, patients prefer practices in the same PCT.[15]

[15] As PCTs boundaries may reflect physical features that are hard to cross, the coefficient on PCT may be interpreted as a (non-linear) distance parameter.

In terms of observed GP characteristics, patients prefer practices with younger GPs, with a higher proportion of female GPs, with a lower proportion of non-European qualified GPs, practices that have opted out of our-of-hours cover and those with PMS contracts. These results for practice gender and ethnicity mix, and average age, are robust across all model variants that we estimated and confirm earlier research findings on the choice of GPs in the UK. The literature suggests that female patients prefer consultations with female GPs so we expect that on average patients are more likely to choose practices with a higher proportion of female GPs. GPs who have qualified outside Europe are less likely to have English as a first language, so practices with a higher proportion of such GPs will have less demand. The positive effect of a practice opting out of providing services to patients outside normal working hours seems paradoxical at first sight. However, patients at a practice which has opted out will not necessarily experience worse access. When practices opt out the responsibility for providing out of hours care for their patients passes to the PCT. This need not lead to a reduction in the availability of out of hours care for patients compared to practices which do not opt out because much of the out of hours care is subcontracted by practices to commercial and cooperative deputising services. It may be that practices which opt out are then able to provide better care during normal hours. The effect of the practice opting out is much less robust than the effects of other practice characteristics. Patients may prefer practices with PMS contracts since such PMS contracts usually require the practice to provide additional services.[16]

5.2 Alternative quality measures

To further examine the effect of quality we estimate a series of modifications to our baseline model. In Table 3 we compare five different specifications of clinical quality. Although all models also contain the full set of practice characteristics used our Table 2 baseline model, we report only the average marginal effects for the quality measures and distance. Results for the other characteristics were very similar to those in the baseline model. Column (1) presents estimates using total 2006/7 QOF points. Column (2) examines the separate effects of the components of the 2006/7 QOF. This model performs slightly better than the other,

[16] We also estimated models which included a dummy variable for the practice's ability to dispense as well as prescribe. The average marginal effect of dispensing status was small and non significant. Practices are allowed to dispense medicines for patients who would find it otherwise difficult to use a pharmacy. Although this is more convenient for patients who register with a dispensing practice, other patients may prefer to register with practices which are more conveniently situated with respect to pharmacies, which may explain the insignificant effect of dispensing status on demand.

simpler, models which use only one QOF points measure, but two of the components (holistic care and patient experience) have negative, though insignificant, effects. This is possibly because of collinearity amongst the five components. Column (3) examines this further and uses only the 2006/7 clinical points. The results show that clinical points are positively associated with choice of practice but the model performs slightly worse than the model with total 2006/7 QOF points. The effects of distance are very similar for these first three models using quality measures derived from the 2006/7 QOF.

Columns (4) and (5) present results from models with total QOF 2009/10 points and the average of total QOF points over the period 2006/7 to 2009/10 respectively. In both cases greater distance has a negative marginal effect and higher QOF total points has a positive marginal effect. The marginal effect of total 2009/10 QOF points is much smaller and is less precise than the effect of total 2006/7 QOF points. The instrumented results, reported later, suggest that this is due to endogeneity.

In Table 4 we examine patient satisfaction with their practice and willingness to recommend it as measures of practice quality. We again do not report estimated average marginal effect for other practice characteristics as these are robust to the quality specification, but all models include these variables. Column (1) shows that if overall patient satisfaction is the only measure of quality and no other covariates are included in the model, patient satisfaction is strongly correlated with choice of practice. However, the overall fit of the model is poor compared to those which include a full set of practice characteristics. When we also include other practice characteristics and our baseline measure of clinical quality (total QOF 2006/7 points) in column (2) the marginal effect of overall patient satisfaction becomes negative and insignificant. This suggests that patient satisfaction is summarising the effect of practice characteristics on patient utility, as suggested in Robertson et al (2008), but makes no independent contribution to predicting patient choice of practice once practice characteristics and practice quality are accounted for.[17]

Columns (3) and (4) use patient satisfaction with access as a quality measure. It is statistically significant when it is the only explanatory variable in the demand model, but it has the wrong

[17] The lack of precision on the patient satisfaction measures may also reflect measurement error as these measures are based on an achieved sample of about 5% of patients, whilst the ACSC admission rate and QOF points are based on all relevant patients.

sign, as it is negative. This may reflect a negative correlation between practices with high demand and longer waits for consultations. As with overall satisfaction, access satisfaction becomes insignificant when other practice characteristics and total QOF 2006/7 points are included in the model in column (4). Column (5) shows that the patient survey measure "would recommend" a practice is positively associated with choice and column (6) that this variable retains its significant positive marginal effect when practice characteristics and total QOF 2006/7 points are included. The overall performance of this last model is very similar to the model where total QOF 2006/7 points is used as the quality measure (Table 3, column (1)).

We investigated two further QOF based measures of clinical quality (reported achievement and population achievement which allow for lower and upper thresholds and exception reporting). Neither measure was significant and reported achievement had the wrong (negative) sign. Finally, emergency admissions for ambulatory sensitive conditions (ACSC 2006/7) were insignificant when added to baseline model with total QOF 2006/7 points. (See Appendix Table B1).

This battery of test of alterative quality measures supports our baseline estimates in which we use 2006/7 total QOF points as the single overall measure of practice quality to predict patient choice. In statistical terms 2006/7 total QOF points fits the data very nearly as well as the model including all separate QOF sub-components and predicts a little better than total QOF 2009/10 points and the average of total QOF points 2006/7 to 2009/10. Importantly, it is also more plausible as a measure which affects patient choices. It is publicly reported on the NHS Choices web site aimed at helping patient choice, unlike the more nuanced measures of the components of the total score, or adjustments using QOF data to deal with gaming, or measures based on ACSC emergency admissions. Finally, a lagged measure is more likely to be exogenous to current choices (we further address endogeneity in section 5.6).

5.3 Distance effects

Because of the importance of distance in determining practice choice we investigate the robustness of baseline model to alternative specifications of distance. Table 5 reports estimates from model with different assumptions about the way in which distance affects the utility derived from practice choice. The statistically significant negative effects of distance

are similar in all the specifications, except for log distance model which has worse goodness of fit. Figure 3 plots the marginal effect of distance on the probability of choice of practice and shows that the negative marginal effects of distance decrease with distance with distance in all the polynomial specifications. The effect of quality is positive and significant in all specifications. Adding squared and cubed distance to the linear model reduces the average marginal effect of quality but adding further fourth and fifth powers of distance makes no difference to the effect of quality and has miniscule implications for goodness of fit. We therefore prefer the simpler cubic specification as our baseline model.

5.4 Patient preference heterogeneity

Using the baseline specification, we begin by allowing the parameters to differ by age and gender. Previous literature has suggested that preferences for medical practitioners differ across men and women and individuals of different ages. We estimate separate models for 12 age and gender group and report the results in Table 6. We present only the parameters on quality and distance, but the other practice characteristics have very similar patterns of marginal effects across age and gender groups. The table shows the impact of quality and distance on choice are very similar for men and women. Broadly, the effect of both quality and distance on choice appear to be non-linear in age, being most important to men and women in the middle of the age distribution. Individuals in the middle age group are most likely to be time constrained (they will be more likely to have both working household members and children) so the larger effect of distance for this group is understandable. Choices by the youngest group of men (those aged 25-34) are least affected by quality and distance has the smallest negative effect for older women. This lower effect of quality in young men may reflect either a general lack of awareness of health issues and/or a lack of need for health care in this age group.

