Draft Paper Prepared for 39th EuroQol Plenary 2022
PLEASE CHECK WITH AUTHORS BEFORE CITING

Variations in self-reported health for the general population and for ten condition-specific patient groups in England: an exploratory analysis of repeated cross-sectional general practice data with 3.96 million patient records

Yan Feng[1], Hugh Gravelle[2], Vladimir Gordeev[1]

1. Centre for Evaluation and Methods, Queen Mary University of London
2. Centre for Health Economics, University of York

Aim

We use a large sample of general practice patients to investigate the individual and practice factors associated with individual health and how much of the unexplained variation is at patient, practice and CCG levels.

Methods

We linked data from the NHS's General Practitioner (GP) Patient Survey, Quality and Outcomes Framework, and GP workforce databases between 2012/13 and 2016/17. The resulting dataset covers almost all GP practices in England, with a nationally representative sample for the general population. We also constructed ten condition-specific data sets. We used mixed-effects models to identify factors that can explain the variation in health as measured by the EQ-5D-5L index, calculated Intraclass Correlation Coefficients to decompose the unexplained variation in the EQ-5D-5L index, and explored the impact of missing values by comparing results from complete case and multiply-imputed data sets. We also investigate whether results are sensitive to change in the mailout strategy designed to increase response rates.

Results

Results from 10% samples of complete cases (n = 283,266) and multiple imputation (n = 396,190) produced similar results. Most variables with statistically significant associations with the EQ-5D-5L index are patient characteristics, and a few are about GP practice. Many of those variables (such as multimorbidity, gender, deprivation, smoking status, satisfaction with access to GP practice) had similar and plausibly signed effects across the ten condition-specific datasets. But there were differences for some variables with different conditions. For example, those reporting their ethnicity as Black had a lower EQ-5D-5L index than those of White ethnicity if they had angina/heart problems but higher values if they have asthma/chest, diabetes, hypertension, or mental health problems. For the general population and the ten condition-specific patient groups, the unexplained variation in the EQ-5D-5L index was almost entirely at patient level, with very small GP practice and CCG contributions. Changes to the design of the GPPS mailout increased response rates but made little difference to estimated effects of explanatory variables.

1. Background

Significant variations in the UK population health have been widely observed for a long time (Marmot et al., 2020) and attributed to many factors (Dahlgren and Whitehead, 1992). Some of those factors are considered “unavoidable”, such as age, and others, such as deprivation are not. For example, the life expectancy gap between England's poorest and most prosperous areas widened, although the general population experienced significant improvement throughout the 20th century (Chief Medical Officer, 2020). When accounting for the health status of individuals, the gap in health widened further. More deprived populations spend a more significant proportion of life in poor health (Office for National Statistics, 2020). The Health and Social Care Act 2012 introduced legal obligations on the Department of Health and Social Care, Public Health England, Clinical Commissioning Groups (CCGs), and NHS England to reduce preventable, unfair and unjust differences in health across the English general population (Health and Social Care Act 2012, c. 7)

In England, General Practitioners (GPs) are gatekeepers for the National Health Services. Almost all residents are registered with a GP practice. GPs play an important role in tackling remediable differences in health across the general population and patient groups. This is partly due to the nature of their work to provide interventions to reduce or eliminate the impact of health risk factors. GPs are responsible for promoting health (e.g., smoking cessation and advice on lifestyle) with a broader team of professionals to residents within the communities they serve. They also provide preventive care (i.e., vaccination and screening services) to their patients. These interventions are documented in literature as having an impact on reducing preventable illness and premature death (Department of Health, 2017; Department of Health, 2014). GPs are often the first point of contact for those with physical or mental health problems. They also look after patients with chronic illnesses. Previous literature suggested that improvement in access to primary health care services (Starfield et al., 2005) and quality of primary care (Doran et al., 2008) can narrow variations in health by improving the health of disadvantaged groups.

Previous studies have identified factors that are associated with variation in health for the general population in England, such as level of deprivation, sex, region, age, social class, education, housing tenure, economic position, and smoking behaviour (Raleigh and Kiri, 1997; Kind et al., 1998; Marmot et al., 2020). However, the role of general practice was never been

the focus in those studies. Furthermore, we could not find any previous study that decomposing the variation in health for the general population in England and patient groups with chronic conditions that could not be explained by observed factors.

Previous studies generally examine variation in health using objective measures such as life expectancy, mortality, and morbidity (Public Health England, 2021). There has been little work examining the factors affecting individuals' self-reported health outcomes. A recently published study used practice level data on all English GP practices over five years to examine the relationship between patient-reported health, as measured by the EQ-5D-5L instrument, and primary care quality (Feng and Gravelle, 2021). Authors found that practices with higher clinical quality and better patient access reported better practice level patient self-reported health, though the implied effects were very small. Authors also reported that most of the variation in practice level patients' self-reported health, was between practices rather than within them over time. A limitation of the study is that they only had access to practice level rather than individual patient level data.

The availability of patient-level EQ-5D-5L data in the General Practice Patient Survey (GPPS) data from 2012/13 to 2016/17 provides an opportunity to explore the variation in health of the English general population and among patients with certain chronic conditions. In addition to the EQ-5D-5L instrument, the GPPS includes many patient characteristics, including specific health conditions, socio-economic status, and demographics. We linked the GPPS data with two general practice databases (Quality and Outcomes Framework (QOF) and GP workforce databases), including practice characteristics variables, such as clinical quality and practice workforce.

In this paper, we aim to address two questions. First, which factors explain patient self-reported health, measured by the EQ-5D-5L instrument, for the general population in England and for ten groups of patients with specific chronic conditions. Second, how much of the unexplained variation in patient self-reported EQ-5D-5L can be attributed to patient, GP practice, and CCG levels, and whether this decomposition differs for the general population and the ten patient groups.

2. Data

Background. The English National Health Service (NHS) provides healthcare that is tax-financed and free at the point of use (apart from a small charge for approximately 10% of prescriptions). NHS primary care is provided by general practices owned and run by family doctors (GPs). All individuals residing in England are entitled to register with a general practice, and almost all do so because practices provide primary care and are gatekeepers for elective (non-emergency) hospital care. In September 2015, there were 7674 general practices with an average list of 7450 patients and 3.8 full time equivalent GPs. Practices are paid by a mix of capitation, lump sums, items of service fees, and quality incentives. Approximately 8% of the practice income is from the QOF that rewards practices for achievement of quality indicators, mainly for the management of chronic conditions and prevention. Practices are reimbursed for the costs of their premises but have to fund all other expenses, such as the employment of nurses and clerical staff, from their revenue. Practices are grouped in 207 to 211 (depending on the year) Clinical Commissioning Groups (CCGs) which receive needs weighted budget from the Department of Health and Social Care to purchase healthcare from secondary care providers. CCGs undertake clinical governance of general practices and can commission some services directly from them.

GPPS data: GPPS is an annual survey that involves all GP practices in England conducted by Ipsos MORI on behalf of the English Department of Health and Social Care. The survey was introduced in 2007 to provide patients with the opportunity to provide feedback about their experiences of their GP practice. In each financial year (April-March), the questionnaire is sent to a random sample of approximately 5% of adult patients (different in each year and registered with their practice for at least 6 months) in every general practice. Response rates were between 33% and 39% during the 5-year period from 2012/13 to 2016/17 that we used. The survey was distributed in 2 waves (July-September and January-March) in the 4 years from 2012/13 to 2015/16 and in one wave (January-March) in 2016/17. Data collection was mainly by postal paper questionnaires with options to respond online or over the telephone. The mailout strategy was changed in 2015/16 with redesigned cover letters in each full survey mailing, and a postcard reminder being sent to all sampled patients one week after the first survey pack mailing.

