The impact of primary care supply on quality of care in England

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Abstract

Background: Previous research has shown that greater supply of general practitioners (GPs) per head leads to better health. However, little is known about how this effect is achieved.

Aim: To assess the relationship between primary care supply and the quality of primary care in England.

Material and methods: We use data from the English Longitudinal Study of Aging (ELSA) which provides a panel of individuals aged 50 and over living in England. Waves 2, 3 and 4 (2004-05, 2006-07 and 2008-09, respectively) include individual indicators of quality of care. The survey data are linked to Primary Care Trusts (PCT) level data on primary care supply measured by the number of GPs in the area of residence and the average distance to the general practice. We use multilevel modelling regression analysis to investigate the impact of GP supply on quality of care controlling for individual and area covariates.

Results: We analyse 35 indicators of quality of care covering 13 medical conditions. In the pooled analysis across all 35 indicators, our findings suggest that, after controlling for individual demographic characteristics, socioeconomic factors, perceived health, and area level deprivation, a larger number of GPs in the area has a statistically significant and positive impact on quality of care, and distance from GP practice has a statistically significant and negative impact. These impacts were concentrated in indicators of care related to CVD, arthritis and hearing problems.

Conclusion: Our study provides evidence that individuals living in areas with a larger number of GPs per 1,000 registered patients and in areas where the average distance to the general practices is shorter have a higher probability of achieving the minimum standards of care relevant for their conditions. This provides evidence for one mechanism by which primary care supply might affect health.

Introduction

Many countries use regulation or financial incentives to try and increase the supply of general practitioners (GPs) to areas perceived as underserved. Such policies rest on the premise that increasing the supply of primary care will improve the health of the individuals in the area. Although the premise is plausible, its evidence base is rather weak. Studies to date, which have mainly used state-level data from the USA (see, e.g., Shi et al. 2004, Starfield et al., 2005), suggest that increased supply of primary care improves health. Because of the variations in insurance plans and coverage, modes of service delivery, and

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contractual arrangements in the US, there is a risk of confounding, especially when applying these results to the UK. In one of the few UK studies Gravelle et al. (2008), use rich multilevel data to estimate the effect of area supply of GPs on individual health. They test for and find that GP supply is endogenous, and control for it using instrumental variables. They found that, after allowing for endogeneity, an increase in GP supply has a significant positive effect on self-reported individual health. In a subsequent study Morris and Gravelle (2008) examined the relationship between GP supply and obesity in England and found that after allowing for endogeneity, an increase in GP supply was associated with a reduction in individual body mass index.

While, based on the above, there is some evidence that higher levels of primary care supply are associated with better health, there is little evidence as to how this effect is achieved. Gravelle et al. (2008) suggest it could be because higher levels of primary care supply reduce access costs thereby increasing the number of consultations – i.e., higher levels of supply increase *quantity* of use. They also suggest it could be because higher levels of supply mean that GPs have shorter patient lists giving them time to provide longer consultations or to invest in other activities that improve the quality of care – i.e., higher levels of supply increase *quality* of care. In this paper we use household survey data supplemented with area level data on primary care supply to shed light on some of these issues, in this case specifically focusing on the impact of primary care supply on quality of care (QoC).

There have been few previous studies of the relationship between primary care supply and quality of care. Using US data, Rizzo and Zeckhauser (1992) measure the quality of physician services by the average time spent by physicians per patient. They find a positive and significant impact of physician supply on quality. Also using US data Perrin and Valvona (1986) examine the impact of physician supply on process quality, measured by the appropriate, discretionary, and inappropriate use of ancillary tests and treatments. They find small negative effects of primary care supply on the frequency of ancillary tests. Using Norwegian data Carlsen and Grytten (2000) measure quality based on patient satisfaction, and find a positive but diminishing impact of physician density.

In a study that most closely matches our approach, Jurges and Pohl (2011) use German data to study the relationship between area GP supply (number of GPs per 100,000 residents, number of GPs per 100,000 residents aged 50+) and the quality of preventive care provided to older adults. Quality of care is measured as the degree of adherence to medical guidelines (for the management of risk factors for cardiovascular disease (CVD) and for the prevention of falls), reported by patients. The outcome variable was the percentage of recommended care received by respondents, based on the percentage of care guidelines for CVD and for falls that were met. Separate quality of care variables for CVD risk and falls were regressed against GP density plus individual and area covariates. The authors found non-significant associations between GP supply and quality of care, leading them to conclude that their 'results shed doubt on the notion that increasing physician supply will increase the quality of care provided in Germany's present health care system.'

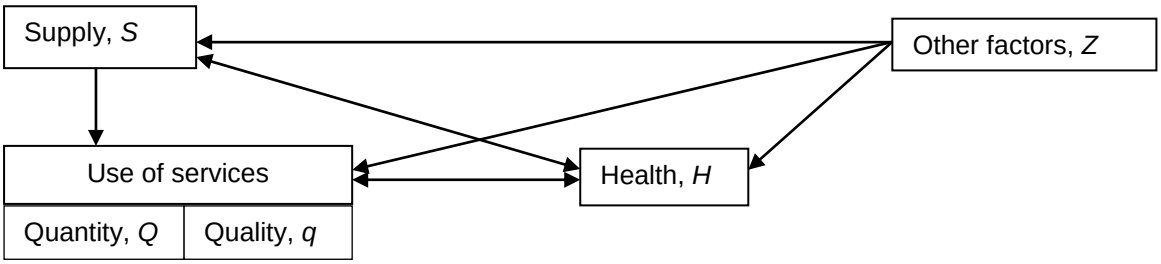
In summary, there is little evidence on the impact of primary care supply and quality of care, the results are conflicting, and we are not aware of any UK studies. With this background in

mind, the aim of our study is to assess the relationship between primary care supply and the quality of primary care in England.

Economic framework

Our analysis is based within the following economic framework (Figure 1).