Table 7 allows for heterogeneity of preferences across patients living in small areas with different levels of rurality, income deprivation, educational qualifications, self assessed health, and ethnicity. In all cases patients are more likely to choose practices which have higher clinical quality and are closer, but there are some interesting differences by small area

characteristics of the patients.[18] The marginal effects of practice characteristics on the probability of choice of practice are smaller for rural LSOAs than urban LSOAs, but the magnitudes of the marginal effects of characteristics relative to distance are not greatly different. For example, a 1 point increase in QOF points would have the same effect on choice probability as a reduction in distance of 1.9 metres for rural patients and 1.8 metres for urban patients. However, there is a difference across patients by patient deprivation. The choices of patients in LSOAs which are in the top quintile of income deprivation, or the top quintile for no educational qualifications, or for poor self- assessed health are more affected by distance and less by quality. For patients from LSOAs in these top quintiles, a 1 point increase in total QOF points has the same effect on choice probabilities as a 1 metre decrease in distance, whereas for small areas in the other quintiles, the effect of a 1 QOF point increase has the same effect as a 2 metre decrease in distance.

The analyses in Table 7 allow for observed heterogeneity. Table 8 compares the results from a mixed logit model, which allows for unobserved heterogeneity, and our baseline conditional logit specification. To facilitate comparison, the table reports coefficient estimates rather than AMEs and we present estimates for all the variables in the model. The upper part of the table shows that the mean values of the mixed logit coefficients are very similar to those from the baseline conditional logit model of Table 2. The lower part of the table shows that standard deviations of the mixed logit coefficients, except for the distance and quality variables, are not significantly different from zero. As the mean estimates are similar across the two models and the mixed logit model cannot easily be used to estimate average marginal effects, we prefer to report results from the more restrictive conditional logit models.

5.5 Catchment areas and closed lists: specification of the choice set

In interpreting the results we assume that practice lists are determined by patient decisions, rather than practice decisions. But because practices have a legal obligation to make home visits if these are medically necessary, they will be reluctant to accept patients who live a considerable distance from the practice. Practices are allowed to agree catchment areas with their PCTs and are not obliged to accept patients who live outside this catchment area. Thus

[18] The qualitative patterns of the other covariates are mostly very similar to those in the non-stratified model. Patients from all types of small area are more likely to choose practices with a higher proportion of female GPs, a smaller proportion of non-European qualified GP and have younger GPs.

an observed negative effect of distance on the probability of patients in an LSOA being on the list of a practice may be due to decisions by practices as well as by patients.

In Appendix C we sketch a model of practice choice of catchment area and discuss the implications for interpretation of our estimates. We show that if practices preferentially accept patients who live closer to the practice this will not produce an association between the proportion of a particular LSOA's patients choosing a practice and the practice's quality. The argument is as follows. It is possible that a practice whose patients are closer to the practice will have higher quality, either because it is harder to achieve higher quality if there is less contact between patients and GPs or because practices with higher quality have higher demand from patients and set smaller catchment areas for any given list size. Either of these mechanisms would lead to a negative association between practice quality and the average distance from the practice of the practice's patients from *all* LSOAs in its catchment area.[19] But it would not imply any relationship between the proportion of any particular LSOA choosing the practice and practice quality since the latter depends on the average distance of all practice patients.

Practices can close their lists to patients even if they live in the practice catchment area. Practices might wish to exclude patients who are more difficult to treat and who would therefore lower average quality. But a practice can refuse an application to join its list from a patient in their catchment area only if it has formally notified their local PCT that its list is closed. If the practice list is open it cannot refuse patients in its catchment area. For practices intending to stay in business list closures must be temporary since each year around 8% of patients will leave a practice list (primarily due to residential moves) (Hippisley-Cox et al, 2005). Our practice list data are a snapshot of the distribution of patients across practices at a given date and reflects patient choices over a number of years, so we think that list closure is unlikely to have major implications for our results.

Nevertheless, although we do not think that practices' ability to set catchment areas or to close their list to new patients can account for a positive association between the proportion of an LSOA's patients on a practice list and the quality of the practice, we undertake two further robustness tests. If catchment areas are a binding constraint on patients, then models

[19] Jenkins and Campbell (1996) found that higher quality practices in London had smaller catchment areas.

estimated with large radii or without restrictions on the number of patients from the LSOA registered at the practice, should yield different results from those estimated with tighter constraints. First, we estimate models in which the radius of the choice set for LSOAs is restricted progressively from 10km down to 8km, 6km, 4km and 2km. Second, we restrict the choice set for LSOAs to practices which have at least 1, 5, 10, or 50 of their patients drawn from the LSOA. By restricting the choice sets for LSOAs we make it less likely that the observed distribution of LSOA patients across practices in the choice sets is due to decisions by GPs about catchment areas.

Tables 9 and 10 report these investigations. Table 9 presents the average marginal effects from models in which we attempt to capture catchment area effects by restricting LSOA choice sets by distance. Table 9 shows that the average marginal effect of distance becomes larger (absolutely) as the choice set becomes smaller. This is to be expected: as Figure 3 shows the effect of distance declines with distance to the practice and restricting the choice set reduces the average distance to practices.

While the average marginal effects for both quality and distance change in Table 9 as we restrict the choice set, the ratio of the marginal effect of quality to distance is quite stable across the definition of the choice set. The ratio of quality marginal effect to distance marginal effect is approximately 18 percent higher for choice sets defined over 10km compared to over 2km. Table 10 reports average marginal effects from models in which LSOA choice sets are restricted to practices which have a minimum number of patients from the LSOA on their list. Again the trade-off between quality and distance is similar across the different definitions of choice sets. The similarity of the estimates across the restricted choice sets is thus in line with the choice process being the same across the sets and unaffected by GP behaviour in deciding catchment areas or temporarily closing lists.[20]

[20] This may be because few patients would wish to be further away from their practice than the maximum distance GPs are willing to travel to patients.

5.6 Endogeneity and measurement error

Although we have examined a number of different quality variables, it is possible that we measure quality with error. It is also possible that practice quality is determined in part by the demographic, socio-economic and health characteristics of the patients on its list (see Appendix C). If different patient types have different preferences over practice characteristics the quality measure may be correlated with unobserved demand factors. The endogeneity bias could go either way: practices which are better could attract more complex patients with whom it is more difficult to achieve QOF points, or better educated individuals who may be easier to treat may be more likely to choose better practices. To address this we have used a lagged measure of practice quality as our preferred measure, as this reduces bias arising from unobserved patient characteristics that affect both current quality and the patient preferences towards quality.

To further allow for possible endogeneity and measurement error, we estimate a model in which we instrument practice quality by the average quality of neighbouring practices. The quality of neighbouring practices is a good predictor of practice quality because neighbouring practices will have similar types of patient who are exposed to similar environments, and will operate under similar cost conditions when producing quality. The instrument will be uncorrelated with practice demand errors provided that there are no unobservable factors affecting demand which are correlated across neighbouring practices and which affect practice quality.

We implement the instrumental variable using two stage residual inclusion (Terza et al, 2008). We first estimate an OLS model of practice quality for all practices in the choice sets of LSOAs in the East Midlands. In addition to the instrument (average quality of neighbouring practices), the first stage quality model contains the variables in the choice model, averaged over the LSOAs whose choice sets contain the practice. The practice observations are weighted by the number of LSOA choice sets in which a practice appears. The residuals from the first stage model are included in the second stage conditional logit model as an additional explanatory variable. The estimated coefficient on the quality measure in the choice model is an unbiased estimate of the effect of quality if the instrument

is valid. We bootstrap the standard errors on the coefficients in the second stage choice model. [21]

Table 11 presents the results of instrumenting our preferred measure of practice quality (total 2006/7 QOF points) with the average total 2006/7 QOF points of the practice's nearest neighbouring practices and including the residuals from the first stage quality model in the second stage. The full first stage results are in Table B2. The nearest neighbour instruments have F statistics of 18.54 for quality, which is comfortably greater than the conventional critical value of 10 (Stock et al, 2002). The residuals are significant in the 2SRI second stage models, suggesting that the quality measure is endogenous.