The EQ-5D instrument (3L version) was included as part of the survey in 2011/12 as a measure of patients' self-report health. The 5L version replaced the 3L version of the instrument from

2012/13. Patients were asked to self-report their health using the EQ-5D-5L instrument over five dimensions (mobility, self-care, usual activities, pain/discomfort, anxiety/depression) with five severity levels for each dimension (none, slight, moderate, severe, extreme problems). The GPPS dropped the instrument from 2017/18 onwards.

QOF data: QOF is a financial incentive programme introduced in 2004 to motivate GP practices in England to improve the quality of chronic disease management. Almost all English GP practices joined the programme. In each financial year, the QOF payments to general practices are linked to their achievement against sets of indicators. Practices scored points based on their achievement of each indicator. The bulk of the QOF indicators are for clinical quality (such as controlling blood pressure for hypertensive patients). For instance, in 2012/13, 669 QOF points were allocated to indicators in the clinical domain (out of the maximum available points of 1,000). Achievements of QOF indicators in the clinical domain provide proxies for the overall clinical quality of GP practices on managing long-term conditions and condition-specific clinical quality.

Linked GPPS, QOF and workforce data: We linked the GPPS and QOF data by GP practice and financial year to generate a five-year pooled patient-level data (2012/13 and 2016/17). In addition to the full general population GPPS sample, we selected ten samples of patients who self-reported having Alzheimer's disease or dementia, Angina or long-term heart problem, Arthritis or long-term joint problem, Asthma or long-term chest problem, Cancer in the last five years, Diabetes, Epilepsy, High blood pressure, Learning difficulty, and Long-term mental health problem. The ten conditions were matched to groups of QOF clinical indicators for care of specific chronic conditions. The definitions of ten chronic conditions in the GPPS and QOF data sets are identical for some conditions but not for all. For instance, there is no difference in the definition of Diabetes, Epilepsy, High blood pressure between the two data sets. There are some differences in definitions for other conditions. For example, the QOF data is for clinical quality for patients with for Dementia, but for patients with Alzheimer's disease *or* dementia in the GPPS data set. Data for eight conditions cover the five-year period, while Epilepsy and Learning difficulty data is only available for 2012/13 and 2013/14. The general population and the ten condition-specific data sets were linked to GP workforce data to include variables about the practice workforce, such as the proportion and type of full-time equivalent (FTE) staff. Our primary data sources are NHS Digital (QOF and GP workforce data)

and NHS England (GPPS data). Data from NHS Digital is publicly available. For this project, permission to access patient-level GPPS data was granted by NHS England.

The initial pooled data set over 5 years includes 4,328,745 individual patient observations of which 3,961,896 observations contained full information for the EQ-5D-5L index over five years period.

3. Methods

3.1. Variables

Patients' self-reported health: We used the EQ-5D-5L index to measure patients' self-reported health. The index is derived from patient self-reported health using the 5L version of the EQ-5D instrument by applying a crosswalk value set for England (van Hout et al., 2012). The index values range from –0.594 to 1. The higher index the better the patients' overall health status. An index value of 1 indicates full health, and -0.594 suggests the health state is worse than death. This is the dependent variable in all regression analyses.

Clinical quality of general practices: The overall clinical quality of a GP practice is calculated for each financial year and measured by weighted practice QOF population achievement rate in the pooled data set. The population achievement rate for a QOF clinical indicator for a condition is the number of patients for whom the indicator was achieved divided by the total number of patients with the condition for whom the indicator was relevant. Overall practice population achievement for all clinical indicators is the average population achievement rates for indicators weighted by the maximum points available for the indicators. The clinical quality for each chronic condition is the average of population achievement rates weighted by the maximum points available for the indicators relevant for that condition.

All regression analyses control for *characteristics of patients and general practices*. Patient characteristics include the number of diseases reported by the patient, overall experience with general practices, the experience of making appointments with their practices, satisfaction with practice opening hours, gender, age, working status, whether a parent or guardian for children under 16 years old, smoking status, and ethnicity. We use the Index of Multiple Deprivation (IMD) rank of the small area in which the patient lives to attach a measure of deprivation to each patient. Since the IMD ranks small areas from most to least

deprived we reverse the rank so that patients resident in more deprived areas have a higher deprivation score. Practice characteristics include practice list size, the number of different types of staff adjusted by practice list size, the distribution of full-time equivalent GPs by age, gender, and country of qualification, the number of patients to whom the practice dispenses medicines because they live more than one mile from the nearest community pharmacy, and the rural or urban location of the practice.

Year dummies and GPPS waves (wave 1 for surveys distributed in January to March, wave 2 for surveys distributed in July to September) are also included in all regressions.

3.2 Modelling the variations of self-reported EQ-5D-5L

GPPS data is repeated cross-sectional as the survey applied random sampling to select patients each year. The pooled data set has a three-level structure where patients are nested within their general practices and practices are nested within CCGs. Using the Stata command *mixed* (StataCorp, 2021a, p. 479), we estimate a three-level mixed-effects model:

$$Y_{igt} = \beta_0 + P'_{igt}\beta^P + G'_{gt}\beta^G + T'\beta^T + W'\beta^W + v_c + u_{gc} + e_{igc} \quad (1)$$

where Y_{igt} is the self-reported EQ-5D-5L index by patient *i* in practice *g* in year *t*; P'_{igt} is a vector of patient characteristics for patient *i* in practice *g* in year *t*; G'_{gt} is a vector of practice characteristics for practice g in year t; T' is a vector of year dummies; W' is a vector of wave dummies.

The fixed part of the three-level mixed-effects model includes P'_{igt} , G'_{gt} , T' and W'. The overall random term is decomposed into three terms - v_c is a random error for CCGs with $\sim N(0, \sigma_v^2)$, u_{gc} is a random error for general practices with N $\sim N(0, \sigma_u^2)$, and e_{igc} is a patient level random error with N $\sim N(0, \sigma_e^2)$. To explore how observed factors contribute to patients' self-reported EQ-5D-5L index, we look at the estimated coefficients for variables in the fixed part of model (1). Standard errors are clustered at CCG level.

We estimate the mixed-effects model (1) on the pooled data set and on the ten condition-specific datasets. In the model with pooled data set, we used a 10% random sample from the 3,961,896 observations to reduce the computational burden in complete cases analysis and multiple imputation analysis (see Section 3.4). We set the seed in STATA and applied sampling with replacement in order to ensure the pooled data analyses is replicable. In the models for

ten specific conditions, the dependent variable is the EQ-5D-5L index for patients with the specified condition. The condition specific clinical quality measure is based on the QOF clinical indicators for the relevant patient reported specific condition. Overall clinical quality of a GP practice is also included in the ten condition-specific regressions.

3.3. Decomposition of variations of self-reported EQ-5D-5L index

The three error terms in model (1) are the components of EQ-5D-5L index which are not explained by observed patient and practice explanatories. We calculate the Intraclass Correlation Coefficient (ICC) to quantify the proportion of the total unexplained variance in the EQ-5D-5L index ($\sigma_v^2 + \sigma_u^2 + \sigma_e^2$) that is attributed to unobservable factors at CCG, general practice, and patient levels.

ICCs range between 0 to 1 and lower values indicate that a smaller proportion of the total unexplained variation is at the CCG, general practice, or patient level. We calculate the three ICCs for the pooled sample and for the ten condition-specific samples.

3.4. Multiple imputation for missing values

To examine whether the impact of missing values should be taken into account, we report the percentages of missing values by variables in the last column of **Table 1**. This check is particularly important for the GPPS data, as the data were collected from individual patients who responded to the survey voluntarily. The NHS Digital data on GP workforce and QOF measures were extracted from administrative and management systems and GP practices are legally required to share data with NHS Digital (Health and Social Care Act 2012).