Figure 1. Stylised depiction of the relationship between primary care supply, use of primary care services, quality of primary care and health



There is some evidence that higher levels of primary care supply are associated with higher levels of health. It has been suggested that underpinning these relationships is the assumption that primary care supply *S* affects health *H* via its effect on the use of services, based on the number of visits *Q*, and also the impact on the quality of care *q* provided. Health affects *S*, *Q* and *q*, as do other factors *Z*, such as socioeconomic indicators, financial incentives and area characteristics. Previous research has used regression analysis to investigate the impact of *S* on *H*; here we focus on one possible mechanism for this, namely the impact of *S* on *q*.

Data and variables

Our analysis is based on data from the English Longitudinal Study of Aging (ELSA). ELSA provides data from a representative sample of adults aged 50 or more living in private households in England. The sample was drawn from households that had previously responded to the Health Survey for England (HSE) in 1998, 1999 or 2001. Individuals selected for the ELSA survey have been interviewed every two years since 2002.

We use data from waves 2, 3 and 4 (run in 2004-05, 2006-07 and 2008-09, respectively) of ELSA, which provide detailed information on the quality of health care received as well as measures of health status, demographic and socioeconomic factors. The number of individuals included in our data is 8,676; most of whom responded to more than one wave, yielding to a total 21,571 observations.

We link individual survey data to area level information on supply of primary care services and other area indicators using Primary Care Trusts (PCTs) codes. PCT codes for the ELSA data were obtained under special license from the data owners. England was divided into 152 PCTs during the main period of our analysis (there were 303 PCTs before 2006, and

have been 151 since 2010). We use the PCT Mapping tool available from the NHS Information Centre[2] to present the data for every year based on the 152 PCTs structure.

Quality of care indicators

We analyse 35 indicators of quality of primary care covering 13 medical conditions. The definitions of each indicator are presented in Appendix 1. These were derived to assess the care of vulnerable older people across a number of conditions (Steel et al., 2008). The conditions were chosen according to their prevalence, impact, effectiveness of available prevention/treatment, importance in older people, feasibility of measurement, and the potential for quality improvement. The indicators were designed to represent processes of care that have been linked to improved outcomes in each of these conditions, and were constructed with input from an expert panel of clinicians, who were asked to review and score the degree to which the indicators reflected good practice in the UK. All indicators were intended to assess the quality of the delivery of care to a minimum acceptable standard, rather than the optimal level (Steel et al., 2008), and are based on individual self-reported by patients.

We considered using other measures of the quality of primary care, in particular the use of *Quality and Outcomes Framework* (QOF) data[3]. We decided not to use QOF data for our analysis, mainly because it is available at the practice level only, and also because there is a risk of confounding due to the financial incentives that QOF provides.

Supply of primary care indicators

We consider two area-based measures of supply of primary care services: the number of GPs in the area of residence and the average distance to the general practice.

Information on the number of GPs was taken from the *NHS staff numbers* database available from the NHS Information Centre[4] . We define the variable as the average number of whole-time equivalent (WTE) GPs per 1,000 registered patients in the PCT of residence of the individual. Data on the number of GPs from 2006, 2007 and 2009 was linked to waves 2, 3 and 4 of ELSA, respectively. Information on NHS staff numbers before 2006 was reported using the old (303) PCTs structure, and the PCT Mapping Tool to convert this to the new (152) PCT structure is not suitable for staff data.

Distance to GP premises information was taken from the *Barriers to Housing and Services* domain of the Index of Multiple Deprivation (IMD) 2004 and 2007 extracted from the *Neighbourhood Statistics* website (http://www.neighbourhood.statistics.gov.uk/). The indicator is based on the average road distance measured from each population weighted Census Output Area centroid to the nearest premises. GP premises were used rather than GP practices, as GP practices may be administrative addresses only and not locations where GPs actually see patients. The data was aggregated up to PCT level by taking the average across the small middle layer super output areas within each PCT, based on a look-

[2] http://www.ic.nhs.uk/statistics-and-data-collections/population-and-geography/pct-mapping-tool

[3] http://www.nhsemployers.org/payandcontracts/generalmedicalservicescontract/qof/Pages/QualityOutcomesFramework.aspx

[4] http://www.ic.nhs.uk/statistics-and-data-collections/workforce/nhs-staff-numbers/

up table from small areas to PCTs. Distance to GP premises data from the IMD 2004 was applied to wave 2 of ELSA, while the IMD 2007 data was linked to wave 3 and 4.

Other covariates
A comprehensive set of individual and area covariates is included in our models. The individual covariates are age, gender, marital status (4 categories), ethnic group (2 categories), self-reported health status (2 categories), educational attainment (7 categories), employment status (5 categories) and total net household financial wealth. The financial wealth variable is derived in ELSA using very detailed data considering a number of finance aspects such as savings and debts. We also included a measure of area deprivation proxied by the percentage of individuals aged 25 to 54 in the area with no or low qualifications. This is extracted from the *Education, Skills and Training* domain of the Index of Multiple Deprivation 2004 and 2007 and linked to individual data using PCT codes using the same process described above.

Econometric approach

We explore the impact of primary care supply on the quality of care using regression analysis. Consider a simple model of quality of care for individual *i* living in area *j*:

$$q_{ij} = \alpha' + \beta' S_j + \delta' Z_{ij} + \varepsilon_{ij} \qquad \text{Eq. [1]}$$

where *q* denotes quality of care, *S* are the measures of primary care supply, and *Z* are other indicators included in the regression model such as demographic, socioeconomic indicators and area deprivation. *S* is available at the area (PCT) level only, while *Z* includes individual level covariates and area level indicators. β is the coefficient of interest to be estimated.

