

# An examination of trends in antibiotic prescribing by area-level deprivation in England

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## Research article

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## Abstract

**Background** As part of an approach to reduce antimicrobial resistance, there has been strategic focus placed on reducing antibiotic prescribing. Given these policy drivers, there is a pressing need to understand the nature of antibiotic prescribing by primary care, and to understand how this changes by socioeconomic deprivation, when controlling for confounding variables. This is crucial in order to inform future antibiotic prescribing targets to ensure such targets do not impact on people with the most health need and thus potentially widen health inequalities.

**Methods** Antibiotic prescribing data for the years 2014-2018 were matched with the Index of Multiple Deprivation (IMD 2015) deciles and graphically presented to explore trends over time. Multi-level analysis on antibiotic use was used to assess the impact of deprivation alongside a range of other confounding variables, including health need, geographic region and GP quality rating.

**Results** Our study highlighted three key results: (1) GP surgeries located in the most deprived areas had the highest levels of antibiotic prescribing (adjusting for health need accounted for most of this variation); (2) there was inequalities in the prescribing of broad spectrum antibiotics according to deprivation; (3) there was significant geographical variation in antibiotic prescribing.

**Conclusion** Future antibiotic prescribing targets should account for deprivation and/or health need to ensure GP practices located in the most deprived communities are not inappropriately penalised.

## Background

Antimicrobial resistance poses a significant challenge to modern day medicine and has been described by the World Health Organisation (WHO) as a global health security threat.<sup>1</sup> Since the 1940s, over 140 antibiotics have been developed for humans where they have had huge benefits in treating infectious disease; however, this 'golden age' of antibiotics appears to be over – with only two novel classes of antibiotics launched in the last 30 years.<sup>2</sup> As bacterial resistance becomes more frequent, there has been a strategic focus toward developing antimicrobial stewardship policies in order to minimize the burden of antimicrobial resistance.<sup>3</sup> In response to these challenges, the WHO has set up a taskforce on antimicrobial resistance with the aim of developing national and regional action programs.<sup>1</sup> In response, the UK Department of Health has developed an antimicrobial resistance strategy,<sup>4</sup> which has the overall aim of reducing the use of antibiotics when it is safe and appropriate to do so: the target is to reduce the levels of inappropriate antibiotic prescribing by 50% by 2020.<sup>5</sup>

In addition to targets for overall prescribing, particular focus has also been placed on reducing the prescribing of specific broad spectrum antibiotics, such as co-amoxiclav, the cephalosporins, and the quinolones, owing to their potential to cause severe adverse effects, such as *Clostridium difficile* infection. Optimizing prescribing practices is considered a key component of this strategy, which highlights the importance of understanding antibiotic prescribing patterns across different areas, although very few studies have reported this; the majority of research has focused on antibiotic prescribing in subsets of practices<sup>6,7</sup> or across a single region.<sup>8</sup> Previous work by Curtis and colleagues has shown that, in England, higher prescribing rates of antibiotics are associated with more deprived areas, as well as greater GP practice size, a higher proportion of older or younger patients, and ruralness.<sup>9</sup> It is not known, however, if these higher prescribing rates are driven by health need (e.g. people living in deprived areas are more likely to have health conditions that are associated with the use of antibiotics) or other factors, such as health seeking behavior or quality of GP services.

Given the policy drivers to reduce prescribing of antibiotics, and that the majority of antibiotics are prescribed in primary care<sup>10</sup>, there is a pressing need to understand the nature of antibiotic prescribing by primary care in England, and to understand how this changes by socioeconomic deprivation, when controlling for confounding variables. This is crucial in order to inform future antibiotic prescribing targets at a practice level to ensure such targets do not impact on people with the most health need and thus potentially widen health inequalities. This study, therefore, aimed to: (1) examine the trends of antibiotic prescribing by area level deprivation; (2) analyse the proportion of broad spectrum antibiotics, (including co-amoxiclav, the cephalosporins and the quinolones) prescribed by area level deprivation; and use modelling approaches to examine whether (3) geographic region and (4) the quality of the GP services influences prescribing rates, alongside health need.

