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Development of the maternity formula for 2025/26 allocations

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Overview

Introduction

The Advisory Committee for Resource Allocation (ACRA) plays a key part in the setting of resource allocations for integrated care boards (ICBs).

ACRA is an independent, expert, technical committee made up of academics, GPs, NHS managers and public health experts. ACRA's role is to develop evidence-based recommendations on how to estimate the relative need for healthcare resources across different populations, using data on people's characteristics and how those characteristics are associated with future healthcare needs. More detail is outlined in ACRA's terms of reference.

These relative needs are designed to guide resource allocation in a way that supports equal opportunity of access for equal need and contributes to reducing health inequalities that are amenable to healthcare. These aims are confirmed when NHS England commissions ACRA in each allocation round.

Following the 2023/24 allocations round, ACRA were commissioned to recommend any updates to the need estimates for 2025/26 onwards.

As part of the development programme for resource allocations, an update to the maternity model was prioritised for development. The maternity component is part of the ICB core allocations model and covers the costs of deliveries and ante and postnatal care.

The maternity model was last refreshed for the 2016/17 allocations round. This same model was used for subsequent allocation rounds.

This publication sets out the development of the maternity model and describes updates and changes that have been presented to ACRA during the development process. It also sets out the final model as recommended by ACRA. The updated model will be used to estimate need for maternity services in the 2025/26 allocations formula.

ACRA makes its recommendations based on the best available evidence. ACRA is supported in this through the work of its Technical Advisory Group (TAG). ACRA and TAG undertake detailed scrutiny of the development work undertaken for allocations

and their decisions regarding what formulae constitute the best assessment of relative need are informed by a set of criteria. These are set out in ACRA's terms of reference and are provided in Annex A.

ACRA's view is that the updated maternity model provides an improved estimate of relative need compared to the current model. The committee have recommended that the updated model is used in the calculation of 2025/26 allocations.

Background to allocations

The principle at the heart of the approach to setting allocations is ensuring equal opportunity of access for equal need.

The approach to allocations is also informed by NHS England's duty to have regard to the need to reduce inequalities between patients in terms of access to services and outcomes.

These 2 aims are reflected in the allocations target formula, which produces a target allocation or "fair share" for each area, based on a complex assessment of factors such as demography, morbidity, deprivation, and the unavoidable cost of providing services in different areas.

Target allocations methodology

The formulae for target allocations estimate the relative need and relative unavoidable costs between ICBs for healthcare services. There are separate formulae for ICBs' core responsibilities, specialised services and primary medical care. For each of these, the relative need is calculated for each GP practice, which is then aggregated to ICB level. It does not seek to calculate an absolute level of need for each area but to assess relative need (and relative unavoidable costs).

The relative need for each practice is based on:

- the age and sex distribution of the population (all else being equal, areas with older populations typically have a higher need per head) and additional need over and above that due to age (all else being equal, areas with poorer health have a higher need per head)
- unmet need and health inequalities
- the unavoidably higher costs of delivering health care due to location alone, known as the Market Forces Factor (this reflects that unit staff, land and

building input costs are higher in some parts of the country, for example, in London)

- the higher costs of providing emergency ambulance services in sparsely populated areas, an adjustment for the higher costs of unavoidably small hospitals with 24-hour accident and emergency services in remote areas and an adjustment for the unavoidable costs of the private finance initiative (PFI)

As the need for different types of health services varies across the country, there are separate formulae for ICB core responsibilities, specialised services and primary medical care. Within each of these, there are separate components and adjustments – for example, the distribution of need for ICB core responsibilities is different for general and acute, mental health, community, maternity and prescribing services.

Each component of the allocation formula is based on statistical modelling that examines the association between the utilisation of health services on the one hand and the characteristics of individual patients and the areas where they live on the other. These models are used to decide which factors to include in the formula to predict future need per head and the relative weight on each of the factors.

Typically, the models estimate need related to age and sex and additional need over and above that due to age and sex as a single set of weights, rather than separately estimating weights for age and additional need. This is because additional need varies by age group. For instance, the health impact of living in a deprived area may be greater for an older person than a younger one.

The statistical models also include ‘supply’ variables to take account of the availability of health care services; where services are more easily available this generally leads to higher use. As utilisation driven by available capacity is not a reflection of need, where the supply variables are included in the models, they are sterilised and set to the national average when calculating relative need. This means areas are not penalised in the formula for lower utilisation due to relatively lower or less accessible capacity.

The previous maternity model

The previous maternity model was introduced in the 2016/17 allocations round. This formula modelled costs per birth in 2013/14. This was the first maternity model for allocations that was based on individuals. Although the maternity pathway payment

was introduced in 2013/14, the model was not based on the pathway payments as there was no access to the data determining tier of care at that time. More detail is available in Maternity Pathway Payment System - A simple guide. The costs included in the model were based on outpatient attendances and inpatient episodes.

Costs were calculated using the costs recorded in Secondary Uses Service (SUS+) (usually tariff prices where tariffs apply). Where costs were not available national tariffs were applied if applicable or reference costs. At this point, there were only 2 national tariffs for birth episodes – with and without complications and comorbidities.

The model tested a range of need and supply variables to identify which variables were statistically significant in predicting costs per mother (the sum of maternity activity in 2013/14). The variables included in the final model are in table 1.