Our main models combine the information from the responses to all the quality of care questions the individuals responded to. We also construct models combining indicators by disease area as well as investigating each of the 35 indicators of QoC separately. The data used in our study allows us to explore different specifications accounting for the number of repeated responses for each individual related to different indicators of quality of care, as well as repeated observations measured over time for those QoC indicators included in more than one wave in ELSA.

Analyses of all indicators combined
The full list of the 35 quality of care indicators was only included in wave 2 (2004-05) in ELSA. We run an analysis combining information on the 35 indicators of QoC using data only from this wave.

In ELSA individuals only respond to the QoC questions that are relevant to them, based on their health conditions and characteristics (see Appendix 1). Therefore, data on each of the 35 indicators is not available for every individual, and individuals might respond to QoC questions for multiple indicators. To exploit the repeated responses of each individual answering a number of quality of care indicators in our analysis we expand the individual data to create a dataset where the observations are ‘indicators by individuals’, i.e., the

responses of each individual to each of the QoC indicators (8,676 individuals in wave 2 times 35 indicators). Observations for QoC indicators that were not relevant for the individual were missing, yielding a dataset of 23,659 responses to QoC indicators in wave 2.

A number of econometric models are possible using these data. In a first, simple analysis we pool the observations from all the responses and adjust for clustering at the PCT level in order to estimate the effect of PCT level primary care supply, accounting for the fact that observations within each PCT are not independent from each other. This assumes that our expanded dataset of indicator-level observations are independent within individuals, which is unlikely. In order to account for this we estimate multilevel regression models.

Multilevel analyses recognise explicitly that observations are nested within groups. This type of model takes into account the correlation structure of the data, estimating variation at different levels of the data separately, and yielding more efficient results and appropriate standard errors. In our case, using data from ELSA wave 2 only, indicator level responses are nested within individuals and individuals are nested within PCTs. The 3-level multilevel model is thus our preferred specification. For indicators of QoC *m* nested within individual *i* living in PCT *j*, the 3-level multilevel model is defined as:

$$q_{mij} = \alpha' + \beta' S_j + \delta' Z_{ij} + \mu_i + u_j + \varepsilon_{mij} \qquad \text{Eq. [2]}$$

Where μ_i and u_j are the individual-specific and PCT-specific error components, respectively, capturing unobserved heterogeneity at these levels, and the other variables are defined as before. We also run 2-level models, modelling indicators by individuals nested within individuals and indicators by individual nested within PCTs.

Analyses of indicators by disease area

We derive subgroup of indicators based on the disease area. We consider 13 different conditions. The number of indicators included in each disease area varied from 1 to 7 indicators (see Table 1 and Appendix 1).

Information on the indicators of quality of care for some conditions were collected in wave 2 only. These include QoC indicators for high cholesterol, ischaemic heart disease (IHD), osteoporosis, incontinence, vision and hearing problems. The econometric approach to estimate the effect of primary care supply on these sets of indicators is equivalent to that described above for the “all indicators combined” analyses.

For the remaining disease-specific groups of indicators (hypertension, stroke, diabetes, osteoarthritis, falls, pain and depression) information was collected in more than one wave. In these cases we make use of the repeated observations over time for each individual as well as the repeated observations due to responses to multiple QoC indicators by each individual. For indicators of QoC *m* nested within individual *i*, responding in time period *t*, and living in PCT *j*, the model takes the form:

$$q_{mitj} = \alpha' + \beta' S_{tj} + \delta' Z_{itj} + \mu_i + u_j + \varepsilon_{mitj} \qquad \text{Eq. [3]}$$

Repeated responses over time and multiple responses to QoC indicators are both nested within individuals, therefore the models continue to be structured in a 3-level multilevel model. We add year control indicators as covariates in these models.

Analyses of individual indicators
We analyse the impact of primary care supply in each of the 35 indicators of quality of care separately. For those disease areas where only one indicators of QoC was available (stroke, vision and pain) these analyses are equivalent to those undertaken in the "indicators by disease area" analyses.

The model to investigate the impact of primary care on individual indicators collected in only one wave is defined as a 2-level multilevel model. For individual *i* living in PCTs *j*:

$$q_{ij} = \alpha' + \beta' S_j + \delta' Z_{ij} + u_j + \varepsilon_{ij} \qquad \text{Eq. [4]}$$

For individual indicators collected in more than one wave we have repeated observations within individuals, and we use a 3-level model with *i* individuals responding in *t* time periods and living in *j* PCTs:

$$q_{tij} = \alpha' + \beta' S_{tj} + \delta' Z_{itj} + \mu_i + u_j + \varepsilon_{tij} \qquad \text{Eq. [5]}$$

All the indicators of QoC are defined as binary variables taking value 1 if the indicator is met, and 0 otherwise. Therefore, for all models we use logistic regression and report odds ratios.

Results

Summary statistics
Table 1 provides the summary statistics for the QoC indicators (all combined and by disease area). Summary statistics for each of the 35 indicators are presented with the analyses of individual indicators in Table 5.

The probability of meeting quality of care standards in our population when combining information on the 35 QoC indicators in wave 2 in ELSA is 63.3%. Standards of care for hypertension, IHD, pain and hearing problems are among those more likely to be met, while quality of care standards for prevention of falls, osteoarthritis and stroke are the least likely to be achieved.

Table 2 summarises the characteristics of our study population. On average there are 0.59 GPs per 1,000 registered patients, and the average distance to GP premises is 1.6 kilometres. The mean age of our sample is 69 years and 57% are females. The majority of our sample are married or widowed; 97% are white; and 45% report bad or very bad health. Over 43% of the sample have no qualifications and nearly 65% are retired. The mean net household financial wealth is £47,374, and on average the percentage of adults with no or low qualifications in the area of residence of the individual is 43%.

Analyses of all indicators combined

The results for our main models, which combine information on the 35 indicators of QoC available in wave 2, are reported in Table 3. We consider a number of regression model specifications, incorporating increasingly more levels in the regression model structure.