Table 11 reports the quality and distance estimates from the 2SRI choice model estimated on the full sample of LSOAs in column (1), the average results from 100 bootstrap replications of the choice model in column (2) and the ratio of the full sample 2SRI average marginal effect estimates to the standard deviation of the bootstrap estimates in column (3). Comparison of columns (1) and (2) show the results are not sensitive to which sample is used and column (3) shows the marginal effects are statistically significant. Instrumenting increases the estimated average marginal effect of quality from the baseline estimate of 0.00013 (Table 2) to 0.00074 for 2006/7 QOF points. This suggests that practices which provide good quality also attract more complex patients, lowering measured performance.

We also use the average quality of neighbouring practices to instrument quality as measured by average QOF points 2006/7-2009/10 and total QOF points 2009/10. The F statistics for the instruments are 19.17 and 29.62 respectively and the residuals are significant in the second stage estimates. The instrumented estimates of the average marginal effects of the quality measures are again larger than the unistrumented estimates (compare Table 4), particularly so for 2009/10 QOF points. After instrumenting the average marginal effects are very similar across the three measures of quality (0.00074 for 2006/7 QOF points, 0.00087 for averaged

[21] We draw 100 random bootstrap samples of 987 LSOAs with replacement from the set of 987 practices chosen by patients in the East Midlands. We estimate the first stage quality model for the practices in the choice sets of LSOAs in each bootstrap sample, weighting the observations by the number of times the practice appears in the choice sets (including multiple draws of the same LSOA as separate observations). We estimate the second stage choice model for each bootstrap sample of LSOAs, adding the residuals from the first stage quality regression, and weighting LSOAs by number of times they appear in the bootstrap sample. We then compute the standard deviation of the 100 estimates of the second stage coefficients.

2006/7-2009/10 QOF points, and 0.00064 for 2009/10 QOF points), again suggesting endogeneity in the raw quality measures.

5.7 Summarising the effects of quality on patient demand

In Table 12 we summarise the estimated effects of quality on practice choice and compare these with the effects of the average age of the practice GPs, the proportion of female GPs, and the proportion who qualified outside Europe. We compare the effects of $1/10^{th}$ standard deviation increases in each of the variables. In addition to the average marginal effects (the change in probability that a patient will choose the practice in response to the change in the practice characteristic or quality), we report the extra distance in metres patients would be willing to travel to be in a practice whose characteristic or quality had increased,[22] the number of additional patients a practice would gain, and the elasticity of practice numbers with respect to the characteristic or quality. We report the calculations for our baseline model using un-instrumented quality and for the 2SRI model of Table 11.

Using first the estimates from our uninstrumented baseline model, column (1) shows that the absolute magnitudes of the average marginal effects of quality is small compared to other features of the GP practice. The increase in the probability of a practice being chosen by a patient if its QOF points increase by $1/10^{th}$ standard deviation is 0.00082, which is similar to the effect of a one standard deviation in average age of a GP but considerably smaller than the response to a one standard deviation change in the proportion female or trained outside the EU. Column (2) shows patients are willing to travel 12.4 metres for a one standard deviation in QOF points, whereas they would be willing to travel between an extra 56.7 metres to a practice with a $1/10^{th}$ SD greater proportion of female GPs.

However, what matters in terms of the incentives for practices to increase quality is the number of patients they will gain. This depends both on the effect of quality on the probability of a patient choosing the practice and the number of patients in whose choice set the practice lies. An average practice has 74,529 potential patients aged 25 and over resident within 5 km and 25,070 within 2 km. Column (3) shows that the estimated increase in practice patients from a $1/10^{th}$ SD increase in quality is 103.6. Thus although the effect of a

[22] This is equal to 1000 times marginal rate of substitution between quality or the practice characteristic and distance measured in kilometres, as defined in section 4.2 in (10).

1/10th standard deviation increase in quality on the probability of an individual patient choosing the practice is small, the number of additional patients gained by the practice is not trivial, though smaller then the number of patients gained by 1/10 standard deviation increases in the proportion of GPs that are female or trained inside the EU (486 and 1342 respectively).

Column (4) presents the elasticity of practice demand with respect to quality. This measure is scale invariant and so is not affected by differences in the variance of the quality measure and the practice covariates (which does affect the comparison of the estimates in columns (2) and (3)). This quality elasticity is large: a 1% increase in 2006/7 QOF points implies a 1.44% increase in practice list size. Thus quality appears to be important to patient choice. Results in the right hand panel (columns (5) to (7)) of the table use the less conservative instrumented measure. They reinforce the importance of quality, as the average marginal effect of quality estimate in column (5) is nearly 6 times as high as that in column (1). If this estimate is used, then the average patient would be willing to travel an extra 31 metres for a 1/10th of a standard deviation increase in quality, which would result in a gain of an extra 260 patients for the practice. These estimates suggest a very high quality elasticity of nearly 3.6.

6 Conclusion

The issue of whether choice and competition will increase quality of health care services is both current and important. A pre-requisite for increased competition to increase quality is that demanders are responsive to quality. We have tested whether they do in an important setting – the choice by patients of their family physicians who, in the context we examine, determine access to all health care services at zero direct monetary cost for the patient.

We examine the choices of 3.4 million patients from amongst nearly 1000 family doctor practices. We find quality is important: patients are more likely to choose practices with higher measured (and published) clinical quality. Patients trade off quality against distance. The results are robust to alternative estimation methods, to the way in which distance was assumed to affect choice of practice, to possible restrictions on patient choice sets and across age, gender and socio-economic circumstances of patients. While the effect of quality on the probability of an individual patient choosing a family practice is small, this does not translate into a small incentive for practices to increase quality in order to attract more patients. What

matters for practices is how many additional patients will be attracted by an increase in quality and this depends both on the small effect of quality on the probability of choice by an individual patient and on the large number of patients who could choose the practice. Using the most conservative of our model specifications we estimate that a one standard deviation increase in measured clinical quality would attract approximately 15 percent more patients to a family practice. Thus practices seeking to attract patients could do so by raising quality. If the marginal revenue from additional patients sufficiently exceeds their marginal cost so as to cover the costs of higher quality then greater competition in this market could potentially improve quality for patients.

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Figure 1. East Midlands SHA: practice locations and LSOAs