## Methods

Prescribing data

Antibiotic prescribing data were obtained from the NHS Business Services Authority ePACT2 system (NHSBSA Copyright 2018). The data were downloaded for English General Practices (GPs) for the four years from April 2014-March 2015 to April 2017-March 2018. All GP practices open for the entire year were included in the analysis. Antibiotic prescribing was measured according to the items per STAR-PU (Specific Therapeutic Group Age-sex weightings Related Prescribing Units) weighting, which shows the amount of prescription items that have been prescribed, compared to what would be anticipated given the number and characteristics of patients registered in the practice. The numerator is the total number of prescription items for antibacterial drugs (as defined by the British National Formulary, Chap. 5.1), and the denominator is the total number of oral antibacterial drugs (as defined by British National Formulary, Chap. 5.1) ITEM based STAR-PU. As such, it is possible to use STAR-PU, instead of the number of patients, to allow for comparisons between General Practices; this approach adjusts for age and sex in prescribing. Lower values of items per STAR-PU indicate less oral antibacterial prescribing. In addition, we also report a subset of broad spectrum antibiotics (namely co-amoxiclav, cephalosporins and quinolones); our threshold of reporting was when the percentage exceeds 10% of all antibiotics dispensed within that practice; the threshold of 10% is based upon NHS England targets.<sup>11</sup> This measure looks at the quantity of these drugs (as a percentage), versus the total number of antibiotics prescribed. Practice codes were cross-referenced with the NHS Digital GP Practice Database,<sup>12</sup> and any practices that were not open for the full relevant year were excluded. Practices not classified as GP practices (e.g. out of-hours or specialist prescribing) were also excluded. To account for outliers in the prescribing data owing to potential incorrect coding of GP practices in the database, we excluded the top and bottom 1% of items prescribed by items per STAR-PU and the percentage of broad spectrum antibiotics.

Overall, 29,631 GP surgeries were included in the analysis for antibiotic prescribing over the four years for which we have data (representing 7,700 unique surgeries). Seven GP surgeries were excluded as they did not have a corresponding IMD decile, and a further 606 were removed as they represented the top and bottom 1% of antibiotic items per STAR-PU data (see histogram in Supplementary Fig. 1 to illustrate before and after comparisons). There is an approximate negative linear correlation between the concentration of GP practices in England and IMD decile. For the most recent data (2017-18), 1,086 GP practices are located in IMD decile 1 compared to just 437 in IMD decile 10 (see Supplementary Fig. 2 for graphical representation).

#### Deprivation data

The location of the GP practice based on their address from the reference database was matched to the corresponding Lower Layer Super Output Area (LSOA). Deprivation data was derived from the Index of Multiple Deprivation (IMD) 2015 produced by the Department for Communities and Local Government. This index, constructed from seven domain indices were combined to produce an overall measure of deprivation, which ranks every LSOA in England from 1 (most deprived) to 32,844 (least deprived area). Ranks were converted to deciles to visually illustrate antibiotic prescribing by GPs in different levels of deprivation whereby 1 represents the most deprived areas and 10 represents the least deprived. The IMD 2015 data is used for all years in subsequent analysis as it is produced once every 4/5 years.

#### Confounding variables

A number of variables were also included in our model specifications. We included ethnic composition, as it has previously been shown that different ethnic groups have different antibiotic consumption patterns,<sup>13</sup> these data were obtained from the Office of National Statistics (based on the 2011 census data available from: <https://www.nomisweb.co.uk>) to determine the ethnic composition of each LSOA. We also included urbanity in the model (produced from the 2011 census), as it has previously been shown that GPs working in rural areas were less likely to delay prescribing of antibiotics.<sup>9</sup> The measure of urbanity, based on the Department for Environment and Rural Affairs' rural/urban classification, uses a twofold grouping: (1) urban; (2) rural.