Quality of care standards are significantly more likely to be achieved if the individual lives in an area with more GPs per patients and where the average distance to the GP premises is smaller. The confidence interval of the odds ratios becomes just slightly wider when we account for the full hierarchical structure of the data in the 3-level model, but remain statistically significantly at the 1% level. On average, an increase in one GP per 1,000 patients in the area increases the probability of meeting QoC standards by approximately 2.9 times, while an increase in one kilometre in the average distance to GP premises decreases the odds of meeting QoC standards by 7%.

With respect to the effect of the other covariates, age has a negative effect on achievement of quality of care indicators (all ORs less than one), but this effect becomes non-significant when accounting for the correlation of responses within individuals. Females are significantly less likely to receive care that meets the minimum acceptable standards as identified by our quality of care indicators, and this remains significant in the 3-level model. Similarly, compared with being married, those who are single or widowed are less likely to meet the quality of care indicators. Individuals staying home taking care of the family are more likely to achieve the indicators of quality of care.

Analyses of indicators by disease area

The results using the 3-level multilevel modelling approach for each of the disease domains are presented in Table 4. We consider 13 conditions separately, and in addition we combine the indicators of hypertension, high cholesterol, stroke, IHD and diabetes into a cardiovascular disease (CVD) group.

We find evidence of a positive effect of a larger number of GPs in the area on CVD quality of care indicators, as well as those for high cholesterol, arthritis and hearing problems. In most of the remaining disease domains the number of GPs per 1,000 patients have a positive effect (odds ratios larger than 1) but the effect is not statistically significant. The impact of the average distance to GP premises is generally negative in the disease specific models, but not statistically significant.

The impact of age on QoC varies by disease, with a positive effect in hypertension, hearing and vision problems indicators, and a negative impact for indicators related to high cholesterol and IHD. Females are significantly less likely to receive care that meets hypertension standards, while being single or widowed has a negative impact on QoC for a number of disease areas. Non-white ethnic groups are more likely to meet standards of care for hypertension, arthritis and vision problems, and those reporting bad health have generally a larger probability of meeting care standards, with the exception of pain management. Individuals with educational attainment lower than a degree are generally less likely to meet the minimum standards of care, especially for high cholesterol, arthritis and depression. Being permanently sick, retired or taking care of the family increases the probability for some disease-specific indicators as compared with those on employment. Larger net financial wealth increases the probability of CVD and high cholesterol good management, but reduces the likelihood of meeting prevention of falls standards of care.

Area deprivation decreases the probability of achieving IHD and vision problems QoC indicators, but increases the probability of good pain management.

Analyses of individual indicators
The estimates of the impact of the area supply of primary care measures in each of the 35 indicators of quality of care separately are presented in Table 5. All the models control for the same set of covariates as before.

We find evidence of a positive and significant effect of the number of GPs per 1,000 registered patients on individual indicators of quality of care for 6 of the 35 indicators (in the hypertension, high cholesterol, diabetes, osteoarthritis and incontinence disease areas). We find a negative and significant effect of distance to practice in 2 of the 35 indicators (hypertension and incontinence). The specific QoC indicators with a significant relationship with the supply of primary care services are the following:

- Has a doctor or nurse explained high blood pressure in a way you could understand? (Hypertension)
- Have doctors or nurses taken your preferences into account when making treatment decisions about your high cholesterol? (High cholesterol)
- In the past year, has any doctor or nurse examined your bare feet? (Diabetes)
- Doctor or nurse ever talked to you about how to keep your pain from getting worse? (Osteoarthritis)
- Did any doctor or nurse recommend you to try paracetamol before other medicines? (Osteoarthritis)
- Did a doctor or nurse ask you to provide a sample of urine for testing? (Incontinence)
- Did doctor or nurse take targeted history? (Incontinence)

Discussion

In this paper we have explored the impact of primary care supply on quality of primary care provided in England to older adults. We found that individuals living in areas with a larger number of GPs per 1,000 registered patients and in areas where the average distance to the general practices is shorter have a higher probability of achieving the minimum standards of care relevant for their conditions. When analysing the impact for different subsets of quality of care indicators according to the different disease areas, we found the impact to be concentrated on indicators of care related with CVD, arthritis and hearing problems. The analysis of each of the individual indicators shed light onto the impact on some specific standards of care related to other diseases such as diabetes and incontinence.

Our study has implications for analyses of the impact of primary care supply. The finding that better primary care affects quality of care is of interest in a health system where increasing emphasis is placed on quality improvement (Department of Health, 2009). In addition, using the economic framework described above, we identify a potential mechanism by which better primary care might affect health, i.e., via improved quality of care. Furthermore, our study has resonance for the evolving role of GPs as commissioners in the NHS in England. Primary care is becoming increasingly more important in England with health services being transferred from hospitals to community settings and with an increasingly influential role of GPs in the commissioning of NHS activities (Department of Health, 2010). GPs will be required to develop new skills and take on new responsibilities such as being part of Clinical Commissioning Groups, which could restrict their contact time with patients, effectively

reducing the supply of GPs.[5] [6] Our study sheds light on the potential negative impact of this on the quality of primary care.

The main strength of our analysis is related to the richness of our data and the methodology applied. We have information for a comprehensive list of individual indicators of quality of care which were meticulously derived. Previous work (e.g., Jurges and Pohl, 2011) has focused on fewer indicators of quality of care for a narrow set of conditions, or on measures for which there was ambiguity about whether or not the indicator reflected appropriate care. The QoC indicators included in our analyses cover the relevant conditions affecting the population under study and were derived to represent minimum good practice in the UK. Additionally, they reflect processes of care under the direct control of the health care system, rather than health outcomes which are affected by a series of other factors (Steel et al., 2008). Furthermore, our methodology allows us to exploit the repeated responses of each individual at the same time that accounts for the hierarchical and correlated structure of the data. By doing so we are able to combine information on the total number of indicators available as well as looking at specific subgroups of indicators without losing any observation in the analyses. Combining indicators in our data also allows us to take a system-wide perspective and investigate whether supply of primary care services have an impact on quality of care overall.