Since the dependent variable in our analyses is the EQ-5D-5L index, we drop observations with missing or incomplete EQ-5D-5L data (366,849 observations out of 4,328,745 observations, or 8.5%). Our pooled sample has complete data for the EQ-5D-5L index, population achievement rate, year dummy, list size per 1,000 patients, and survey waves. For those variables with missing data we use multiple imputation which can applied to produce unbiased results if the data are missing at random or missing completely at random (Sterne et al., 2009).

We applied multiple imputation methods to the pooled sample and ten condition specific data sets for which a complete case analysis (dropping all observations with any missing items)

would have led to a considerable proportionate reduction in sample size. The missing data for those variables with missing observations were estimated using chained equations (STATA command: *impute chained*). For ordinal variables with missing values, such as overall experience with the general practices, Ordered Logistic regressions were applied. Logistic regressions were applied to deal with binary variables that reported missing values (such as taking parent/legal guardian responsibility or not). For nominal variables with missing values, we imputed missing data using predictive mean matching. For all other variables with missing values, linear equations were applied. An imputed data set was then created. We used this process to create five complete datasets. Three to five imputations are considered sufficient to give reasonable efficiency provided that the fraction of missing information is not excessive, e.g. less than 30% (Rubin 1996, p. 480). Recent literature suggested that a small number of imputations (5 to 20) may be sufficient when fractions of missing data are low (StataCorp, 2021b, p. 11). Each of the five complete data sets was analysed using a mixed-effects model as shown in model (1) (STATA command: *mi estimate: mixed*). Finally, the estimated coefficients and standard errors from each complete data set were combined for inference. We applied multiple imputation with a mixed-effects model on the pooled data set and ten condition-specific data sets. All analyses were conducted using STATA/MP 17.0 (StataCorp, 2021c).

As a sensitivity analysis, we also estimate mixed-effects model (1), on the pooled data set and ten condition specific data sets, using complete cases only.

4. Results

4.1 Summary statistics

Summary statistics for the pooled data set are presented in **Table 1**. The proportion of missing values for all variables involved in the data analyses is reported between 0 to 8.09%. During the five years, 542,087 to 678,489 patients from 6,208 to 7,944 general practices participated in the GPPS each year. Variable definitions and data sources are summarised in **Appendix 1**. We identified ten patient groups that self-reported ten long-term conditions. The condition names that we use in this paper, the original condition names used in GPPS and QOF data sets, and the QOF indicators under each condition to define clinical quality over the five years are reported in **Appendix 2**.

Figure 1 reports the mean value of the EQ-5D-5L index used in the pooled data set and ten condition-specific datasets. The mean values of the EQ-5D-5L index were stable over the five years in all 11 data sets. Unsurprisingly, the general population sample, which includes respondents with no health problems, reported higher mean EQ-5D-5L index values (between 0.79 and 0.80) over the five years compared to those for the ten specific condition samples. For the ten condition-specific samples, patients with Alzheimer or Dementia reported the lowest mean EQ-5D-5L index (0.42 to 0.43), followed by patients with long-term mental health problems (0.51 to 0.52). Patients with high blood pressure reported the highest EQ-5D-5L index (0.72) among the ten patient groups over the five years.

4.2 Observed factors that explain the variations of self-reported EQ-5D-5L index

Selected results from analysing complete cases and multiple imputation analyses used mixed-effects models for pooled sample are reported in **Table 2** (with full results reported in **Appendix 3**). The magnitudes of the estimated coefficients for the two models are very close to each other in most instances. Results are qualitatively the same across the two estimation methods for coefficients that are statistically significant at 5% level.

In general, the estimated coefficients are plausible. In the mixed-effects model with multiple imputation (last column of Table 2) the patient self-reported EQ-5D-5L index is positively and statistically significantly associated with not having any disease, good/very good overall experience with the practice, good/very good experience of making an appointment with the practice, being satisfied with the practice opening hours, being male, young, never smoked, Asian or Black, and reported with the least deprivation status. Most practice characteristics reported statistically insignificant association relationship with EQ-5D-5L index. Patients self-reported EQ-5D-5L index is positively and statistically significantly associated with practice dispensing list size (adjusted by practice list size) and being rural practices.

Results from the mixed-effects models with multiple imputation applied to ten condition-specific data sets, are reported in **Table 3**. They are broadly similar to findings that derived from the pooled data analysis used mixed-effects model with multiple imputation. For instance, in the pooled data analysis we found that the patient self-reported EQ-5D-5L index is positively and statistically significantly associated with not having any disease (in comparison to having one disease, two or more diseases, and prefer not to say). In all ten

condition specific analyses, patient self-reported EQ-5D-5L index reports positively and statistically significant association relationship with having one disease (in comparison to having more than one disease).

There are three main findings from analysing the ten condition specific data sets. First, patient self-reported EQ-5D-5L index is positively and statistically significantly associated with practice condition specific QOF clinical quality for three conditions, including diabetes, epilepsy, and asthma/chest problems. However, the effect is insignificant in the pooled sample for general population. Second, patient self-reported EQ-5D-5L index is positively and statistically significantly associated with practice list size for seven conditions, though its effect is insignificant in the pooled sample. Third, the effects of some variables differed across the ten conditions. For example, those reporting their ethnicity as Black had a statistically significantly lower EQ-5D-5L index than those reporting their ethnicity as White if they report of having angina/heart problem, but higher EQ-5D-5L index if they have asthma/chest, diabetes, hypertension, or mental health problems.

The full results from ten condition specific mixed-effect models with completed cases are available on request from authors, and with multiple imputation is reported in **Appendix 4 (**corresponding to Table 3**)**. Like the analyses of pooled data set, complete case and multiple imputation results from analysing the ten condition-specific data sets are very close to each other.

4.3. Decomposition of unexplained variations of self-reported EQ-5D-5L index

We decomposed the unexplained variation in the EQ-5D-5L index in the mixed-effects models into three components: patient, general practice, and CCG related. The variance and ICCs from the pooled mixed-effects model and ten condition-specific mixed-effects models with multiple imputation are available on request from authors. For the general population in England, variation in self-reported EQ-5D-5L index was almost entirely attributed to individual characteristics (99.44%) rather than general practices (0.46%) nor CCGs (0.10%). For the ten patient groups, variation in self-reported EQ-5D-5L index was also almost entirely associated with unobserved individual patient characteristics (between 96.57% to 99.28%). The proportion of unexplained variation in the EQ-5D-5L index at the GP practice level was reported between 0.49% (patients reported with hypertension) and 3.21% (patients reported

with Alzheimer or Dementia). Across the general population in England and the ten patient groups, the unexplained variations in the EQ-5D-5L index are generally not at CCG level (0.10% to 0.58%).

5. Discussion

This paper is the first attempt to explore which factors contribute to the variation in EQ-5D-5L for the general population and for patients with at least one of ten chronic conditions in English general practices and to decompose the unexplained variation to patient, practice and CCG levels. We used patient-level GP Patient Survey data for five years, between 2012/13 and 2016/17, linked to data on clinical quality from the Quality and Outcomes Framework and data on the workforce in general practices.

Results from mixed-effects models estimated on complete cases and multiply imputed data sets were similar across the 11 pairs of analyses (one from pooled sample and ten from condition specific samples). For the pooled sample analyses, most of the variables that report statistically significant association relationship with EQ-5D-5L index are patient characteristics. We found that better reported overall experience with the practice, better experience with making an appointment, and satisfaction with practice opening hours were associated with higher EQ-5D-5L index. Male patients, being young, Asian or Black, those who reported no chronic or no co-morbidity, were a parent/legal guardian, had a full-time job, did not smoke, lived in less deprived areas also reported higher EQ-5D-5L. For practice characteristics, we only found practices in rural areas (in comparison to urban areas) and practices with larger dispensing list size were associated with higher EQ-5D-5L index. The ten analyses on condition specific data sets report broadly similar results like the pooled data analyses. There are three main findings from the condition specific data analyses that worth mentioning. First, the condition specific clinical quality that measured by practice performance against QOF was positively and statistically associated with the EQ-5D-5L index in three conditions. Second, patient self-reported EQ-5D-5L index was positively and statistically significantly associated with practice list size for seven conditions. Third, the effects of some variables on the EQ-5D-5L index, such as ethnicity, differed across the ten conditions.