## Statistical analysis

To assess the impact of deprivation on the level of antibiotic prescribing, we used multiple bar graphs reporting items per STAR-PU and the proportion of broad spectrum antibiotics in each deprivation decile by year. To complement this graphical analysis, we also used a random-effects regression model to estimate the association between deprivation and antibiotic prescribing. This was seen as the most appropriate model specification, as the items of antibiotics prescribed per STAR-PU were approximately normally distributed (after removing the top and bottom 1% of data). The parameters were calculated using the XTREG command in the statistical software package Stata.<sup>14</sup> The parameter estimates in all models are given with 95% confidence intervals, with standard errors clustered at the individual level. A visual inspection of a plot of the model residuals indicated that homoscedasticity was unlikely to influence the

results, while the variance of inflation (VIF) ratio was low (2.3), implying that multicollinearity was also unlikely to be problematic. There was relatively little missing data (~ 5%), with the results from the test proposed by Verbeek and Nijman<sup>15</sup> indicating that small amount of non-response across the four waves of data was unlikely to be non-random.

## Results

### Antibiotic prescribing by area level deprivation

Overall, in England, the prescribing of antibiotics items per STAR-PU decreased between 2014 and 2018. In 2014–2015, the mean antibiotic items per STAR-PU was 1.11, while in 2017–2018, the mean was 0.96 – a difference of 13.6%; the largest reduction in prescribing was observed between 2014 and 2015 (9.4%). A socio-spatial gradient in antibiotic prescribing was observed: GP surgeries located in the most deprived areas had higher antibiotic items per STAR-PU, compared to GP surgeries located in the least deprived areas (Fig. 1); this trend was evident across all years. In terms of a reduction in antibiotic prescribing over time, GP surgeries located in the most deprived areas (IMD-1) reduced prescribing by 0.17 items per STAR-PU (a reduction of 16.95%), compared to GP surgeries located in the least deprived areas (IMD-10) that reduced prescribing by 0.12 items per STAR-PU (a reduction of 13.11%).

### Prescribing of co-amoxiclav, cephalosporins, and quinolones

The proportion of GP surgeries which prescribed over the target of 10% broad-spectrum antibiotics (co-amoxiclav, cephalosporins, and quinolones) in terms of total antibiotics prescribed is shown in Fig. 2. The decline in broad-spectrum antibiotics (as a proportion of all antibiotics prescribed) has reduced over time, particularly in the years 2014–2015 to 2016–2017. More significantly, over the four years which we have data, those GP practices located in the most affluent areas have a higher proportion of prescriptions for broad spectrum antibiotics compared to those GP practices in the most deprived areas. Although the proportion of broad-spectrum antibiotics has decreased across all areas over time, the inequality in prescribing between the most and least deprived areas has remained constant at around one fifth (22.3% in 2014–2015; 25.2% in 2015–2016; 20.5% in 2016–2017 and 21.6% in 2017–2018).

### Confounding factors associated with antibiotic prescribing

Two models were developed to understand the factors which drive antibiotic prescribing in English GP practices (Table 1). Both models controlled for socio-demographic variables, however model 2 included health need (using diabetes and COPD prevalence as proxies). Excluding measures of 'need', model 1 demonstrated that living in the most deprived decile (compared to the least deprived) was associated with an increased likelihood of antibiotic prescribing by 0.149 items per STAR-PU, and a clear gradient was observable across most of the deprivation deciles. Deprivation was a significant predictor of increased antibiotic prescribing in all IMD 2015 deciles (deciles 1–8,  $p < 0.01$ ; decile 9,  $p < 0.05$ ). When including health need, deprivation was a less important driver of antibiotic use. In model 2 (which will be discussed subsequently), living in the most deprived decile (compared to the least deprived) was associated with an increased likelihood of antibiotic prescribing by 0.033 items per STAR-PU, and this was only significant in the three most deprived deciles ( $p < 0.05$ ). GP surgeries located in areas where there were greater proportion of people of white ethnic origin, and those found in rural areas also showed higher rates of antibiotic prescribing. Compared to London, GP surgeries located in all other areas of England had significantly higher rates of antibiotic prescribing – with the East of England reporting the highest levels, at around 0.164 items per STAR-PU higher than London (followed closely by those surgeries in the North East of England (0.156), and the North West (0.139)). GP surgeries located in areas where health need (using diabetes and COPD prevalence as proxies) is greatest, showed higher rates of antibiotic prescribing (0.029 and 0.053 STAR-PU units for diabetes and COPD respectively). Furthermore, over the four years for which we have data, antibiotic use overall has dropped substantially, a 0.177 STAR-PU reduction was observed between 2014-15 and 2017-18.