This study has a number of limitations. First, in the analyses that combine information from a series of indicators we implicitly assume that each individual indicator has equal weight. It might be the case that achieving the standards of care for some indicators is more important than for others, and they should thus be appropriately weighted in our analyses. However, as explained above the indicators were derived to reflect minimum acceptable standards of care for each condition and therefore the assumption that they are all equally important might not be as unrealistic as if they reflected different levels of the optimality of care. Secondly, our primary care supply variables were limited to GPs per 1,000 registered patients and distance to practice. Alternative measures might include supply of other members of the primary care team, such as practice nurses, who are becoming increasingly important in primary care in England. This might be important if other primary care staff are employed as substitutes for GPs, in which case areas with lower supply of GPs might not have lower primary care supply overall. In previous work (Vallejo-Torres and Morris, 2010) we have found that the number of GPs and the number of practice nurses are positively correlated, but further research using alternative primary care supply variables would be beneficial. Finally, although unlikely, our results might be affected by reverse causality. If GPs choose to work on areas where the quality of care is already below or above average, the relationship we observed between supply of primary care and quality of care might be biased. Jurges and Pohl (2011) used an instrumental variables approach and found no evidence of endogeneity of supply of primary care in models of quality of care.

We have identified a link between supply of primary care and the quality of services provided in England. Future work is needed to investigate other potential mechanisms that explain the relationship between supply of primary care services and improved health, such as the impact of the level of provision of primary care services on the intensity of utilisation, i.e. on quantity. Further research about the ultimate impact that the quantity and the quality of

[5] http://www.gponline.com/News/article/1110486/huge-variation-money-paid-gp-commissioners/
[6] http://www.guardian.co.uk/society/datablog/2012/mar/12/gp-commissioning-data-false-economy

primary care services use have on individual and population health is also required. Additionally, while our study shows that across all QoC indicators primary care supply has a significant and positive effect, we have identified variations in impact between different disease areas and individual indicators. Although in almost every single case the impact of primary care supply is positive, we are unable to explain the variation in statistical significance. Further research would be beneficial to investigate the reasons for this variation.

Our study provides evidence that individuals living in areas with a larger number of GPs per 1,000 registered patients and in areas where the average distance to the general practices is shorter have a higher probability of achieving the minimum standards of care relevant for their conditions. This provides evidence for one mechanism by which primary care supply might affect health.

References

Carlsen, F., Grytten, J. 2000. Consumer satisfaction and supplier induced demand. *Journal of Health Economics* 19: 731–753.

Department of Health. 2009. *Improving quality in primary care*. London: Department of Health.

Department of Health. 2010. *Equity and Excellence: Liberating the NHS*. London: Her Majesty's Stationary Office.

Gravelle, H., Morris, S., Sutton, M. 2008. Are family physicians good for you? Endogenous doctor supply and individuals health. *Health Service Research* 43: 1128-44.

Jurges, H., Pohl., V. 2011. Medical guidelines, physician density, and quality of care: evidence from German SHARE data. *European Journal of Health Economics* (forthcoming).

Morris, S., Gravelle, H. 2008. GP supply and obesity. *Journal of Health Economics* 27: 1357-67.

Perrin, J.M., Valvona, J. 1986. Does increased physician supply affect quality of care? *Health Affairs* 5: 63–7.

Rizzo, J.A., Zeckhauser, R.J. 1992. Advertising and the price, quantity, and quality of primary care physician services. *Journal of Human Resources* 27: 381–421.

Starfield, B., Shi, L., Macinko, J. 2005. Contribution of primary care to health system and health. *The Milbank Quarterly* 83: 457-502

Shi, L., Macinko, J., Starfield, B., Xu, J., Regan, J., Politzer, R., Wulu, J. 2004. Primary care, infant mortality, and low birth weight in the states of USA. *Journal of Epidemiology and Community Health* 58: 374–80.

Steel, N., Bachmann, M., Maisey, S., Shekelle, P., Breeze, E., Marmot, M., Melzer, D. 2008. Self reported receipt of care consistent with 32 quality indicators: national population survey of adults aged 50 or more in England. *British Medical Journal* 337a:957

Vallejo-Torres L., Morris S. 2010. Factors associated with the use of primary care services: the role of practice nurses. *European Journal of Health Economics* 12: 373-81.

Table 1: Summary statistics of quality of care indicators by disease area

Disease area	Number of QoC indicators	Mean	SD	ELSA Wave
All	35	0.633	0.482	2
Hypertension	3	0.772	0.420	2-4
High cholesterol	2	0.636	0.481	2
IHD	3	0.729	0.445	2
Stroke	1	0.417	0.494	2-4
Diabetes	7	0.587	0.492	2-4
Arthritis	5	0.350	0.477	2-4
Osteoporosis	2	0.669	0.471	2
Falls	2	0.303	0.459	2 & 4
Pain	1	0.771	0.421	2 & 4
Incontinence	4	0.519	0.500	2
Vision	1	0.571	0.495	2
Hearing	2	0.790	0.407	2
Depression	2	0.637	0.481	2 & 4

Notes: QoC = Quality of care; IHD = Ischaemic heart disease. ELSA waves 2, 3 and 4 were in 2004-05, 2006-07 and 2008-09, respectively. All QoC indicators are coded so that 1 = indicator is met, 0 otherwise.