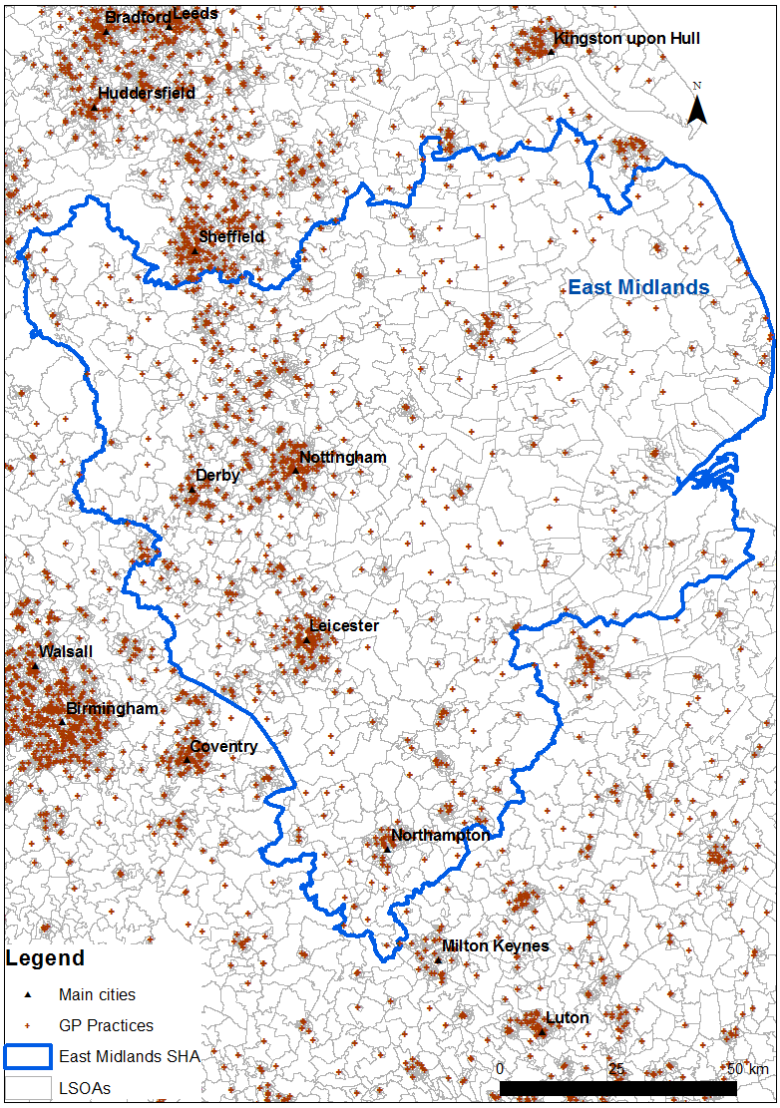
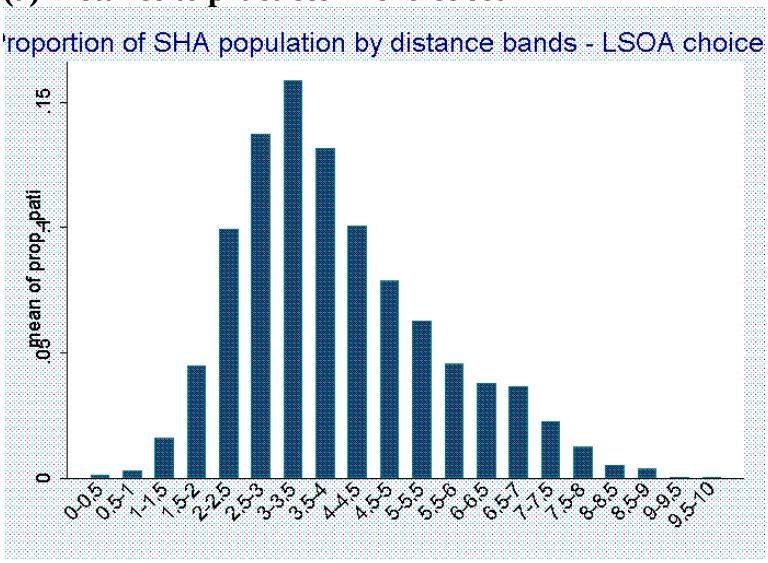


Figure 2. Distributions of distances to nearest practice and to practice chosen

(a) Distance to practices in choice set



(b) Distance to practice chosen

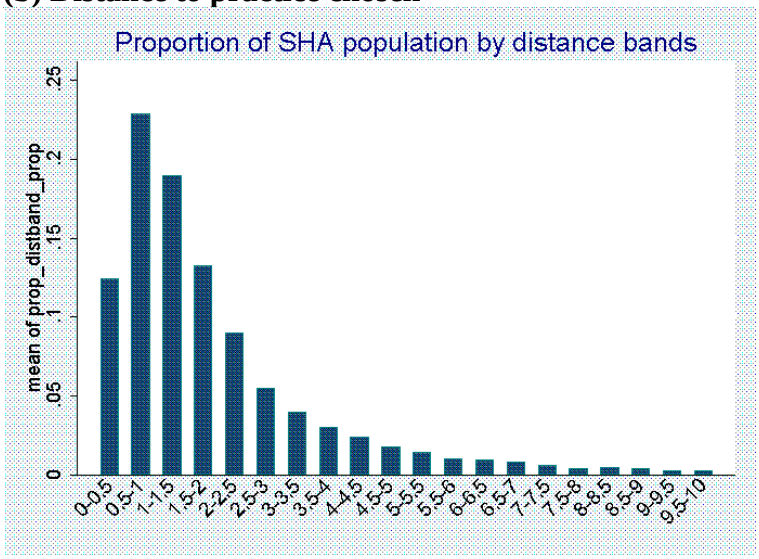
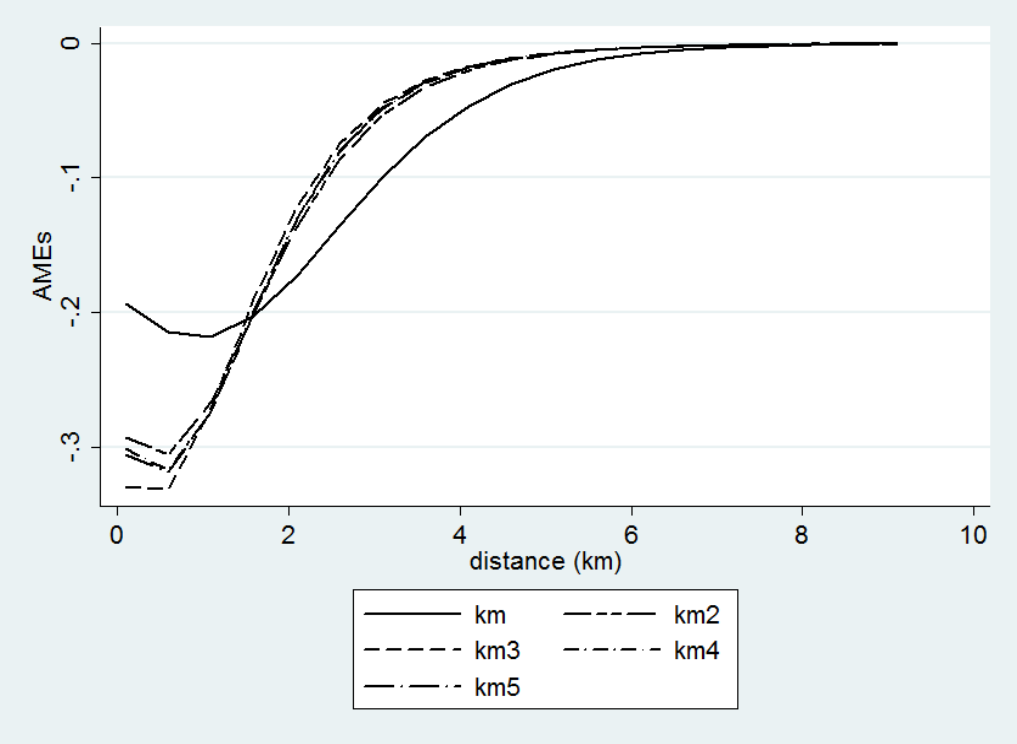


Figure 3. Estimates of the average marginal effects of distance



Notes: Plot of the average marginal effects of distance for linear (km), quadratic (km2), cubic (km3), quartic (km4), and quintic (km5) specifications for models in Table 5.

Table 1. Descriptive statistics

	mean	sd	min	max	N
GP practice characteristics					
Average GP age 2009	47.9	6.7	31.5	72.5	994
Proportion female GPs 2009	0.362	0.248	0	1	994
Proportion GPs trained outside Europe 2009	0.267	0.354	0	1	994
Opted out of out of hours care 2009	0.613	0.487			994
PMS contract 2009	0.479	0.500			994
Dispensing practice 2009	0.204	0.403			994
Patients[1] aged 25 and over registered with practice	4886	3063	653	24988	994
Total patients[1] registered with practice	7020	4412	1087	34946	994
Quality measures					
QOF 2006/7 clinical points	632.8	36.4	330.5	655	987
QOF 2006/7 organisational points	166.5	21.0	13.2	181	987
QOF 2006/7 patient experience points	103.3	16.1	0	108	987
QOF 2006/7 additional services points	35.3	2.8	6	36	987
QOF 2006/7 holistic care points	18.3	3.1	0	20	987
QOF 2006/7 total points	956.1	63.6	426.5	1000	987
Population achievement 2009/10	0.721	0.041	0.379	0.829	985
Reported achievement 2009/10	0.782	0.041	0.484	0.887	985
QOF 2009/10 total points	940.5	46.9	545.5	1000	994
Average QOF total points 2006/7-2009/10	954.6	44.8	545.5	1000	994
ACSCs 2006/7 per 10,000	259	76	28	679	989
Overall patient satisfaction 2009	0.89	0.06	0.57	0.99	994
Satisfaction with opening hours 2009	0.80	0.06	0.45	0.97	994
Prop patients would recommend practice 2009	0.82	0.10	0.38	0.99	994
Average distances from LSOA to practices					
Distance to practices in LSOA choice set (km)	4.833	1.647	0.348	9.888	2875
Distance to chosen practice (km)	1.892	1.336	0.125	9.867	2875
Distance to nearest practice (km)	1.198	1.164	0.023	9.81	2875
Practices in different PCT					
Proportion practices in choice set in different PCT	0.272	0.445	0	1	2875
Proportion practices chosen in different PCT	0.191	0.393	0	1	2875
Proportion of nearest practices in different PCT	0.049	0.216	0	1	2875
LSOA characteristics					
Proportion female	0.507	0.022	0.276	0.618	2875
Proportion pop in fair or good self-rated health	0.907	0.032	0.760	0.983	2875
Proportion of adults without qualification	0.231	0.071	0.035	0.430	2875
Proportion non white	0.065	0.130	0	0.948	2875
Income deprivation score	0.143	0.110	0.013	0.830	2875
Urban	0.731	0.444			2875
Proportion of LSOA registered at nearest practice	0.399	0.263	0.001	0.998	2875
Number of practices in LSOA choice set	22.3	10.2	1	30	2875