Table 1

Association between antibiotic use and deprivation in England. Robust standard errors in parentheses \*\*  
 $p < 0.01$ , \*  $p < 0.05$ .

MODEL NUMBER	(1)	(2)
VARIABLES	Excludes measures of 'need'	Includes measures of 'need'
	Coefficient (Robust Standard Error)	Coefficient (Robust Standard Error)
1 (Most Deprived)	0.149 (0.012) **	0.033 (0.013) *
2	0.129 (0.012) **	0.031 (0.012) *
3	0.110 (0.011) **	0.025 (0.011) *
4	0.075 (0.011) **	-0.002 (0.011)
5	0.062 (0.011) **	0.004 (0.010)
6	0.058 (0.012) **	0.007 (0.011)
7	0.040 (0.012) **	0.002 (0.011)
8	0.032 (0.011) **	0.002 (0.011)
9	0.023 (0.012) *	0.001 (0.011)
10 (Least Deprived)	Reference	
% White	0.002 (0.000) **	0.002 (0.000) **
Rural	Reference	
Urban	-0.038 (0.006) **	-0.022 (0.006) **
London	Reference	
East of England	0.198 (0.011) **	0.164 (0.010) **
East Midlands	0.140 (0.012) **	0.085 (0.011) **
North East	0.247 (0.014) **	0.156 (0.013) **
North West	0.206 (0.011) **	0.139 (0.010) **
South East	0.127 (0.010) **	0.106 (0.019) **
South West	0.089 (0.011) **	0.050 (0.010) **
West Midlands	0.148 (0.010) **	0.089 (0.010) **
Yorkshire and Humber	0.175 (0.012) **	0.112 (0.011) **
Time		
2014–2015	Reference	
2015–2016	-0.101 (0.001) **	-0.108 (0.002) **
2016–2017	-0.120 (0.002) **	-0.132 (0.002) **
2017–2018	-0.159 (0.002) **	-0.177 (0.002) **

MODEL NUMBER	(1)	(2)
Diabetes prevalence (%)		0.029 (0.002) **
COPD (%)		0.053 (0.005) **
Wald Chi <sup>2</sup> Statistic	9210.16	9880.89
Observations	28,809	28,809

## Discussion

This paper adds to the growing evidence base exploring antibiotic prescribing trends, over time, by deprivation in England. It is also the first to explore the prescribing of broad spectrum antibiotics (co-amoxiclav, cephalosporins, and quinolones) as a percentage of total antibiotic prescribing according to area-level deprivation. We identified three key findings that may be of importance to healthcare professionals and policy makers: (1) there were significant inequalities in antibiotic prescribing according to deprivation – with GP surgeries located in the most deprived areas having the highest levels of antibiotic prescribing according to items per STAR-PU measure; (2) there is variation in the prescribing of broad spectrum antibiotics, (co-amoxiclav, cephalosporins, and quinolones) as a percentage of total antibiotics prescribed according to deprivation; (3) according to the nine English regions, there was significant geographical variation in antibiotic prescribing – with the lowest levels of antibiotic prescribing, by items per STAR-PU, observed in London.