Table 2: Summary statistics of covariates

	Mean	SD
GP Supply		
GPs per 1,000 patients (number)	0.590	0.073
Distance to practice (Km)	1.643	0.679
Demographics		
Age (years)	69.421	9.448
Female	0.573	0.495
Marital status		
Married	0.607	0.488
Single	0.048	0.214
Divorced	0.109	0.312
Widowed	0.236	0.424
Ethnic group		
White	0.970	0.171
Self-reported health		
Bad health	0.456	0.498
Education		
Degree	0.104	0.305
Higher (less than degree)	0.112	0.316
A levels	0.058	0.234
GCSE	0.154	0.361
CSE	0.049	0.216
Other qualifications	0.088	0.284
No qualifications	0.434	0.496
Employment status		
Employed	0.172	0.377
Retired	0.648	0.478
Unemployed	0.008	0.087
Permanently sick	0.086	0.281
Family carer	0.080	0.272
Net household financial wealth indicator (£)	47,374	142,843
Percentage with no qualifications in area (%)	43.020	6.586

Note: Unless otherwise indicated, all variables are binary variables taking the value one if the respondent is in that category and zero otherwise.

Table 3: Logit models for the probability of meeting quality of care indicator - all indicators combined (ELSA wave 2)

	1-level model			2-level model			2-level model			3-level model		
Level 1:	Indicators by individuals ψ			Indicators by individuals			Indicators by individuals			Indicators by individuals		
Level 2:				PCTs			Individuals			Individuals		
Level 3:										PCTs		
	OR	**[95% CI]**		**OR**	**[95% CI]**		**OR**	**[95% CI]**		**OR**	**[95% CI]**	
GPs per 1,000 patients	2.615***	[1.580	4.327]	2.594***	[1.380	4.876]	2.970***	[1.712	5.151]	2.869***	[1.430	5.756]
Distance to practice (Km)	0.932**	[0.880	0.987]	0.944*	[0.887	1.005]	0.917***	[0.863	0.975]	0.927**	[0.863	0.997]
Age	0.996*	[0.991	1.001]	0.996*	[0.992	1.000]	0.997	[0.991	1.002]	0.997	[0.992	1.002]
Female	0.867***	[0.806	0.932]	0.867***	[0.817	0.920]	0.858***	[0.793	0.929]	0.858***	[0.793	0.929]
Single	0.871*	[0.754	1.008]	0.866**	[0.760	0.987]	0.822**	[0.692	0.976]	0.819**	[0.690	0.973]
Divorced	1.001	[0.892	1.123]	0.999	[0.913	1.093]	0.992	[0.880	1.117]	0.988	[0.877	1.114]
Widowed	0.893***	[0.820	0.972]	0.889***	[0.824	0.958]	0.867***	[0.784	0.959]	0.862***	[0.780	0.954]
White	0.988	[0.808	1.207]	0.966	[0.824	1.133]	1.002	[0.808	1.242]	0.990	[0.797	1.231]
Bad health	1.043	[0.978	1.113]	1.048	[0.988	1.110]	1.054	[0.975	1.140]	1.058	[0.979	1.144]
Higher (less than degree)	1.037	[0.911	1.180]	1.031	[0.912	1.166]	1.043	[0.888	1.226]	1.038	[0.883	1.220]
A level	0.932	[0.794	1.093]	0.927	[0.803	1.070]	0.912	[0.754	1.103]	0.905	[0.749	1.094]
GCSE	0.910*	[0.812	1.020]	0.913	[0.815	1.022]	0.886	[0.763	1.029]	0.889	[0.766	1.032]
CSE	0.944	[0.793	1.123]	0.946	[0.812	1.103]	0.950	[0.775	1.163]	0.951	[0.777	1.164]
Other qualifications	0.981	[0.847	1.137]	0.985	[0.867	1.120]	0.957	[0.808	1.134]	0.958	[0.809	1.135]
No qualifications	0.938	[0.835	1.053]	0.932	[0.842	1.032]	0.933	[0.815	1.067]	0.928	[0.811	1.062]
Retired	1.027	[0.918	1.150]	1.028	[0.942	1.123]	1.041	[0.928	1.168]	1.041	[0.928	1.168]
Unemployed	1.147	[0.753	1.749]	1.149	[0.836	1.579]	1.267	[0.830	1.934]	1.263	[0.828	1.924]
Permanently sick	1.035	[0.894	1.199]	1.031	[0.920	1.155]	1.068	[0.915	1.246]	1.061	[0.909	1.238]
Family carer	1.111	[0.969	1.274]	1.110*	[0.986	1.249]	1.151*	[0.986	1.343]	1.148*	[0.984	1.340]
Financial Wealth	1.000	[1.000	1.000]	1.000	[1.000	1.000]	1.000	[1.000	1.000]	1.000	[1.000	1.000]
% with no qualif in area	0.998	[0.992	1.005]	0.999	[0.994	1.005]	0.998	[0.992	1.003]	0.998	[0.992	1.005]
N	23,659			23,659			23,659			23,659		

Notes: PCT = Primary Care Trust; OR = Odds ratio; CI = Confidence interval. * p<0.1. **p<0.05. ***p<0.01. ψ Adjusts for PCT level clustering.

Table 4: Logit models for the probability of meeting quality of care indicator - by disease area (all numbers are odds ratios)