The coefficients estimated from the fixed effect part of the mixed-effect models are broadly plausible. Results from age bands worth mentioning. The summary statistics across the eight

age bands show a clear trend of decrease in the average EQ-5D-5L index with increasing in age (from 0.89 for 18-24 years old to 0.59 to 85 years old and above). In the 11 regression analyses, patients' age in general were negatively associated with self-reported EQ-5D-5L index. However, the trend of decreasing in the average EQ-5D-5L index with the increased age stopped at 55-64 years old for most of the 11 analyses. The average EQ-5D-5L index is still lower than that reported by 18-25 years old, but the decrease in magnitude was not as large as that were reported by the 45-54 years old. Furthermore, we observed people at 65-74 years old reported good health in many cases across the 11 analyses, and for some analyses it is indifferent or better than reported by the 18-24 years old. 85 years old and above showed the lowest level of self-reported EQ-5D-5L. This is unambiguous across the 11 analyses. One explanation is that age is likely to be associated with people's self-reported number of diseases. As a result, the effect of age in the regression analyses are affected.

We decomposed the variation of the EQ-5D-5L index that observed factors could not explain into patient, general practice, and CCGs levels. For patients with at least one of ten chronic conditions, almost all (at least 96.57%) of unexplained variation was at patient level. In the pooled sample of general population, irrespective of whether they had chronic conditions an even greater proportion of the unexplained (99.44%) was at patient level, with 0.46% attributed to practices and 0.10% to CCGs.

A strength of this study is the unique data set that we used, a nationally representative sample for the English general population. The data set includes around four million patient-level records over five years. We could also identify patient groups that self-reported ten common chronic conditions using this data set. We linked this patient-level data set with GP workforce data and QOF data. The linked data set provided a rich list of patient and practice characteristics, which enabled our analyses to explore which factors explained the variation in the EQ-5D-5L index - not only health factors and demographic characteristics of patients but also socio-economic status (research aim one). Furthermore, the linked data set allowed the mixed-effects model to decompose variations that cannot be explained by observed factors (research aim two). Another strength of the study is the robustness of our findings. For both research aims, we conducted analyses to check the impact of changes in GPPS design in 2015 (by including interaction terms between independent variables in model (1) and dummy variable for years pre and post 2015) and decision on number of imputations (with

alternative number of imputations at 2, 3, and 4). We also compared results from complete case and multiply-imputed data.

A limitation of the study is that the definitions of ten chronic conditions in the GPPS and QOF data sets differ for some conditions so that the patient reported condition may not fully correspond to the condition for which care was incentivised by the QOF.

6. Conclusions

The findings from our study identifies factors that explain the variation in health for the general population and ten patient groups with chronic conditions in England. Policymakers might consider developing interventions to reduce or eliminate the effects for some of those factors that we identified, such as smoking and deprivation status of individuals, or patient satisfaction with access to their GP practice, to improve people's health in England and to reduce "avoidable" variation in health. Furthermore, our findings suggest that residual variation in health, measured by EQ-5D-5L index, for the general population and ten patient groups with chronic conditions in England are almost all attributed to individual patient factors but not GP practices or CCGs. The implication is that to improve variation in patient self-reported health, policy makers might consider introducing interventions or incentives that can be directly applied to patients rather than on GP practices or CCGs.

In future work we plan to extend the analyses to examine deprivation related inequality in EQ-5D-5L using concentration indices (Gravelle 2003; Heckley et al., 2016). We will also examine which practice and patient variables are associated with failure of 366,849 respondants to provide a full report of EQ-5D-5L, and their implications for interpretation of models of EQ-5D-5L.

Acknowledgement

The project is funded by the EuroQol Research Foundation (Award Number: EQ Project 20180740). The team received permission from NHS England to access patient-level GPPS data on 28th March 2019. We would like to thank Thomas Cadman (NHS England) and Joanna Barry (Ipsos MORI) for their help with the GPPS data. Yan Feng is a member of the EuroQol Research Foundation. The authors declare no conflict of interest.

References

Chief Medical Officer. 2020. Annual Report - Health trends and variation in England. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945929/Chief_Medical_Officer_s_annual_report_2020_-_health_trends_and_variation_in_England.pdF. Last accessed on 21/11/2021.

Dahlgren G, Whitehead M. 1991. Policies and Strategies to Promote Social Equity in Health. Stockholm, Sweden: Institute for Futures Studies.

Department of Health. 2014. Living Well for Longer: National Support for Local Action to Reduce Premature Avoidable Mortality. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/307703/LW4L.pdf. Last accessed on 21/11/2021.

Department of Health. 2017. Towards a Smokefree Generation: A Tobacco Control Plan for England. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/630217/Towards_a_Smoke_free_Generation_-_A_Tobacco_Control_Plan_for_England_2017-2022__2_.pdf. Last accessed on 21/11/2021.

Doran T, Fullwood C, Kontopantelis E, Reeves D. 2008. Effect of financial incentives on inequalities in the delivery of primary clinical care in England: analysis of clinical activity indicators for the quality and outcomes framework. Lancet. 372:728-36.

Feng Y and Gravelle H. 2021. Patient Self-Reported Health, Clinical Quality, and Patient Satisfaction in English Primary Care: Practice-Level Longitudinal Observational Study. Value in Health. 24(11): 1660-1666.

Gravelle, H. Measuring income related inequality in health: standardisation and the partial concentration index, Health Economics, 2003, 12, 803-820.

Health and Social Care Act. Health and Social Care Act 2012 [Chapter 7]. Available from: http://www.legislation.gov.uk/ukpga/2012/7/pdfs/ukpga_20120007_en.pdf. Last accessed on 21/11/2021.

Heckley, G., Gerdtham, U., Kjellsson, G. (2016). A general method for decomposing the causes of socioeconomic inequality in health. Journal of Health Economics, (48) 89-106.

Kind P, Dolan P, Gudex C, Williams A. Variations in population health status: results from a United Kingdom national questionnaire survey. BMJ. 1998 Mar 7;316(7133):736-41.

Marmot M, Allan J, Boyce T, Goldblatt P, Morrison J. Institute of Health Equity; London: 2020. 2020 Health equity in England: the Marmot review 10 years on.

Office for National Statistics, 2020. Health state life expectancies by national deprivation deciles, England 2016 to 2018.

Public Health England. 2021. Health Profile for England 2021. https://fingertips.phe.org.uk/static-reports/health-profile-for-england/hpfe_report.html. Last accessed on 21/11/2021.

Raleigh VS, Kiri VA. Life expectancy in England: variations and trends by gender, health authority, and level of deprivation. J Epidemiol Community Health. 1997 Dec;51(6):649-58.

Rubin DB. 1987. Multiple Imputation for Nonresponse in Surveys. New York: John Wiley & Sons.

Starfield B, Shi L, Macinko J. 2005. Contribution of primary care to health systems and health. Milbank Q. 83(3):457-502.

StataCorp. 2021a. Multilevel Mixed-Effects Reference Manual. Release 17. https://www.stata.com/manuals/me.pdf. Last accessed on 18/01/2022.

StataCorp. 2021b. Stata Manual – Multiple-Imputation Reference Manual. Release 17. https://www.stata.com/manuals/mi.pdf. Last accessed on 21/11/2021.
StataCorp. 2021c. Stata Statistical Software: Release 17. College Station, TX: StataCorp LLC.
Sterne JA, White IR, Carlin JB, Spratt M, Royston P, Kenward MG, Wood AM, Carpenter JR. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. BMJ. 2009 Jun 29;338:b2393.
van Hout B, Janssen MF, Feng Y-S., et al. 2012. Interim scoring for the EQ-5D-5L: Mapping the EQ-5D-5L to EQ-5D-3L value sets. Value in Health. 15, 708–715.