While this is the first study to focus specifically on antibiotic prescribing according to area-level deprivation in England, there have been studies that have explored prescribing trends of antibiotics in other areas, or have explored trends in England with a different focus of enquiry. For example, Covvey and colleagues evaluated antibiotic prescribing trends in Scotland, and concluded that higher rates of antibiotic prescribing were found in area areas of higher deprivation, as measured according to the Scottish Index of Multiple Deprivation (SIMD).<sup>16</sup> Unlike our study, which used items per STAR-PU as a measure of prescribing, this study used antibiotic items per 1000 people per day. As such, no comparisons can be made between studies in terms of numbers of antibiotics prescribed; however, in line with our findings, there was a significant association between deprivation and antibiotic prescribing – although health need was not accounted for in their analysis. Another study by Mölter and colleagues, who analysed antibiotic prescribing by GP practice in England, identified spatial clusters of high and low spots of prescribing (so-called ‘hot’ and ‘cold’ spots).<sup>17</sup> The work showed that the distribution of antibiotic prescribing was heterogeneous, with the majority of the hot spots located in the North of England. Importantly, the work concluded that, in addition to a national level strategic approach, local antimicrobial stewardship approaches may also be needed at an area level to account for specific pressures and needs. Although our work did not specifically explore ‘hot-spots’ of prescribing, our findings relating to significant geographical inequalities in antibiotic prescribing support this approach. Indeed, our study showed that, when controlling for demographic, health need and quality variables, highest levels of prescribing were found in the North East, followed by the East of England and the North West of England; lowest levels of antibiotic prescribing were consistently found in London. Finally, a study by Curtis and colleagues, who described antibiotic prescribing trends across England for the years 1998 to 2017, showed that there was significant geographical variation in prescribing.<sup>9</sup> At a CCG level, comparing the lowest and highest levels of antibiotic prescribing, the variation was two-fold, while for cephalosporin prescribing, the variation was seven-fold. The work also showed that higher prescribing trends were associated with a greater GP practice size, the proportion of patients greater than 65 years, or less than 18 years, ruralness and deprivation. Our study builds on these important findings and shows that, controlling for prevalence of COPD and diabetes (two long-term conditions associated with increased utilisation of antibiotics), appears to account for the majority of the prescribing inequalities between GP practices in high and low areas of deprivation; when controlling for COPD and diabetes prevalence, only GP practices located in decile 2 still had significant higher levels of antibiotic prescribing and therefore the deprivation signature had largely been removed.

Given the emphasis and strategic importance – at both a national and international level – of developing and implementing antibiotic stewardship policies, our findings are timely and potentially have important implications for policymakers. The approach of reducing the use of antibiotics appears to be working, given that our data shows a reduction in antibiotic items per STAR-PU each year. This is in line with other research using monthly prescribing data which showed a reduction between 2013 and 2017 of 14.1%.<sup>18</sup> Over a similar time period (between 2014–2015 and 2017–2018), our data showed a 13.6% reduction). For the year 2017/18, the English national

antibiotic prescribing target was 1.16 items per STAR-PU, while for the year 2018/19 the target is to reduce, by 17 percent, to 0.965 items per STAR-PU.<sup>19</sup> This prescribing measure accounts for age, and sex of the population served; for example, men aged 75 years and above are weighted as 1.0, while men aged between 35 and 44 years are weighted as 0.3; in contrast, women aged 75 years and above are weighted as 1.3, while women aged between 35 and 44 years are weighted as 0.6.<sup>20</sup> While this weighting is helpful, and is thought to reflect how antibiotic usage will vary according to age and sex, it does not consider any measure of deprivation and / or health need. Our results, therefore, show that implementing a one-sized national antibiotic prescribing target may not be appropriate, as this has the potential to target GP practices located in the most deprived communities, serving patients with the greatest health need. It would be prudent, therefore, for any future antibiotic prescribing targets to acknowledge that GP practices located in the most deprived communities are likely to have a higher health need in terms of antibiotic use, and account for this in their targets. In addition, any future revision of the prescribing measure items per STAR-PU should also consider incorporating a measure of deprivation into their weighting. This finding was also echoed by Pouwels and colleagues,<sup>7</sup> who suggest it would be advantageous to avoid the same prescribing targets for all GP practices, or it would be important to develop alternative approaches for that encompass additional predictors of antibiotic prescribing (e.g. deprivation). This is similar to the way in which NHS funding allocation policy incorporates deprivation.<sup>21</sup>