[1] Whether resident in the East Midlands SHA or outside it.

Table 2. Estimated marginal effects of quality, distance and practice characteristics

	Average Marginal Effect	z
QOF 2006/7 Total points	0.00013	6.87
Distance (cubic)	-0.06778	-14.18
Practice in different PCT	-0.04751	-10.12
GP age	-0.00144	-13.31
Prop female GPs	0.01508	6.12
Prop GPs non Europe trained	-0.03029	-10.36
Opted Out	0.00543	2.49
PMS contract	0.00564	2.95
BIC	11714907	
McFadden R^2	0.3955	
N LSOA	2,870	
N GP practices	987	
N patients	3,364,263	

Notes: Table reports average marginal effects of variables on number of patients aged 25 and over registered with the practice. Models also contained a dummy for missing PMS status.

Table 3. Comparison of models with alternative QOF based quality measures

Quality measured by	QOF 2006/7 total points (1)		QOF 2006/7 total points (2)		QOF 2006/7 clinical points (3)		Av 2006/7-09/10 total points (4)		QOF 2009/10 total points (5)	
	AME	z	AME	z	AME	z	AME	z	AME	z
QOF 2006/7 total points	0.00013	6.87								
QOF 2006/7 clinical points			0.00015	2.71	0.00019	5.69				
QOF 2006/7 organisational points			0.00018	4.90						
QOF 2006/7 patient experience			-0.00003	-0.78						
QOF 2006/7 additional services			0.00139	4.12						
QOF 2006/7 holistic care points			-0.00020	-0.47						
Av QOF total points 2006/7-2009/10							0.00026	6.947		
QOF 2009/10 total points									0.000017	2.569
Distance (cubic)	-0.06778	-14.18	-0.07626	-9.83	-0.06695	-12.00	-0.09046	-17.89	-0.03005	-7.334
BIC	11714907		11710963		11724753		11783137		11806537	
McFadden R2	0.3955		0.3957		0.3950		0.3949		0.3937	
N LSOA	2870		2870		2870		2870		2870	
N GP practices	987		987		987		994		994	
N patients	3364263		3364263		3364263		3372124		3372124	

Notes: Table reports average marginal effects. Models also contain same covariates as model in Table 2.

Table 4. Models with quality measured by patient satisfaction

	Quality measure: overall satisfaction				Quality measure: access satisfaction				Quality measure: would recommend			
	(1)		(2)		(3)		(4)		(5)		(6)	
	AME	z	AME	z	AME	z	AME	z	AME	z	AME	z
QOF 2006/7 total points			0.00012	6.338			0.00012	6.322			0.00013	6.996
Overall Satisfaction	0.24984	41.60	-0.00725	-0.885								
Access Satisfaction					-0.18348	-5.50	-0.01072	-1.571				
Would recommend									0.27598	225.71	0.02226	3.121
Distance (cubic)			-0.06504	-10.928			-0.06419	-11.372			-0.07284	-15.016
BIC	19439563		11714835		19466172		11714636		19374984		11713209	
McFadden R2	0.0018		.3955		0.0004		.3955		0.0051		.3956	
N LSOA	2870		2870		2870		2870		2870		2870	
N GP practices	994		987		994		987		994		987	
N patients	3372124		3364263		3372124		3364263		3372124		3364263	

Notes: Table reports average marginal effects. Models (2), (4), (6) contain same practice covariates as model in Table 2.

Table 5. Alternative distance specifications

	Linear		Quadratic		Cubic		Quartic		Quintic		Log distance	
	AME	z	AME	z	AME	z	AME	z	AME	z	AME	z
QOF 2006/7 Total points	0.00019	7.89	0.00014	7.10	0.00013	6.87	0.00013	6.96	0.00013	6.94	0.00026	6.45
Distance	-0.07747	-16.36	-0.06962	-14.60	-0.06778	-14.18	-0.06914	-14.34	-0.06894	-14.24	-0.21689	-13.44
BIC	11886627		11720567		11714907		11713827		11713833		12363341	
McFadden R^2	0.3867		0.3952		0.3955		0.3956		0.3956		0.3621	
N LSOA	2,870		2,870		2,870		2,870		2,870		2,870	
N GP practices	987		987		987		987		987		987	
N patients	3,364,263		3,364,263		3,364,263		3,364,263		3,364,263		3,364,263	

Notes: Table reports average marginal effects. The average marginal effect of distance in the log distance model is the effect of a unit increase in log km. Models contain same practice covariates as model of Table 2.

Table 6. Age and gender specific models of practice choice

(a) Female patients

	Female patients		Female 25-34		Female 35-44		Female 45-64		Female 65-74		Female 75+	
	AME	z	AME	z	AME	z	AME	z	AME	z	AME	z
QOF 2006/7 Total points	0.00014	6.90	0.00012	6.30	0.00017	7.17	0.00016	6.80	0.00012	5.46	0.00010	4.88
Distance (cubic)	-0.06828	-14.12	-0.07407	-12.96	-0.07696	-15.69	-0.06912	-14.20	-0.05783	-10.68	-0.05428	-9.36
BIC	5821715		1065304		1190200		2131564		724667		705954	
McFadden R2	0.4027		0.3969		0.4006		0.3960		0.4080		0.4315	
N LSOA	2870		2870		2870		2870		2870		2870	
N GP practices	987		987		987		987		987		987	
N patients	1695176		296655		342635		619342		217724		218734	

(b) Male patients

	Male patients		Male 25-34		Male 35-44		Male 45-64		Male 65-74		Male 75+	
	AME	z	AME	z	AME	z	AME	z	AME	z	AME	z
QOF 2006/7 Total points	0.00012	6.75	0.00006	4.33	0.00014	6.99	0.00015	6.94	0.00011	5.26	0.00012	5.47
Distance (cubic)	-0.06727	-14.09	-0.06176	-9.82	-0.07498	-15.14	-0.07039	-14.93	-0.05593	-10.44	-0.06042	-10.73
BIC	5892072		1159008		1284654		2241766		702826		499963	
McFadden R2	0.3884		0.3779		0.3893		0.3865		0.3966		0.4109	
N LSOA	2870		2870		2870		2870		2870		2870	
N GP practices	987		987		987		987		987		987	
N patients	1668912		311551		359641		638990		207999		150643	

Notes: Table reports average marginal effects. Models contain same practice covariates as model of Table 2.

Table 7. Models stratified by socioeconomic characteristics of small areas (LSOAs)

(a) Rurality, income deprivation, education.