Table 1: Summary statistics – pooled sample with EQ-5D-5L data (N= 3,961,896)

Variable	Mean	Std. Dev.	Min	Max	Missing values
Patient level variables					
EQ-5D-5L index	0.7955	0.2370	-0.5940	1	0.00%
Reported no disease	0.3580	0.4794	0	1	8.09%
Reported one disease	0.3210	0.4668	0	1	8.09%
Reported two or more diseases	0.3037	0.4599	0	1	8.09%
Reported don't want to say about disease	0.0173	0.1305	0	1	8.09%
Overall experience very good/fairly good	0.8806	0.3243	0	1	0.88%
Overall experience neither good nor bad	0.0808	0.2726	0	1	0.88%
Overall experience bad or very bad	0.0386	0.1926	0	1	0.88%
Experience: make appointment very good/fairly good	0.7857	0.4103	0	1	4.22%
Experience: make appointment neither good nor bad	0.1196	0.3245	0	1	4.22%
Experience: make appointment bad/very bad	0.0946	0.2927	0	1	4.22%
Satisfaction with open hours very/fairly good	0.8004	0.3997	0	1	0.78%
Satisfaction with open hours neither good nor bad	0.0904	0.2867	0	1	0.78%
Satisfaction with open hours bad very bad	0.0757	0.2645	0	1	0.78%
Do not know when practices open	0.0335	0.1799	0	1	0.78%
Male patient	0.4375	0.4961	0	1	1.21%
Female patient	0.5625	0.4961	0	1	1.21%
Patients 18-24 years old	0.0410	0.1983	0	1	1.20%
Patients 25-34 years old	0.0947	0.2928	0	1	1.20%
Patients 35-44 years old	0.1285	0.3346	0	1	1.20%
Patients 45-54 years old	0.1763	0.3811	0	1	1.20%
Patients 55-64 years old	0.2028	0.4021	0	1	1.20%
Patients 65-74 years old	0.2049	0.4037	0	1	1.20%
Patients 75-84 years old	0.1157	0.3198	0	1	1.20%
Patients 85 years old or above	0.0362	0.1867	0	1	1.20%
Full time work	0.3512	0.4774	0	1	3.76%
Part-time work	0.1370	0.3438	0	1	3.76%
Neither full nor part-time work	0.5118	0.4999	0	1	3.76%
Legal guardian	0.2018	0.4014	0	1	5.32%

Not legal guardian	0.7982	0.4014	0	1	5.32%
No smoker	0.5367	0.4986	0	1	1.41%
Former smoker	0.3189	0.4661	0	1	1.41%
Occasional smoker	0.0593	0.2362	0	1	1.41%
Regular smoker	0.0850	0.2789	0	1	1.41%
White	0.8797	0.3253	0	1	1.57%
Mixed	0.0079	0.0886	0	1	1.57%
Asian	0.0621	0.2413	0	1	1.57%
Black	0.0259	0.1589	0	1	1.57%
Other ethnic groups	0.0244	0.1543	0	1	1.57%
Indices of multiple deprivation	21.5383	15.4187	0.4770	92.6010	0.07%
Practice level data					
Population achievement rate	0.7742	0.0809	0	0.9980	0.00%
List size 1000 patients	7.5529	4.4643	1.0050	60.7130	0.00%
GP / list size 1000 patients	0.5769	0.2687	0	5.2933	0.16%
Nurse / list size 1000 patients	0.2524	0.1643	0	5.3333	4.03%
Other staff / list size 1000 patients	1.2461	0.5504	0	18.4475	4.03%
GP up to 34 years old	0.1378	0.1755	0	1	4.65%
GP 35-49 years old	0.4373	0.2766	0	1	4.65%
GP 50 years old and over	0.4138	0.2926	0	1	4.65%
GP age unknown	0.0110	0.1005	0	1	4.65%
Male GPs	0.5372	0.2529	0	1	5.46%
Female GPs	0.4628	0.2529	0	1	5.46%
GP qualification from UK	0.6719	0.3568	0	1	4.65%
GP qualification from Euro	0.0492	0.1300	0	1	4.65%
GP qualification other places	0.2266	0.3190	0	1	4.65%
GP qualification unknown	0.0523	0.2049	0	1	4.65%
Dispensing patients/list size 1000 patients	0.0693	0.2011	0	1.0698	0.16%
Rurality – rural	0.1661	0.3721	0	1	0.03%
Rurality – urban	0.8339	0.3721	0	1	0.03%
Survey wave 1	0.4015	0.4902	0	1	0.00%
Survey wave 2	0.5985	0.4902	0	1	0.00%
Proportion of observations in 2012/13	0.2205	0.4146	0	1	0.00%
Proportion of observations in 2013/14	0.2063	0.4046	0	1	0.00%
Proportion of observations in 2014/15	0.1959	0.3969	0	1	0.00%
Proportion of observations in 2015/16	0.1913	0.3934	0	1	0.00%
Proportion of observations in 2016/17	0.1860	0.3891	0	1	0.00%

Table 2: Mixed-effects model use pooled data set with completed cases and multiple imputation

Modelling EQ-5D-5L index	Complete cases	Multiple imputation
Patients characteristics		
One disease	-0.0914***	-0.0890***
More than one disease	-0.2498***	-0.2513***
Prefer not to say	-0.0908***	-0.1053***
Experience: very/fairly good	0.0352***	0.0356***
Experience: not good or bad	0.0193***	0.0198***
Make appt: very/fairly good	0.0228***	0.0235***
Make appt: not good or bad	0.0067***	0.0067***
Open hrs: not good or bad	0.0068***	0.0086***
Open hrs: bad/very bad	-0.0004	-0.0002
Don't know open time	0.0069**	0.0051*
Female patient	-0.0106***	-0.0098***
Patients at 25-34 years old	-0.0303***	-0.0292***
Patients at 35-44 years old	-0.0521***	-0.0512***
Patients at 45-54 years old	-0.0617***	-0.0620***
Patients at 55-64 years old	-0.0329***	-0.0355***
Patients at 65-74 years old	0.0241***	0.0179***
Patients at 75-84 years old	-0.0041	-0.0110***
Patients >= 85 years old	-0.1087***	-0.1122***
Former smoker	-0.0171***	-0.0184***
Occasional smoker	-0.0432***	-0.0422***
Regular smoker	-0.0581***	-0.0578***
Patients as Mixed	-0.0053	-0.0025
Patients as Asian	0.0062**	0.0046**
Patients as Black	0.0196***	0.0195***
Other ethnic background	-0.0115**	-0.0094**
Deprivation	-0.0013***	-0.0013***
Practice characteristics		
Dispensing patients/list size 1000 patients	0.0052	0.0050*
Urban	-0.0028*	-0.0035**
Number of observations	283,266	396,190

Note: estimated models with all covariates are available from authors. *** P<0.001; ** P<0.01; * P<0.05; higher IMD indicates lower deprivation.