	CVD¶	Hypertensionψ	High Cholest¶	IHD¶	Strokeψ	Diabetesψ	Arthritisψ	Osteoporosis¶	FallsT	PainT	Incontinence¶	Hearing¶	Vision¶	DepressionT
GPs per 1,000 patients	2.377*	1.115	8.396**	0.978	28.542	1.494	5.770***	1.076	4.072	5.069	2.871	11.917*	0.469	1.143
Distance to practice	0.951	0.978	0.857	0.907	0.699	0.986	0.923	1.002	1.132	0.963	0.906	1.120	0.887	0.875
Age	0.990**	1.029***	0.979**	0.979**	0.979	0.995	0.995	1.012	1.009	1.017	0.990	1.055***	1.030**	0.987
Female	0.943	0.774***	1.001	0.809	1.167	0.961	1.079	0.975	1.254	1.119	0.964	1.173	1.376	0.890
Single	0.892	0.815	0.701	0.597*	1.120	0.730***	0.889	0.486*	1.878	0.556	0.699	0.242***	1.200	0.909
Divorced	1.010	0.990	0.917	0.977	0.616	0.828**	0.845	1.124	1.155	1.421	1.035	0.820	1.713	1.284
Widowed	0.853***	0.937	0.780*	0.761	0.744	0.796***	0.936	0.773	0.943	0.477**	1.057	0.504***	1.377	1.156
White	1.070	0.694*	0.717	0.978	2.240	1.142	0.562**	0.625	0.651	0.910	0.802	0.814	0.461*	1.886
Bad health	1.060	1.122*	0.911	2.122***	0.801	1.041	1.246***	0.947	3.091***	0.590**	1.084	1.516**	1.559**	1.117
Higher (less degree)	1.048	1.325*	0.707	1.501	3.456	1.107	0.835	0.808	1.460	0.906	1.094	0.880	0.569	0.682
A level	0.968	1.191	0.740	1.108	3.346	1.056	0.863	0.943	1.595	1.229	0.656	0.526	0.397	0.451**
GCSE	0.939	1.232	0.643**	1.105	0.708	1.021	0.738**	0.518*	1.309	0.462	0.727	0.572	0.854	0.733
CSE	0.955	1.127	0.570*	1.096	1.686	0.970	0.841	1.728	1.494	0.531	0.846	0.417*	0.574	1.335
Other qualifications	0.961	1.200	0.674*	0.875	4.097	1.104	0.737*	1.155	1.288	0.578	0.983	0.644	0.603	0.434**
No qualifications	0.855*	1.063	0.600**	1.029	1.296	0.867*	0.827	0.760	1.237	0.409	1.106	0.712	0.733	0.596*
Retired	1.114	1.083	1.008	1.830***	1.748	1.124	1.150	1.212	2.256**	1.373	1.108	0.844	0.483	0.914
Unemployed	1.263	0.950	1.255	1.433	-	1.404	1.347	0.562	0.582	-	4.418	0.369	-	1.175
Permanently sick	0.991	1.199	0.847	1.468	1.039	0.955	1.642***	1.603	2.630**	1.048	1.178	1.129	0.642	1.387
Family carer	1.163	1.142	1.217	1.573*	1.878	1.171	1.040	1.119	1.111	4.516**	1.141	0.717	0.547	1.156
Financial Wealth	1.000*	1.000	1.000***	0.999	0.999	1.000	1.000	1.000	0.999*	0.999	0.999	1.000	0.999	1.000
% with no qualif in area	0.998	1.005	1.001	0.982*	1.040	1.000	1.000	0.999	0.989	1.034*	0.998	1.012	0.968**	1.001
Year control		2.624***			0.865	0.947**	0.943		0.700***	0.927				0.960
N	13,999	10,514	3,311	1,841	263	10,892	7,430	924	1,918	462	2,089	2,318	591	786

All models are based on a 3-level multilevel regression – indicators by individuals & individuals & PCTs. * P<0.1. **P<0.05. ***P<0.01. CVD = Cardiovascular diseases; combines indicators for hypertension, high cholesterol, IHD, stroke and diabetes. ¶ Data from wave 2 in ELSA; ψ Data from wave 2 to 4 in ELSA; T Data from wave 2 & 4 in ELSA.

Table 5: Logit models for the probability of meeting each quality of care indicator

Disease	Name	Mean	SD	GPs per 1,000 OR	Distance practice OR	Sample size	ELSA Wave
Hypertension	hehbpb	0.866	0.341	0.64	1.236	1599	2
	hehbp	0.680	0.466	6.61*	0.881	1595	2
	hehbpa	0.423	0.494	4.26	0.864	1565	2
High cholesterol	hecholb	0.784	0.411	2.08	0.956	1664	2
	hecholc	0.486	0.500	14.25***	0.810*	1647	2
IHD	hehrta	0.847	0.360	0.02	1.396	411	2
	hecgstp	0.694	0.461	1.92	0.905	1314	2
	hebetall	0.703	0.459	NC		118	2
Stroke	hehbpb1	0.417	0.494	28.54	0.699	263	2-4
Diabetes	hesuga	0.934	0.248	1.01	1.403	1649	2-4
	hewee	0.802	0.399	6.04	1.082	951	2-4
	heaceall	0.500	0.500	1.67	1.044	1950	2-4
	heftchk	0.831	0.375	43.41**	0.917	2014	2-4
	heslfcr	0.238	0.426	0.34	0.776	2015	2-4
	heslfcb	0.349	0.477	1.54	0.966	2015	2-4
	hechol	0.856	0.352	5.53	1.143	298	2
Osteoarthritis	hekneb	0.318	0.466	2.11	0.790	1182	2-4
	heartall	0.176	0.381	10.29**	0.981	3768	2-4
	hearte	0.446	0.497	105.03*	0.700	804	2-4
	heartd	0.783	0.412	5.87	0.852	1398	2-4
	hepaf	0.387	0.488	0.16	1.142	278	2-4
Osteoporosis	heoste	0.540	0.499	0.54	1.073	581	2
	heosted	0.886	0.318	17.06	0.692	343	2
Falls	heflall	0.259	0.438	1.43	0.923	1314	2 & 4
	hefld	0.346	0.476	NC		968	2 & 4
Pain	hepai	0.771	0.421	5.069	0.963	462	2 & 4
Incontinence	heincall	0.223	0.417	9.70	0.665*	519	2
	heinctall	0.516	0.500	1.70	0.848	524	2
	heincth	0.619	0.486	0.54	1.060	524	2
	heinctg	0.715	0.452	18.94*	1.013	522	2
Hearing	hehrc	0.734	0.442	2.63	1.174	1547	2
	hehrall	0.902	0.298	NC		772	2
Vision	hedreye	0.571	0.495	0.469	0.887	591	2
Depression	hepsye	0.471	0.500	0.86	0.789	447	2 & 4
	hepsyb	0.855	0.352	5.12	0.860	339	2 & 4

* P<0.1. **P<0.05. ***P<0.01. Controls are included in every model for demographics, marital status, ethnic group, self-reported health, education, employment status, household financial wealth and percentage with no qualifications in area of residence and year. NC = Model did not converge; OR = Odds ratio.