	Rurality				Income deprivation				Proportion adults with no formal education			
	Urban		Rural		Lowest 4 quintiles		Top quintile		Lowest 4 quintiles		Top quintile	
	AME	z	AME	z	AME	z	AME	z	AME	z	AME	z
QOF 2006/7 Total points	0.00017	7.98	0.00003	1.80	0.00014	6.10	0.00010	3.40	0.00013	5.81	0.00014	4.10
Distance (cubic)	-0.08518	-16.35	-0.01548	-3.47	-0.06056	-12.19	-0.09852	-8.22	-0.06336	-11.64	-0.09623	-10.48
BIC	9447553		2247370		9039531		2648384		9386616		2316353	
McFadden R2	0.365		0.501		0.410		0.346		0.396		0.397	
N LSOA	2100		770		2295		575		2295		575	
N GP practices	811		867		984		676		982		744	
N patients	2417776		946487		2720471		643792		2712696		651567	

(b) Self assessed health, Asian ethnicity

	Proportion with poor self assessed health				Proportion of Asian ethnicity			
	Lowest 4 quintiles		Top quintile		Lowest 4 quintiles		Top quintile	
	AME	z	AME	z	AME	z	AME	z
QOF 2006/7 Total points	0.00016	6.51	0.00007	2.77	0.00011	5.18	0.00021	5.93
Distance (cubic)	-0.07075	-13.60	-0.06246	-6.06	-0.05234	-10.40	-0.12061	-13.22
BIC	9322153		2383773		8469297		3221563	
McFadden R2	0.393		0.408		0.430		0.287	
N LSOA	2296		574		2294		576	
N GP practices	977		772		980		601	
N patients	2707346		656917		2687812		676451	

Notes: Table reports average marginal effects. Models also contained a dummy for missing PMS status. Models contain same practice covariates as model in Table 2.

Table 8. Comparison of mixed and conditional logit models

	Mixed logit		Conditional logit	
	Mean of coefficients	z	Coefficient	t
QOF 200607 Total points	0.0029	11.548	0.00224	14.584
Practice in different PCT	-0.891	-10.551	-0.826	-19.004
Distance	-1.556	-38.506	-1.563	-40.057
Distance squared	0.109	9.058	0.121	10.545
Distance cubed	-0.00417	-4.575	-0.00432	-4.881
GP age	-0.0254	-15.52	-0.025	-15.681
Proportion female GPs	0.262	7.771	0.262	7.85
Proportion GPs non Europe trained	-0.522	-18.954	-0.527	-19.333
Opted out	0.0998	2.732	0.0943	2.613
PMS	0.104	3.281	0.098	3.133
Standard deviation of coefficients				
QOF 200607 Total points	0.00317	7.019		
LSOAs from different PCTs	-0.478	-1.762		
Distance km	0.214	8.283		
Distance squared km	-0.00439	-1.563		
Distance cubed km	0.000341	1.979		
GP age	0.00633	1.226		
Female GPs	0.0071	0.2		
GPs trained outside Europe	-0.048	-0.847		
Opted out	0.308	2.088		
PMS	0.0759	0.344		
BIC	11704471		11714907	
McFadden R2	.		0.3955	
N LSOA	2870		2870	
N GP practices	987		987	
N patients	3364263		3364263	

Notes: Table reports coefficients. Models also contain a dummy for missing PMS status.

Table 9. Choice sets: different radii

Choice set radius	10km		8km		6km		4km		2km	
	AME	z	AME	z	AME	z	AME	z	AME	z
QOF 2006/7 total points	0.00013	6.87	0.00014	6.94	0.00019	7.07	0.00029	7.76	0.00044	7.98
Distance (cubic)	-0.06778	-14.18	-0.07751	-14.2	-0.09964	-14.72	-0.15248	-16.76	-0.26363	-23.16
BIC	11714907		11262610		10556052		9096439		5279364	
McFadden R2	0.3955		0.3621		0.3094		0.2267		0.1056	
N LSOA	2870		2806		2670		2428		1925	
N GP practices	987		931		855		729		605	
N patients	3296554		3195654		3008865		2665613		1844381	

Notes: Table reports average marginal effects from models in which the LSOA choice sets are restricted to practices within stated radii. Models contain same practice covariates as model in Table 2.

Table 10. Choice sets: practices with minimum numbers of patients from LSOA

Minimum patients from LSOA in practice	0 patients		1 patient		5 patients		10 patients		20 patients		50 patients	
	AME	z	AME		AME	z	AME	z	AME	z	AME	z
QOF 2006/7 total points	0.00013	6.87	0.00019	7.18	0.00026	7.47	0.00029	7.82	0.00032	7.99	0.00031	7.07
Distance (cubic)	-0.06778	-14.18	-0.09690	-15.60	-0.12680	-18.01	-0.14037	20.94	-0.14739	-24.43	-0.13713	-25.88
BIC	11714907		11351519		10649668		10056703		9195685		7367098	
McFadden R2	0.3955		0.2983		0.2126		0.1711		0.1284		0.0717	
N LSOA	2870		2865		2842		2802		2765		2670	
N GP practices	987		889		814		774		751		719	
N patients	3364263		3353087		3298413		3220697		3118525		2850124	

Notes: Table reports average marginal effects from models in which LSOA choice sets are restricted to practices chosen by minimum numbers (0 to 50) of patients from the LSOA. Models contain same practice covariates as model in Table 2.

Table 11. Instrumented quality

	Full sample AME (1)	Av AME bootstrap models (2)	z (3)
QOF 2006/7 Total points	0.00074	0.00073	4.35
QOF 2006/7 residuals	-0.00044	-0.00044	-3.02
Different PCT	-0.10942	-0.10701	-9.85
Distance (cubic)	-0.11108	-0.10686	-18.82
GP age	-0.00281	-0.00266	-11.50
Female GPs	0.03084	0.02916	6.52
GPs non Europe trained	-0.06328	-0.06204	-10.26
Opted out	0.00803	0.00815	1.78
PMS	0.01021	0.00991	2.36
BIC	11713232	11720971	
McFadden R2	0.3956	0.3955	
N LSOA	2870	1816	
N GP practices	987	965	
N patients	3364263	2128248	
F statistic on first stage IV	18.53		

Notes: Results from two stage residual inclusion (2SRI) conditional logit models. For each model we report the results from the 2SRI model estimated with the full sample of LSOAs, the average of the bootstrap results from 100 replications, and ratio of the observed average marginal effect to the standard deviation of the bootstrap average marginal effects. All models also included a dummy for imputed PMS status.

Table 12. Estimated effect sizes for quality and other practice characteristics

	Estimates from un-instrumented models				Estimates from instrumented models			
	AME (1)	Extra metres (2)	Patients gained (3)	Elasticity (4)	AME (5)	Extra metres (6)	Patients gained (7)	Elasticity (8)
2006/7 QOF points ($1/10^{th}$ SD increase)	0.00082	12.4	103.6	1.44	0.00472	31.0	255.9	3.59
Standard error	0.00012	0.9	9.4	0.06	0.00108	5.3	30.1	0.59
Av age GPs ($1/10^{th}$ SD increase)	-0.00096	-14.6	-120.6	0.003	-0.00188	-12.4	-102.1	0.00
Standard error	0.00007	0.9	5.3	0.00	0.00016	1.2	6.2	0.00
Prop female GPs ($1/10^{th}$ SD increase)	0.00374	56.7	468.1	0.07	0.03824	50.2	414.8	0.06
Standard error	0.00061	7.2	47.3	0.01	0.00586	7.3	45.3	0.01
Prop non-European trained GPs ($1/10^{th}$ SD increase)	-0.01072	-162.7	-1342.4	-0.08	-0.11200	-147.2	-1215.1	-0.07
Standard error	0.00103	-8.7	93.6	0.00	0.01091	-9.6	90.6	0.00

Notes: $1/10^{th}$ SD 2006/7 points 6.36; $1/10^{th}$ SD average GP age: 0.67 years; $1/10^{th}$ SD proportion female GPs: 0.025. $1/10^{th}$ SD proportion non-European trained GPs: 0.035. AME: average marginal effect. Metres: number of metres patients would be willing to travel to practice with one unit higher value of characteristic. Patients gained: number of additional patients aged 25 and over choosing a practice if characteristic increased by one standard deviation. Elasticity: percentage increase in number of patients aged 25 and over choosing a practice from a one percent increase in the characteristic.