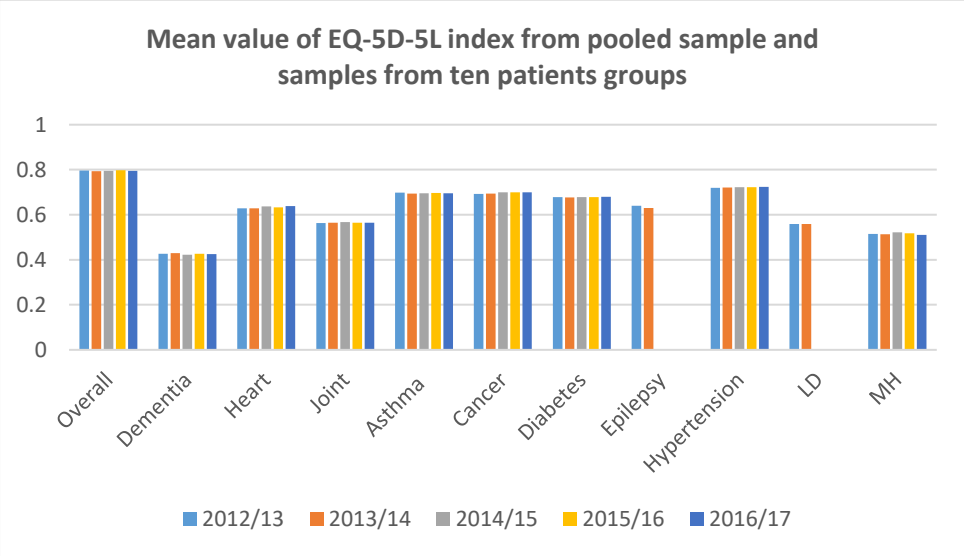
Table 3: Mixed-effects model use ten disease specific data sets with multiple imputation

	Alzheimer/ dementia	Angina/ heart	Arthritis joint	Asthma/ chest	Cancer	Diabetes	Epilepsy	Hyperten-sion	Learning difficulty	Mental health
Patients characteristics										
More than one disease	-0.1317***	-0.1894***	-0.1281***	-0.2008***	-0.1388***	-0.1854***	-0.2411***	-0.1991***	-0.2141***	-0.1953***
Experience: very/fairly good	0.0972***	0.0642***	0.0584***	0.0444***	0.0714***	0.0613***	0.0407**	0.0543***	0.0905***	0.0699***
Experience: not good or bad	0.0536***	0.0408***	0.0409***	0.0277***	0.0460***	0.0344***	0.0370*	0.0334***	0.0825***	0.0472***
Make appt: very/fairly good	0.0412***	0.0414***	0.0372***	0.0332***	0.0358***	0.0520***	0.0514***	0.0412***	0.0464***	0.0488***
Make appt: not good or bad	0.0185	0.0157***	0.0188***	0.0147***	0.0138***	0.0233***	0.0256*	0.0161***	0.0287*	0.0226***
Open hrs: very/fairly good	0.0850***	0.0292***	0.0183***	0.0092***	0.0241***	0.0221***	0.0283**	0.0167***	0.0203	0.0148***
Open hrs: not good or bad	0.0385**	0.0180***	0.0107***	0.0024	0.0179***	0.0115***	0.0089	0.0083***	0.0156	0.0066
Don't know open time	-0.0901***	-0.0502***	-0.0180***	-0.0119***	-0.0084	-0.0457***	-0.0452*	-0.0226***	0.0319	-0.0074
Female patient	-0.0558***	-0.0413***	0.0010	-0.0079***	-0.0175***	-0.0245***	-0.0134**	-0.0180***	-0.0151**	0.0024
Patients at 25-34 years old	-0.0326	-0.0282*	-0.0304***	-0.0527***	-0.0117	-0.0400***	-0.0442**	-0.0296***	-0.0426***	-0.0219***
Patients at 35-44 years old	-0.1226**	-0.0736***	-0.0650***	-0.0838***	-0.0370*	-0.0615***	-0.0576***	-0.0569***	-0.0741***	-0.0412***
Patients at 45-54 years old	-0.2258***	-0.1055***	-0.0737***	-0.1079***	-0.0571***	-0.0853***	-0.0664***	-0.0769***	-0.0914***	-0.0643***
Patients at 55-64 years old	-0.2490***	-0.0683***	-0.0109	-0.0833***	-0.0205	-0.0597***	-0.0223	-0.0521***	-0.1092***	-0.0330***
Patients at 65-74 years old	-0.1917***	0.0179	0.0823***	-0.0116***	0.0442**	0.0195**	0.0546***	0.0078	-0.0690***	0.0621***
Patients at 75-84 years old	-0.2145***	-0.0074	0.0640***	-0.0409***	0.0066	-0.0142*	0.0167	-0.0245**	-0.1180***	0.0108
Patients >= 85 years old	-0.3128***	-0.0936***	-0.0257***	-0.1278***	-0.0956***	-0.0980***	-0.0846***	-0.1136***	-0.2176***	-0.1195***
Former smoker	-0.0015	-0.0278***	-0.0199***	-0.0397***	-0.0310***	-0.0275***	-0.0232***	-0.0218***	-0.0196**	-0.0229***
Occasional smoker	0.0137	-0.0735***	-0.0689***	-0.0791***	-0.0713***	-0.0542***	-0.0493***	-0.0530***	-0.0391**	-0.0619***
Regular smoker	-0.0174	-0.0734***	-0.0744***	-0.0888***	-0.0801***	-0.0698***	-0.0613***	-0.0617***	-0.0384***	-0.0591***
Patients as Mixed	0.0579	-0.0241*	-0.0122*	-0.0022	-0.0299**	0.0026	-0.0682*	-0.0104**	-0.0563*	0.0013
Patients as Asian	-0.0850***	-0.0458***	-0.0373***	-0.0114***	-0.0457***	-0.0008	-0.0693***	-0.0195***	-0.1035***	-0.0654***
Patients as Black	-0.0209	-0.0291***	-0.0049	0.0086*	-0.0097	0.0321***	0.0018	0.0102***	-0.0140	0.0388***
Other ethnic background	-0.0269*	-0.0690***	-0.0544***	-0.0406***	-0.0549***	-0.0180***	-0.0785***	-0.0376***	-0.0903***	-0.0858***
Deprivation	-0.0015***	-0.0023***	-0.0020***	-0.0020***	-0.0023***	-0.0020***	-0.0018***	-0.0019***	-0.0005**	-0.0019***
Practice characteristics										

Condition specific PA	-0.0416	0.0038	-0.0021	0.0174*	0.0023	0.0651***	0.0628**	-0.0003	0.0123	0.0097
List size per 1000 patients	0.0002	0.0010***	0.0007***	0.0006***	0.0004*	0.0003**	0.0003	0.0004***	-0.0007	0.0009***
Urban	-0.0038	-0.0067**	-0.0084***	-0.0083***	-0.0055**	-0.0022	-0.0010	-0.0039**	-0.0141	-0.0007
Dispense patients/list size 1000	0.0055	0.0116**	0.0103***	0.0131***	0.0081*	0.0097**	0.0249	0.0084***	0.0324	0.0228***
Number of observations	26,403	247,513	628,926	401,277	160,891	355,449	16,096	916,440	12,426	152,328

Note: estimated models with all covariates are available from authors. *** P<0.001; ** P<0.01; * P<0.05; higher IMD indicates lower deprivation.