### Strengths and limitations

We believe our modelling results are robust; the residuals are normally distributed, and the variance of inflation ratio (VIFs) is low (2.07) therefore homoscedasticity and multicollinearity are not considered problematic. However, we do acknowledge there are a number of limitations to our work. Firstly, we only assessed the amount of antibiotic prescribing according to items per STAR-PU; we did not consider the appropriateness of prescribing, nor did we consider the patient characteristics for whom the antibiotics were prescribed. It is possible, therefore, that the higher antibiotic prescribing observed in the most deprived areas were prescribed either unnecessarily or inappropriately. Indeed, Smith and colleagues showed that in an English primary care setting, most antibiotics are prescribed for conditions that only sometimes required antibiotics, which was dependent on patient specific indicators (e.g. co-morbidity).<sup>22</sup> Our study does not account for this. It would be prudent, therefore, for future work to assess the appropriateness of antibiotic prescribing for GPs located in deprived areas. A further limitation of our work is in relation to how we adjusted for health need: in our logistic regression model, we only used COPD and diabetes prevalence as proxies for health need measure. In addition to COPD and diabetes prevalence, there are other reasons that may contribute to increased susceptibility of developing a bacterial infection, including poor living conditions,<sup>23</sup> reduced vaccination uptake,<sup>24</sup> poor diet,<sup>25</sup> and higher incidence of smoking.<sup>26</sup> These factors were not accounted for in our analysis. In addition, we also only analysed four years of data as prior to this, there were changes in the methodology of recording of prescribing data, making it challenging to investigate longer-term trends in antibiotic prescribing using our data sources. Furthermore, although deprivation was the focus of our analysis, we only examined the deprivation of the GP surgery where the antibiotics were prescribed as a proxy for the area-level disadvantage where the patient resides. In reality, GP practices serve a larger area than the LSOA of the surgery,<sup>27</sup> and the IMD decile, the ethnic composition of the area and the urban-rural classification might vary according to where people live.

## Conclusion

Despite a trend of reduced antibiotic prescribing, there is still significant geographical variation in prescribing practices. Our analysis has demonstrated higher health need in deprived areas, as well as variation according to English region, and quality rating of GP practice are important factors associated with antibiotic prescribing. Future antibiotic prescribing targets should account for deprivation and/or health need to ensure GP practices located in the most deprived communities are not inappropriately penalised.

## Declarations

### *Ethics approval and consent to participate*

This study was assessed as low risk by the Ethics Sub-committee in the Faculty of Medical Sciences, Newcastle University, given it used secondary anonymized data whereby it was not possible to identify patients. As such, ethical approval was not required.

### *Consent to publication*

Not applicable

### ***Availability of data and materials***

The data analysed in this study were obtained from the NHS Business Services Authority ePACT2 system. Under our data use agreement, we are unable to share the data, although they may be obtained through request to the NHS Business Services Authority.

### ***Competing interests***

None to declare.

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### ***Author contributions***

AT and KT designed the study, with input from RB from a policy perspective. AT supervised all stages of the research, and led the drafting of the manuscript with input from all authors; KT cleaned the data, conducted preliminary analyses with advice and guidance from TR and HB. CB and RB assisted with data analysis, interpretation of study results, and drafting of the manuscript. All authors read and approved the final manuscript. AT is the corresponding author and acts as guarantor of the article.