Appendix A

Table A.1 Data sources

Data set	Variables	Source
Attribution Data Set	Nos patients in each LSOA by age/gender on list of each practice	NHS Information Centre for Health and Social Care.
Quality and Outcomes Framework	QOF points total and by indicator; numbers for whom indicator achieved, exceptions.	www.ic.nhs.uk/statistics-and-data-collections/audits-and-performance/the-quality-and-outcomes-framework.
GP Patient Survey	Patient satisfaction with practice	www.gp-patient.co.uk/archive_weighted/practicereport
Hospital Episode Statistics	Emergency admissions for ambulatory care sensitive conditions	www.hesonline.nhs.uk
General Medical Service Statistics	Age, gender, country of qualification of GPs, practice contract, out of hour status, dispensing status, location.	NHS Information Centre for Health and Social Care
NHS Choices	Location of branch practices	www.nhs.uk/Pages/HomePage.aspx
Neighbourhood Statistics	Socio-economic and demographic measures at LSOA level	www.neighbourhood.statistics.gov.uk/dissemination
Index of Multiple Deprivation	LSOA income deprivation;	www.communities.gov.uk/publications/communities/indiciesdeprivation07
Office of National Statistics	LSOA rurality classification	www.ons.gov.uk/ons/guide-method/geography/products/area-classifications/index.html

Table A2. Ambulatory Care Sensitive Conditions: ICD10 Codes

Asthma	J45 J46
Circulatory system	I110 I130 I132 I10 I119 I129 I139
COPD	J20 J41 J42 J43 J44 J47 J40
Stroke/LVD	I60 I61 I63 I64 I66 I672 I698 R470
EPILEPSY	G40 G41 R56 G253 R568
CHD/LVD	I20 I240 I248 I249 I25 R072 I21 I22 I110 I130 I132 I255 I50 J81
Diabetes	E110 E111 E112 E113 E114 E115 E116 E117 E118 E119 E10 E120 E121 E122 E128 E130 E131 E132 E133 E134 E135 E136 E137 E138 E140 E141 E142 E143 E144 E145 E146 E147 E148
DKD or Dementia	N03 F00 F01 F02 F03
Alcohol-related disease	F10
Perforated appendix	K350 K351
Dehydration & gastroenteritis	A020 A04 A059 A072 A080 A081 A083 A082 A084 A085 A09 E86 K520 K521 K522 K528 K529
Cellulitis	I891 L010 L011 L020 L021 L022 L023 L024 L028 L029 L03 L04 L080 L088 L089 L88 L980
ENT	H66 H67 J02 J03 J040 J06 J312
Gangrene	R02
Influenza and pneumonia	A481 A70 J10 J11 J120 J121 J122 J128 J129 J13 J14 J153 J154 J157 J159
	J160 J168 J18 J181 J189 J180 J188
Iron-deficiency anaemia	D460 D461 D463 D464 D501 D508 D509 D510 D511 D512 D513 D518 D520 D521 D528 D529 D531 D571 D580 D581 D590 D591 D592 D599 D601 D608 D609 D610 D611 D640 D641 D642 D643 D644 D648 E40 E41 E42 E43 E550 E643
Other vaccine preventable diseases	A35 A36 A37 A80 B05 B06 B161 B169 B180 B181 B26 G000 M014
Pelvic inflammatory	N70 N73 N74
Perforated/bleeding ulcer	K20 K210 K219 K221 K226 K250 K251 K252 K254 K255 K256 K260 K261 K262 K264 K265 K266 K270 K271 K272 K274 K275 K276 K280 K281 K282 K284 K285 K286 K920 K921 K922
Atrial fibrillation and flutter	I498 R000 I471 I479 I499 R002 R008 I495
Constipation	K590
Urinary infection	N11 N136 N10 N151 N159 N12 N390 N300 N309 N308
Fracture proximal femur	S722 S720 S721
Peripheral vascular disease	I73 I738 I739
Failure to thrive	R629
Dyspepsia	K21 K30
Hypokalemia	E876
Low birth weight	P050 P052 P059 P072 P073
Migraine	G43 G440 G441 G443 G444 G448 R51
Tuberculosis	A15 A16 A17 A18 A19
Dental conditions	A690 K098 K099 K02 K03 K04 K05 K06 K08 K12 K13

Table A3. Correlations between quality measures

	QOF 2006/7 clinical points	QOF 2006/7 organisational	QOF 2006/7 patient experience	QOF 2006/7 additional services	QOF 2006/7 holistic care	QOF 2006/7 total points	QOF 009/10 total points	2006/7-09/10 total points 2006/7-2009/10	ACSCs 2006/7	Would recommend 2009	Overall patient satisfaction 2009	satisfaction witn opening hours	Populattion achievement 2009/10
QOF 2006/7 organisational	0.531	1.000											
QOF 2006/7 patient experience	0.354	0.443	1.000										
QOF 2006/7 additional services	0.388	0.513	0.549	1.000									
QOF 2006/7 holistic	0.916	0.494	0.320	0.357	1.000								
QOF 2006/7 total points	0.897	0.791	0.638	0.589	0.831	1.000							
QOF 2009/10 total points	0.511	0.351	0.207	0.243	0.489	0.494	1.000						
Average QOF total points 2006/7-2009/10	0.812	0.656	0.467	0.478	0.766	0.856	0.805	1.000					
ACSCs 2006/7	-0.108	-0.049	-0.059	-0.096	-0.089	-0.101	-0.163	-0.147	1.000				
Proportion patients who would recommend practice 2009	0.199	0.182	0.204	0.175	0.225	0.244	0.380	0.377	-0.239	1.000			
Overall patient satisfaction 2009	0.152	0.151	0.172	0.143	0.181	0.194	0.363	0.332	-0.187	0.917	1.000		
Satisfaction with opening hours 2009	0.039	0.071	0.041	0.035	0.045	0.060	0.307	0.199	0.019	0.551	0.651	1.000	
Population achievement 2009/10	0.467	0.232	0.114	0.168	0.441	0.401	0.752	0.611	-0.119	0.167	0.160	0.151	1.000
Reported achievement 2009/10	0.431	0.222	0.108	0.166	0.405	0.373	0.833	0.627	-0.133	0.142	0.126	0.141	0.868

Appendix B. Additional results

Table B1. Models with alternative clinical quality measures

	Baseline model (Quality measure: total 2006/7 QOF points)		Quality measure: reported achievement 2009/10		Quality measure: population achievement 2009/10		Baseline plus ACSCs 2006/7	
	AME	z	AME	z	AME	z	AME	z
QOF 2006/7 total points	0.00013	6.87					0.00012	6.514
Reported achievement 2009/10			-0.00221	-1.079				
Population achievement 2009/10					0.00029	0.1073		
ACSCs 2006/7							-0.000004	-0.58
Distance (cubic)	-0.06778	-14.18	-0.016	-6.869	-0.0182	-7.578	-0.06659	-13.122
BIC	11714907		11808124		11808224		11674461	
McFadden R2	0.3955		0.3936		0.3936		0.3960	
N LSOA	2870		2870		2870		2869	
N GP practices	987		994		994		985	
N patients	3364263		3372124		3372124		3355743	

Notes. Average marginal effects and z statistics reported. All models also contain same covariates as Table 2. Reported achievement for practice *j* is $\sum_q \left(N_{jq} / D_{jq}\right)\left(\pi_q^{\max}\right) / \left(\sum_q \pi_q^{\max}\right)$ where N_{jq} is the number of patients for whom QOF clinical indicator *q* is achieved by practice *j*, D_{jq} is the number of patients who are declared eligible for indicator *q*, $\pi_q^{\max}$ is the maximum number of points achievable for indicator *q*. Population achievement is $\sum_q \left(N_{jq} / \left(D_{jq} + E_{jq}\right)\right)\left(\pi_q^{\max}\right) / \left(\sum_q \pi_q^{\max}\right)$ where E_{jq} is the number of patients exception reported for indicator *q* by practice *j*. ACSCs is the number of emergency admissions for ambulatory care sensitive conditions of practice patients per 10,000 patients registered with the practice.