Figure 1: Mean value of EQ-5D-5L index use pooled sample and samples from ten patients' groups



Appendix 1: Data source and variable definitions

Data source	Variable names	Definition by category
Patient characteristics		
GPPS	Self-reported EQ-5D-5L	Self-reported EQ-5D-5L
GPPS	Self-report health	no disease (baseline); one disease; 2 or more diseases; prefer not to say
GPPS	Overall experience with practice	Very/fairly good; neither good or bad; fairly/very poor (baseline)
GPPS	Experience of making appointment	Very/fairly good; neither good or bad; fairly/very poor (baseline)
GPPS	Satisfaction with open hours	Very/fairly good; neither good or bad; fairly/very poor (baseline); not sure open time
GPPS	Patient's gender	Male (baseline); female
GPPS	Patient's age	18-24 (baseline); 25-34; 35-44; 45-54; 55-64; 65-74; 75-84; 85 or over
GPPS	Work status	Full-time (≥30 hr/week) (baseline); part-time (< 30 hrs/week); other working status
GPPS	Parent/legal guardian for under 16	Yes (baseline); no
GPPS	Smoke status	Never (baseline); former; occasional; regular
GPPS	Ethnicity	White (baseline); Mixed; Asian; Black; Other
GPPS	IMD score	IMD score
Practice characteristics		
NHS Digital QOF	Population achievement	QOF population achievement rate at practice-financial year-indicator level
NHS Digital QOF	Practice list size	Practice list size per 1,000 patients
NHS Digital gp workforce	Proportion of FTE staff by professions	N of FTE nurses per 1,000 patients; N of FTE GPs per 1,000 patients; N of FTE other professionals per 1,000 patients
NHS Digital gp workforce	Distribution of GPs by age groups (%)	Up to 34 (baseline); 35-49; 50 or above; age as unknown
NHS Digital gp workforce	Distribution of GPs by gender (%)	Female GPs (baseline); male GPs
NHS Digital gp workforce	Distribution of GPs by qualification (%)	UK qualified (baseline); EU qualified; other places qualified; unknown for places qualified
NHS Digital gp workforce	Dispensing patients	N of dispensing patients in a practice
GPPS	Rurality band	Urban or Rural (baseline)
GPPS	Survey waves	Wave 1 bewteen July to September (baseline); wave 2 bewteen January to March
GPPS	Year	2012/13 (baseline); 2013/14; 2014/15; 2015/16; 2016/17

Appendix 2: Definitions of the ten disease areas

Ten disease areas in this study	Question (Q31) in GPPS between 2012/13 to 2016/17: Which, if any, of the following medical conditions do you have?	Disease domains defined in QOF	QOF indicators				
			2012/13	2013/14	2014/15	2015/16	2016/17
Alzheimer or dementia	Alzheimer's disease or dementia	DEM	DEM02, DEM04	DEM002-003	DEM002-003	DEM004-005	DEM004-005
Angina or heart	Angina or long-term heart problem	AF, HF, CHD	AF05-07; CHD06, CHD08-CHD10, CHD12; CHD14, HF02-04	AF002-004; CHD002-6; HF002-004	AF004-005; CHD002, CHD005-007; HF002-004	AF006-007; CHD002, CHD005, CHD007; HF002-004	AF006-007; CHD002, CHD005, CHD007; HF002-004
Arthritis or joint	Arthritis or long-term joint problem	OST, RA	OST02-03	OST002-003; RA002-004	OST002; OST005; RA002	OST002, OST005; RA002	OST002, OST005; RA002
Asthma or chest	Asthma or long-term chest problem	AST, COPD	ASTHMA08-10; COPD8, COPD10, COPD13, COPD15	AST002-004; COPD002-006	AST002-004; COPD002-005, COPD007	AST002-004; COPD002-005, COPD007	AST002-004; COPD002-005, COPD007
Cancer	Cancer in the last 5 years	CAN	CANCER03	CAN002	CAN003	CAN003	CAN003
Diabetes	Diabetes	DM	DM02, DM10, DM13, DM15, DM17-18, DM21-22, DM26-31	DM002-016	DM002-004, DM006-009, DM012, DM014, DM018	DM002-004, DM006-009, DM012, DM014, DM018	DM002-004, DM006-009, DM012, DM014, DM018
Epilepsy	Epilepsy	EP	EPILEP06, EPILEP08-09	EP002-003			
Hypertension	High blood pressure	BP	BP04-05	HYP002-005	HYP006	HYP006	HYP006
Learning difficulty	Learning difficulty	LD	LD02	LD002			
Mental health	Long-term mental health problem	DEP, MH	DEP01, DEP 06-07; MH10-13, M16-20	DEP001-002; MH002-010	DEP003; MH002-003, MH007-MH010	DEP003; MH002-003, MH007-MH010	DEP003; MH002-003, MH007-010

Appendix 3: Mixed-effects model use pooled data set with completed cases and multiple imputation (full results)

Modelling EQ-5D-5L index	Complete cases	Multiple imputation
Population achievement (PA)	-0.0015	-0.0009
List size per 1000 patients	0.0001	0.0002
One disease	-0.0914***	-0.0890***
More than one disease	-0.2498***	-0.2513***
Prefer not to say	-0.0908***	-0.1053***
Experience: very/fairly good	0.0352***	0.0356***
Experience: not good or bad	0.0193***	0.0198***
Make appt: very/fairly good	0.0228***	0.0235***
Make appt: not good or bad	0.0067***	0.0067***
Open hrs: very/fairly good	0.0068***	0.0086***
Open hrs: not good or bad	-0.0004	-0.0002
Don't know open time	0.0069**	0.0051*
Female patient	-0.0106***	-0.0098***
Patients at 25-34 years old	-0.0303***	-0.0292***
Patients at 35-44 years old	-0.0521***	-0.0512***
Patients at 45-54 years old	-0.0617***	-0.0620***
Patients at 55-64 years old	-0.0329***	-0.0355***
Patients at 65-74 years old	0.0241***	0.0179***
Patients at 75-84 years old	-0.0041	-0.0110***
Patients >= 85 years old	-0.1087***	-0.1122***
Patients with part-time job	-0.0205***	-0.0202***
Neither full or part-time job	-0.1005***	-0.1020***
Not legal guardian or parent	-0.0211***	-0.0209***
Former smoker	-0.0171***	-0.0184***
Occasional smoker	-0.0432***	-0.0422***
Regular smoker	-0.0581***	-0.0578***
Patients as Mixed	-0.0053	-0.0025
Patients as Asian	0.0062**	0.0046**
Patients as Black	0.0196***	0.0195***
Other ethnic background	-0.0115**	-0.0094**
N GPs/1000 patients	0.0004	0.0004
N nurses/1000 patients	-0.0037	-0.0017
N other staff/1000 patients	-0.0004	-0.0002
GPs 35-49 yrs	0.0025	0.0005
GPs 50 yrs or above	0.0048*	0.0025
GPs age unknown	0.0033	0.0046
male GPs	-0.0019	-0.0017
Qualified from Europe	0.0016	0.0026
Qualified outside UK/Euro	-0.0027	-0.0031*
Qualified unknown places	0.0015	0.0012
Dispensing patients/list size 1000 patients	0.0052	0.0050*

Urban	-0.0028*	-0.0035**
Deprivation	-0.0013***	-0.0013***
2013/14	-0.0004	0.0005
2014/15	-0.0008	-0.0008
2015/16	-0.0034**	-0.0033**
2016/17	-0.0073***	-0.0071***
Survey wave 2	0.0012	0.0013
Constant	0.9903***	0.9922***
Number of observations	283,266	396,190

Note: *** P<0.001; ** P<0.01; * P<0.05; Deprivation is the negative of the IMD.