Appendix 1: Definition of quality of care indicators

Disease	Name	Description
Hypertension	hehbpb	IF aged 50 or older & remains hypertensive after nonpharmacological intervention: Did a doctor or nurse ever suggest that you take medication to lower your blood pressure?
	hehbp	If aged 50 or older and hypertensive: Has a doctor or nurse explained high blood pressure in a way you could understand?
	hehbpa	If aged 50 or older and hypertensive: Have doctors or nurses given you any choice about how to treat your high blood pressure?
High cholesterol	hecholb	If aged 50 or over and has high cholesterol: Has a doctor or nurse explained high cholesterol in a way you could understand?
	hecholc	If aged 50 or over and has high cholesterol: Have doctors or nurses taken your preferences into account when making treatment decisions about your high cholesterol?
IHD	hehrta	If aged 50 or older & has established CHD & is not on warfarin: Did a doctor suggest that you take medication to thin your blood?
	hecgstp	If aged 50 or older & has established CHD & smokes: Has a doctor or nurse ever advised you to stop smoking?
	hebetall	If aged 50 or older & has had a recent myocardial infarction: Did any doctor ever tell you that you should take a medication called a betablocker?
Stroke	hehbpb1	If aged 50 or older and has had a stroke: Doctor or nurse ever suggested you take any medication to lower your blood pressure?
Diabetes	hesuga	If aged 50 or over and has diabetes: Glycosylated haemoglobin or fructosamine test performed in the past 12 months?
	hewee	IF diabetic person aged 50 or older & not have established renal disease & not receiving an ACE inhibitor or angiotensin II receptor blocker: Urine test for protein in the last 12 months?
	heaceall	IF diabetic person aged 50 or older & has one additional cardiac risk factor (i.e., smoker, hypertension, or renal insufficiency/microalbuminuria): Doctor discussed whether you should take ACE inhibitor or A2 receptor blocker?
	heftchk	If aged 50 or over and has diabetes: In the past year, has any doctor or nurse examined your bare feet?
	heslfcr	If aged 50 or over and has diabetes: Have you ever participated in a course or class about diabetes?
	heslfcb	If aged 50 or over and has diabetes: How much do you think you know about managing your diabetes?
	hechol	If aged 50 or over and has diabetes & has a fasting total cholesterol level of 5 mmol/L or greater: Has any doctor talked to you about how to lower your cholesterol?
Osteoarthritis	hekneb	IF ambulatory person aged 50 or older & has had a diagnosis of symptomatic osteoarthritis of the knee for longer than 3 months & has no contraindications to exercise: Doctor or nurse suggested physiotherapy for your knee pain?

Osteoarthritis	heartall	IF ambulatory person aged 50 or older & has had a diagnosis of osteoarthritis : Doctor or nurse ever talked to you about how to keep your pain from getting worse?
	hearte	IF aged 50 or older & has had a diagnosis of osteoarthritis: Did any doctor or nurse recommend you to try paracetamol before other medicines?
	heartd	IF aged 50 or older & has had a diagnosis of osteoarthritis: Has any doctor ever talked to you about what the specific purpose of the treatment?
	hepaf	IF aged 50 or older with severe symptomatic osteoarthritis of the knee or hip has failed to respond to non- pharmacological and pharmacological therapy: Did any doctor recommend that you should have surgery or joint replacement?
Osteoporosis	heoste	IF aged 50 or older & has untreated osteoporosis: Has any doctor or nurse recommended taking calcium pills or Vitamin D?
	heosted	IF woman aged 50 or older & is newly diagnosed with osteoporosis: Were these medicines recommended within 3 months?
Falls	hefld	IF aged 65 or older & reported 2 or more falls in the past year, or a single fall with injury requiring treatment: With any of your past falls, did a doctor or nurse to try to understand why you fell?
	heflall	IF aged 65 or older & reported 2 or more falls in the past year, or a single fall with injury requiring treatment: Did a doctor recommend any additional tests to understand why you fell?
Pain	hepai	IF aged 50 or older & has a newly reported chronic painful condition: Did your doctor or nurse recommend any treatments for your pain?
Incontinence	heincall	IF aged 65 or older & has new UI that persists for over 1 month: Doctor or nurse took targeted history?
	heinctall	IF aged 65 or older & has new UI that persists for over 1 month: Did a doctor or specialist such as a urologist or gynaecologist perform an internal exam?
	heincth	IF aged 65 or older & has new UI that persists for over 1 month: Did a doctor or nurse talk with you about how to treat urinary incontinence?
	heinctg	IF aged 65 or older & has new UI that persists for over 1 month: Did a doctor or nurse ask you to provide a sample of urine for testing?
Hearing	hehrc	IF aged 65 or older & has a problem with hearing: Did doctor refer you to an ear specialist to check your hearing?
	hehrall	IF aged 65 or older & is a hearing aid candidate: Did you get a hearing aid? And did a doctor teach you how to use your hearing aid?
Vision	hedreye	IF aged 50 or older & is diagnosed with a cataract that limits the patient's ability to carry out needed or desired activities: Did any doctor or optician recommend that you have your cataracts removed?
Depression	hepsye	IF aged 50 or older & receives a diagnosis of a new depression episode: When you talked about these feelings, did doctor ask if you had thoughts about suicide?
	hepsyb	IF aged 50 or older is diagnosed with clinical depression: Did you start medication or counselling within 2 weeks of being offered this treatment?