Table B2. First stage estimates of practice quality (total 2006/7 QOF points)

	Coefficient (t stat)
Different PCT	9.624
	(1.739)
Distance	-5.287
	(-0.896)
Distance squared	-0.0685
	(-0.053)
Distance cubed	0.0647
	(0.642)
GP age	-1.167
	(-3.407)
Female GPs	11.25
	(1.355)
GPs non Europe trained	-19.16
	(-2.992)
PMS	5.895
	(0.962)
PMS imputed	-77.16
	(-4.200)
Opted Out	7.109
	(1.130)
2 NN QOF 2006/7	0.177
	(4.306)
Constant	846.3
	(18.451)
Observations	987
BIC	10988
F statistic	18.54

Notes. The model is for the first stage of the two stage residual inclusion patient choice model reported in Table 11. The dependent variable is total 2006/7QOF points. *Different PCT, Distance, Distance squared, Distance cubed* are the averages of these practice-LSOA variables over the LSOAs whose choice sets included the practice. *2 NN QOF 2006/7* is the average of QOF total points 2006/07 in the practice's two nearest neighbours. The F statistic is for the instrument.

Appendix C. Practice choice of catchment area and quality

Suppose that practice *j* sets a catchment area defined by a radius k_j from its surgery. It accepts all patients who wish to join the practice provide they live within the catchment area. The choice set for the LSOA is the set of practices within whose catchment areas the LSOA falls:

$$C_a = \left\{ j \middle| d_{aj} \le k_j \right\} \quad \text{(C1)}$$

We do not observe k_j. We estimate models of patient choice by specifying the LSOA *a* choice set to be all practices *j* within a radius *k* of the LSOA centroid ie we specify the choice set to be

$$C_a^k = \{ j \middle| d_{aj} \le k \} \quad \text{(C2)}$$

If we estimate patient choice models where we only include observations of n_{aj} within a radius *k* from the LSOA centroid and $k > k_j$ for some *j* then the conditional logit model may not yield consistent estimates of patient preferences. If there are LSOAs and practices for which $k > d_{aj} > k_j$ we will not observe any patients from *a* choosing practice *j* but this is due to the choice of catchment area by practice j and does not reflect choices by patients. The estimated coefficients will depend on patient preferences *and* the factors affecting practice decisions on catchment areas.

McFadden (1974) has shown that, when the observed choices maximise a linear utility function where the errors in the utility function follow the extreme value distribution, the estimated conditional logit model coefficients are consistent estimates of the marginal utility from choice characteristics. A subsequent paper (McFadden, 1978) proves that this result also holds when the model is estimated on a data set in which the set of alternatives for each individual satisfies the same type of arbitrary restriction.

Thus if we estimate models where we specify choice sets with

$$k \le \min_j \{k_j\} \quad \text{(C3)}$$

so that none of the practice catchment area constraints bind, we will produce consistent estimates of patient preferences over characteristics of practices. The smaller the *k* defining the choice sets for the estimated model, the more likely is it that the estimated coefficients are the consistent estimates of patient marginal utility. But the smaller is *k* the fewer the number of observations satisfying the constraint and the less the precise the estimates.

These conclusion hold even though the practice catchment area is chosen to maximise practice utility and even if the practice takes account of the possible effect of catchment area on its quality and hence on patient demand. The set of LSOAs within the catchment area is

$$S_j = S(k_j) = \{a | d_{aj} \leq k_j\}. \qquad \text{(C4)}$$

where d_{aj} is the distance from LSOA to practice j. The expected list of practice j is

$$\begin{aligned} n_j = \sum_h n_j^h = \sum_{a \in S_j} \sum_h n_{aj}^h = \sum_{a \in S_j} \sum_h n_a^h P_{aj}^h \\ = \sum_{a \in S_j} \sum_h n_a^h P^h(q_j, d_{aj}; \mathbf{q}_{-j}, \mathbf{d}_{-j}^a, \mathbf{k}_{-j} \cdot) \\ = n(q_j, k_j; \mathbf{d}_j, \mathbf{q}_{-j}, \mathbf{d}_{-j}, \mathbf{k}_{-j}, \cdot) \qquad \text{(C5)} \end{aligned}$$

where n_j^h is the number of patients of type h who chose the practice, n_{aj}^h is the number of patients of type h from LSOA a who choose practice j, n_a^h is number of patients of type h in LSOA a. $\mathbf{q}_{-j}$, is the vector of the qualities of all other practices, $\mathbf{d}_{-j}^a$ is the vector of distances to all other practices from LSOA a, and $\mathbf{k}_{-j}$ is the vector of the catchment area radii of all other practices. $P_{aj}^h = P^h(q_j, d_{aj}, \cdot)$ is probability that a patient of type h in LSOA a chooses practice j.

The list of practice j is increasing in the size of its catchment area and its quality, and decreasing in the size of other practices' catchment areas and quality.

Practice quality q_j is increasing in the effort by the practice and possibly decreasing in its catchment area if nearby patients are more likely to attend the practice to enable it to achieve its quality indicators. Quality may also depend on the mix of patient types on the practice list

$$q_j = q(e_j, k_j, \mathbf{n}_j^h), \qquad q_{ej} > 0,\ q_{kj} \leq 0 \qquad \text{(C6)}$$

where $\mathbf{n}_j^h = (n_j^1, ..., n_j^H)$. Substituting $n_j^h = \sum_a n_{aj}^h P_{aj}^h$ into (C6) and using the implicit function theorem,[23] we can write the quality production function as

$$q_j = q^o(e_j, k_j; \mathbf{d}_j, \mathbf{q}_{-j}, \mathbf{d}_{-j}, \mathbf{k}_{-j}, \cdot) \qquad \text{(C7)}$$

where we allow for the indirect effects of e_j and k_j on quality via their effect on the mix of patients. Note that, although the practice can set a catchment area, it is not permitted to

[23] We assume that $1 < \sum_h \left(\partial q / \partial n_j^h\right)\left(\partial n_j^h / \partial q_j\right)^{-1}$ so that $q_e^o > 0, q_k^o \leq 0$.

directly select by type amongst patients in the catchment area. It will however take account of the effect of its choice of catchment area on the mix of patients.

Practice revenue depends on quality (via the QOF) and on the number of patients and costs are increasing in the number of patients, effort and the distance to patients:

$$R_j = R(n_j, q_j, \cdot), \qquad R_n > 0,\ R_q > 0 \tag{C8}$$

$$c_j = c(n_j, e_j, k_j, \cdot), \qquad c_n > 0,\ c_e > 0,\ c_k > 0 \tag{C9}$$

Practice j is altruistic and cares about practice income and quality

$$u_j = u(y_j, q_j) = u(R_j - c_j, q_j), \quad u_y > 0,\ u_q > 0 \tag{C10}$$

and chooses effort and catchment area to satisfy

$$u_y\left[\left(R_q + R_n n_q\right) q_e^o - c_n n_q q_e^o - c_e\right] + u_q q_e^o = 0 \tag{C11}$$

$$u_y\left[R_n\left(n_k + n_q q_k^o\right) - c_n\left(n_k + n_q q_k^o\right) - c_k\right] = 0 \tag{C12}$$

In the Nash equilibrium where all practices choose their optimal e_j and k_j taking the decisions of other practices as given, the quality and catchment area of each practice will depend on parameters in the practice revenue, cost and utility functions and, via the demand function, on parameters in the patient utility function and on the parameters in the revenue, cost and utility functions of all other practices. Individual patients will ignore the effect of their decisions on practice quality since even when quality depends on the patient mix a decision by a patient to join a practice will have a negligible effect on practice quality.