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None to declare.

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# Figures

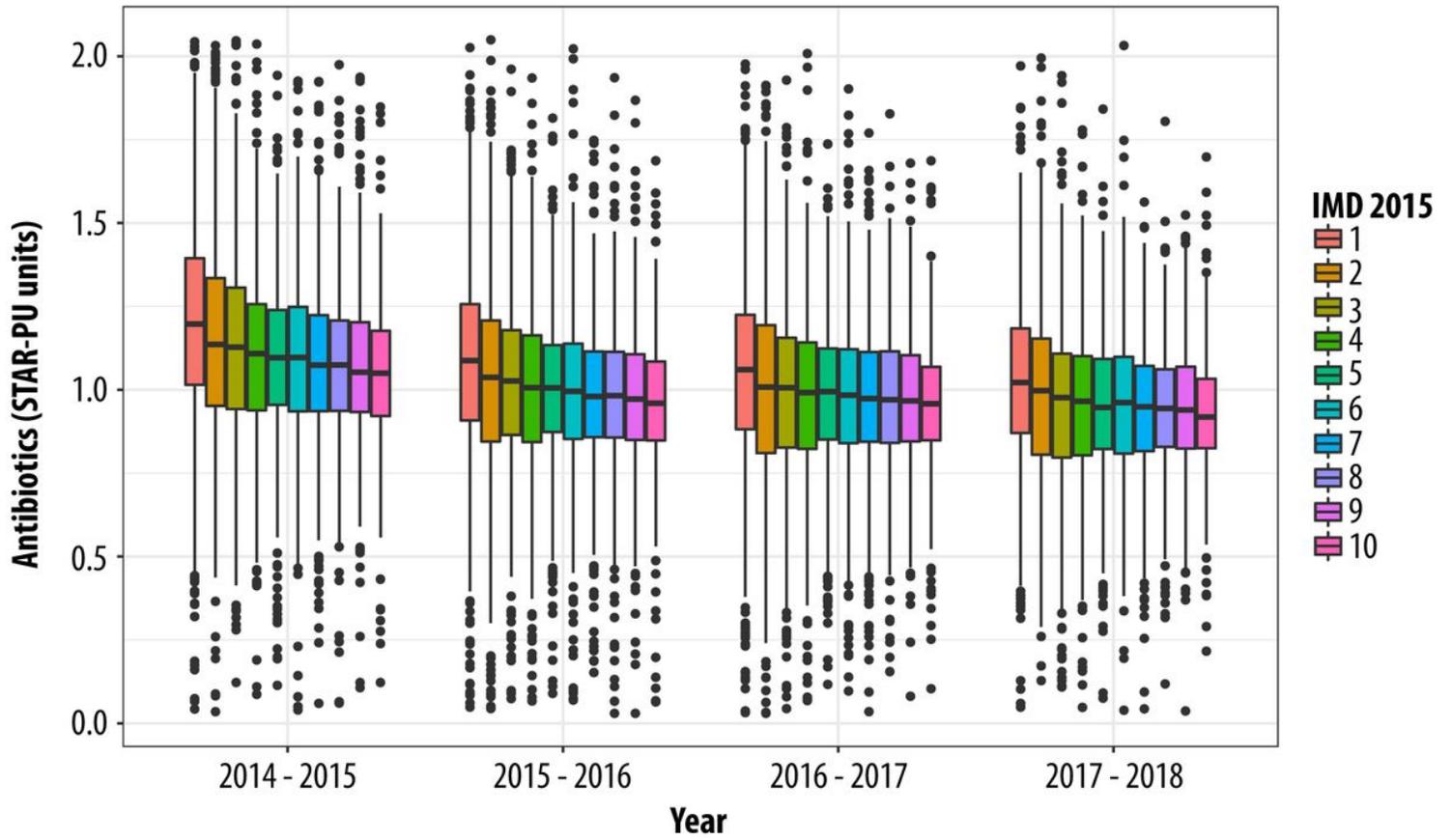
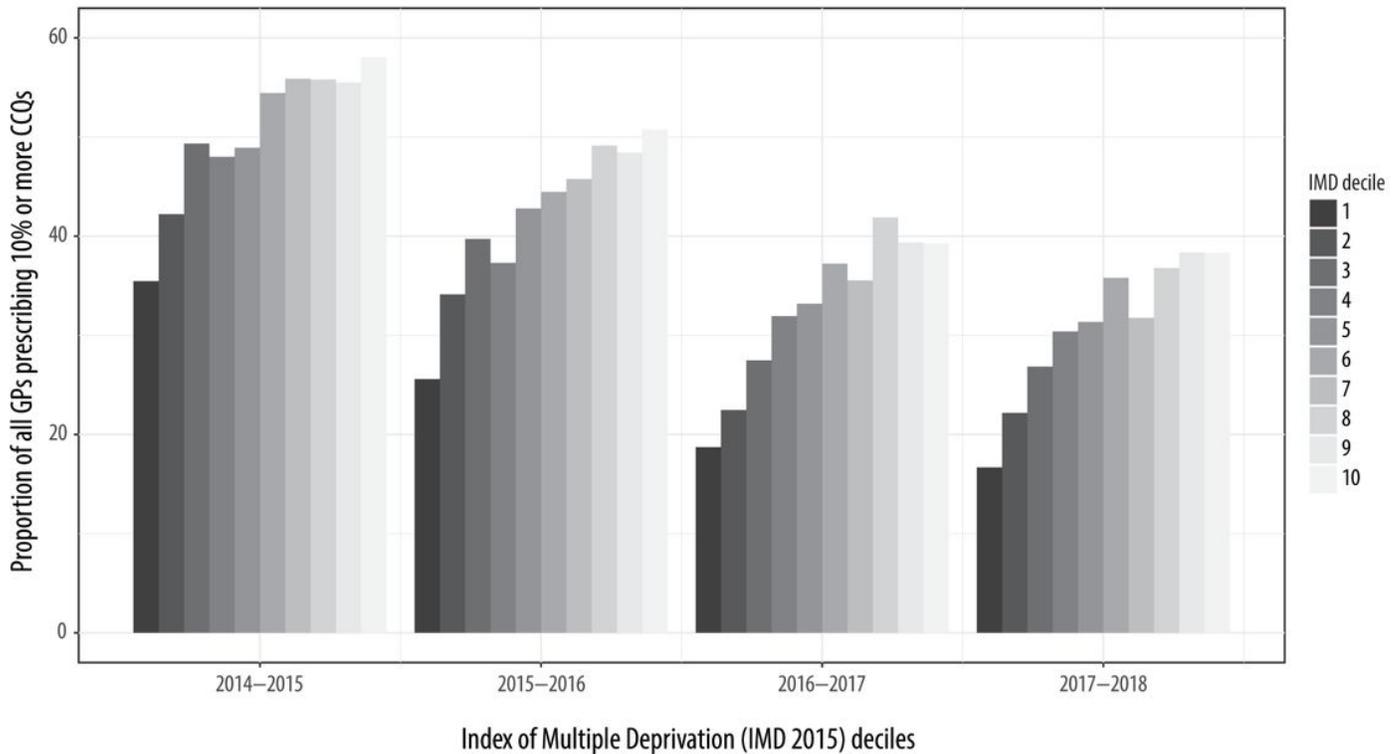


Figure 1

GP practice antibiotic prescribing according to items per STAR-PU (mean) by IMD decile in England (1 most deprived, 10 least deprived)



## Figure 2

The proportion of GP surgeries that prescribe more than 10% broad spectrum antibiotics (CCQs: co-amoxiclav, cephalosporins, and quinolones) by IMD decile (1 most deprived, 10 least deprived)

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Supplementaryfigure1.jpg](#)
- [Supplementaryfigure2.jpg](#)