Appendix 4: Mixed-effects model use ten disease specific data sets with multiple imputation (full results)

	Alzheimer/ dementia	Angina/he art	Arthritis joint	Asthma/ chest	Cancer	Diabetes	Epilepsy	Hypertensio n	Learning difficulty	Mental health
Population achievement (PA)	0.0385	0.0114	0.0010	-0.0038	-0.0096	-0.0315***	0.0120	0.0035	-0.0245	-0.0039
Condition specific PA	-0.0416	0.0038	-0.0021	0.0174*	0.0023	0.0651***	0.0628**	-0.0003	0.0123	0.0097
List size per 1000 patients	0.0002	0.0010***	0.0007***	0.0006***	0.0004*	0.0003**	0.0003	0.0004***	-0.0007	0.0009***
More than one disease	-0.1317***	-0.1894***	-0.1281***	-0.2008***	-0.1388***	-0.1854***	-0.2411***	-0.1991***	-0.2141***	-0.1953***
Experience: very/fairly good	0.0972***	0.0642***	0.0584***	0.0444***	0.0714***	0.0613***	0.0407**	0.0543***	0.0905***	0.0699***
Experience: not good or bad	0.0536***	0.0408***	0.0409***	0.0277***	0.0460***	0.0344***	0.0370*	0.0334***	0.0825***	0.0472***
Make appt: very/fairly good	0.0412***	0.0414***	0.0372***	0.0332***	0.0358***	0.0520***	0.0514***	0.0412***	0.0464***	0.0488***
Make appt: not good or bad	0.0185	0.0157***	0.0188***	0.0147***	0.0138***	0.0233***	0.0256*	0.0161***	0.0287*	0.0226***
Open hrs: very/fairly good	0.0850***	0.0292***	0.0183***	0.0092***	0.0241***	0.0221***	0.0283**	0.0167***	0.0203	0.0148***
Open hrs: not good or bad	0.0385**	0.0180***	0.0107***	0.0024	0.0179***	0.0115***	0.0089	0.0083***	0.0156	0.0066
Don't know open time	-0.0901***	-0.0502***	-0.0180***	-0.0119***	-0.0084	-0.0457***	-0.0452*	-0.0226***	0.0319	-0.0074
Female patient	-0.0558***	-0.0413***	0.0010	-0.0079***	-0.0175***	-0.0245***	-0.0134**	-0.0180***	-0.0151**	0.0024
Patients at 25-34 years old	-0.0326	-0.0282*	-0.0304***	-0.0527***	-0.0117	-0.0400***	-0.0442**	-0.0296***	-0.0426***	-0.0219***
Patients at 35-44 years old	-0.1226**	-0.0736***	-0.0650***	-0.0838***	-0.0370*	-0.0615***	-0.0576***	-0.0569***	-0.0741***	-0.0412***
Patients at 45-54 years old	-0.2258***	-0.1055***	-0.0737***	-0.1079***	-0.0571***	-0.0853***	-0.0664***	-0.0769***	-0.0914***	-0.0643***
Patients at 55-64 years old	-0.2490***	-0.0683***	-0.0109	-0.0833***	-0.0205	-0.0597***	-0.0223	-0.0521***	-0.1092***	-0.0330***
Patients at 65-74 years old	-0.1917***	0.0179	0.0823***	-0.0116***	0.0442**	0.0195**	0.0546***	0.0078	-0.0690***	0.0621***
Patients at 75-84 years old	-0.2145***	-0.0074	0.0640***	-0.0409***	0.0066	-0.0142*	0.0167	-0.0245**	-0.1180***	0.0108
Patients >= 85 years old	-0.3128***	-0.0936***	-0.0257***	-0.1278***	-0.0956***	-0.0980***	-0.0846***	-0.1136***	-0.2176***	-0.1195***
Patients with part-time job	-0.0258	-0.0528***	-0.0443***	-0.0291***	-0.0318***	-0.0392***	-0.0286***	-0.0335***	-0.0253*	-0.0268***
Neither full or part-time job	-0.2832***	-0.2031***	-0.2033***	-0.1831***	-0.1575***	-0.1983***	-0.2396***	-0.1427***	-0.2284***	-0.2448***
Not legal guardian or parent	-0.0697***	-0.0097*	-0.0190***	-0.0308***	-0.0092**	-0.0165***	-0.0419***	-0.0141***	-0.0298**	-0.0190***
Former smoker	-0.0015	-0.0278***	-0.0199***	-0.0397***	-0.0310***	-0.0275***	-0.0232***	-0.0218***	-0.0196**	-0.0229***
Occasional smoker	0.0137	-0.0735***	-0.0689***	-0.0791***	-0.0713***	-0.0542***	-0.0493***	-0.0530***	-0.0391**	-0.0619***
Regular smoker	-0.0174	-0.0734***	-0.0744***	-0.0888***	-0.0801***	-0.0698***	-0.0613***	-0.0617***	-0.0384***	-0.0591***
Patients as Mixed	0.0579	-0.0241*	-0.0122*	-0.0022	-0.0299**	0.0026	-0.0682*	-0.0104**	-0.0563*	0.0013

Patients as Asian	-0.0850***	-0.0458***	-0.0373***	-0.0114***	-0.0457***	-0.0008	-0.0693***	-0.0195***	-0.1035***	-0.0654***
Patients as Black	-0.0209	-0.0291***	-0.0049	0.0086*	-0.0097	0.0321***	0.0018	0.0102***	-0.0140	0.0388***
Other ethnic background	-0.0269*	-0.0690***	-0.0544***	-0.0406***	-0.0549***	-0.0180***	-0.0785***	-0.0376***	-0.0903***	-0.0858***
N GPs/1000 patients	0.0008	0.0035	0.0008	0.0012	-0.0001	0.0006	-0.0083	0.0004	0.0094	-0.0027
N nurses/1000 patients	-0.0073	-0.0056	-0.0043	-0.0022	0.0006	-0.0062	-0.0060	-0.0034	0.0008	-0.0004
N other staff/1000 patients	-0.0039	-0.0027*	-0.0004	-0.0011	-0.0022	-0.0002	-0.0023	-0.0017*	-0.0107	-0.0037*
GPs 35-49 yrs	-0.0138	0.0035	0.0025	0.0029	0.0013	-0.0052	-0.0236	-0.0013	-0.0209	0.0045
GPs 50 yrs or above	-0.0180	0.0069	0.0036	0.0061*	0.0025	-0.0015	-0.0078	0.0022	-0.0104	0.0049
GPs age unknown	-0.0163	-0.0055	0.0001	0.0034	-0.0082	-0.0056	0.0243	-0.0030	0.1967	0.0049
male GPs	-0.0008	-0.0051*	-0.0066***	-0.0073***	-0.0036	-0.0017	-0.0176	-0.0056***	0.0017	-0.0129**
Qualified from Europe	-0.0173	-0.0084	-0.0069*	-0.0012	-0.0061	-0.0032	-0.0087	-0.0034	0.0056	-0.0073
Qualified outside UK/Euro	-0.0110	-0.0169***	-0.0103***	-0.0088***	-0.0130***	-0.0051*	-0.0151	-0.0081***	0.0197*	-0.0124***
Qualified unknown places	-0.0123	-0.0019	-0.0027	0.0010	-0.0013	-0.0025	0.0329	-0.0002	-0.1685	0.0059
Dispense patients/list size 1000	0.0055	0.0116**	0.0103***	0.0131***	0.0081*	0.0097**	0.0249	0.0084***	0.0324	0.0228***
Urban	-0.0038	-0.0067**	-0.0084***	-0.0083***	-0.0055**	-0.0022	-0.0010	-0.0039**	-0.0141	-0.0007
Deprivation	-0.0015***	-0.0023***	-0.0020***	-0.0020***	-0.0023***	-0.0020***	-0.0018***	-0.0019***	-0.0005**	-0.0019***
2013/14	0.0089	0.0023	0.0015	-0.0004	0.0033	-0.0014	-0.0022	0.0015	0.0007	-0.0016
2014/15	0.0085	0.0069***	0.0028**	0.0003	0.0082***	0.0030*		0.0037***		-0.0025
2015/16	0.0120	0.0030	-0.0022	-0.0064***	0.0051*	-0.0009		-0.0002		-0.0135***
2016/17	0.0080	0.0025	-0.0053***	-0.0090***	0.0031	-0.0007		-0.0016		-0.0237***
Survey wave 2	0.0040	0.0048***	0.0034***	0.0018	0.0040**	0.0025*	0.0015	0.0038***	-0.0104	-0.0047**
Constant	1.0071***	0.9527***	0.7891***	1.0304***	0.8883***	0.9510***	0.9818***	0.9769***	0.9531***	0.8309***
Number of observations	26,403	247,513	628,926	401,277	160,891	355,449	16,096	916,440	12,426	152,328

Note: *** P<0.001; ** P<0.01; * P<0.05; Deprivation is the negative of the IMD.