Table 1: Variables in existing maternity model

Variable	Description
Age of mother	Dummy variable for age of mother (5 year age groups)
Multiple births in 2013/14	Multiple birth episodes in 2013/14
0 births in 2013/14	No birth episode in 2013/14
1 birth during 2010-2014	1 birth during 2010-2014
2+ births during 2010-2014	2+ births during 2010-2014
Low birth weight	% of births <2500g by GP practice
Index of Multiple Deprivation (IMD) 2015 (overall)	Overall IMD score at Lower Super Output Area (LSOA) level
Pakistani	% of LSOA residents with Pakistani ethnicity
Black African	% of LSOA residents with Black African ethnicity
Proportion never worked	Proportion of LSOA residents never worked
Proportion in social housing	Proportion of LSOA residents in social housing
Quality Outcomes Framework (QOF) diabetes prevalence	QOF diabetes prevalence by GP practice
Overnight maternity beds	Gravity weighted bed supply
Obstetric ultrasound supply	Gravity weighted ultrasound supply
Morbidity	152 diagnostic flags (from previous 2 years)

Clinical Commissioning Groups (CCG) dummies	Dummy variable for 211 CCGs

The model produced an estimated cost per birth for each GP practice. This was then applied to the estimated number of births for each GP practice to calculate a total cost per practice.

At the time this model was produced it was recognised that there were a number of improvements which could be made to improve the performance and robustness of the model in future:

- the first birth variable was only able to account for births in the 4 years of data available to the project. A better variable could be created with a longer time span of data
- the model performed less well for those individuals that only had antenatal or postnatal care during the 2013-14 financial year
- the modelling was not able to use the definitions used to assess a patient within the maternity pathway

The refreshed maternity model described in this paper addresses these issues as well as reflecting the latest maternity pathways, including ante-natal care.

Development of the new maternity model

Overview

The development of the maternity model for 2025/26 allocations is a refresh of the previous model, using more up-to-date data, improved activity costing and additional explanatory variables. The maternity model is different to other models in that the model is based on all people who gave birth during 2022/23 rather than the whole cohort of registered patients.

The update to the maternity model has followed the same approach as the previous model in developing an individual level model for estimating the cost of births. The model is based on births and their associated costs in 2022/23.

The datasets used for the modelling are built using pseudonymised patient data that cannot be attributed to individuals. The data have been pseudonymised and created according to all relevant GDPR principles.

Calculating costs for the maternity model

The dependent variable for this update to the maternity model is the cost of births in the 2022/23 financial year. This includes all associated antenatal and postnatal care for these deliveries, even if that did not occur within the financial year. This resolves the issue identified in the previous model, where the model performed less well for those who only had ante or postnatal care during the financial year.

There are 3 main steps in creating the dependent variable for the maternity model:

- identifying the number of births in 2022/23
- calculating the cost of the delivery for each birth
- calculating the costs of antenatal and postnatal care through the identification of the level of these pathways for each delivery

Calculating the number of births

Hospital deliveries are identified in the SUS+ dataset using 36 delivery Healthcare Resource Groups (HRGs). Homebirths are identified using the Maternity Services Dataset (MSDS). Where a delivery is identified as a homebirth in MSDS but also has a delivery episode in SUS+, the hospital delivery episode in SUS+ is used.

For the purposes of developing a maternity model for allocations to ICBs, deliveries for overseas visitors, private patients and those from the devolved administrations are excluded, as they are not the responsibility of the ICB. Stillbirths are included.

The total number of births identified in 2022/23 was 540,484 in SUS+ and 3,281 home births in MSDS. The homebirths were crossmatched to SUS+ on psuedoID and labour onset date, leaving 1,961 homebirths. Once matched to the Master Patient Index (MPI), the number of births remaining was 508,231. This drop in numbers is due to missing NHS numbers.

Once implausible births (less than 35 weeks after another birth) and deliveries where ICBs are not the responsible commissioner have been removed, there are 495,013 births in the modelling dataset.

Calculating the cost of delivery

The cost (based on the national tariff) for the birth episode is taken from SUS+ where this has been recorded. Where the cost has not been populated it is set to the indicative price as published in the 2022/23 national tariff. The 36 delivery HRGs map to 6 delivery tariffs. There is a separate tariff for homebirths. Any additional costs associated with length of stay in hospital are also included. The delivery tariffs for 2022/23 are in Annex B.

Calculating the cost of the antenatal and postanal pathways

In addition to the cost of the births, costs have been estimated for antenatal and postnatal care. The maternity pathway payment system in the national tariff has 3 indicative prices for the antenatal phase and three indicative prices for the postnatal phase. These prices are categorised as standard, intermediate and intensive and relate to the amount of care required by the mother. The categories for the antenatal and postnatal phase are determined using several “maternity factors”. The “intensive” category has the highest tariff and the “standard” category has the lowest tariff. The 2022/23 tariffs are in table 2. The maternity factors and descriptions of the conditions they cover are in Annex C.

We have used the diagnostic and other information provided in MSDS to determine which price to apply to the antenatal and postnatal phases. Where the diagnostic information has not been recorded in MSDS, we have used SUS+ data where mapping between SNOMED (Systematized Nomenclature of Medicine, a structured clinical vocabulary for use in an electronic health record) codes used in MSDS and ICD-10 International Classification of Diseases (10th revision) codes used in SUS+ is possible. The majority of maternity factors that are dependent on diagnoses are identified through SUS+.

Table 2: Antenatal and postnatal tariffs (£) (2022/23)

	Antenatal	Postnatal
Standard	1,039	219
Intermediate	1,663	277
Intensive	2,767	744

Through applying the identified maternity factors, the proportions of births that are classified in each category of the antenatal and postnatal pathways are in table 3.

Table 3: Proportion of births in each pathway

	Antenatal	Postnatal
Standard	58%	64%
Intermediate	31%	34%
Intensive	11%	2%

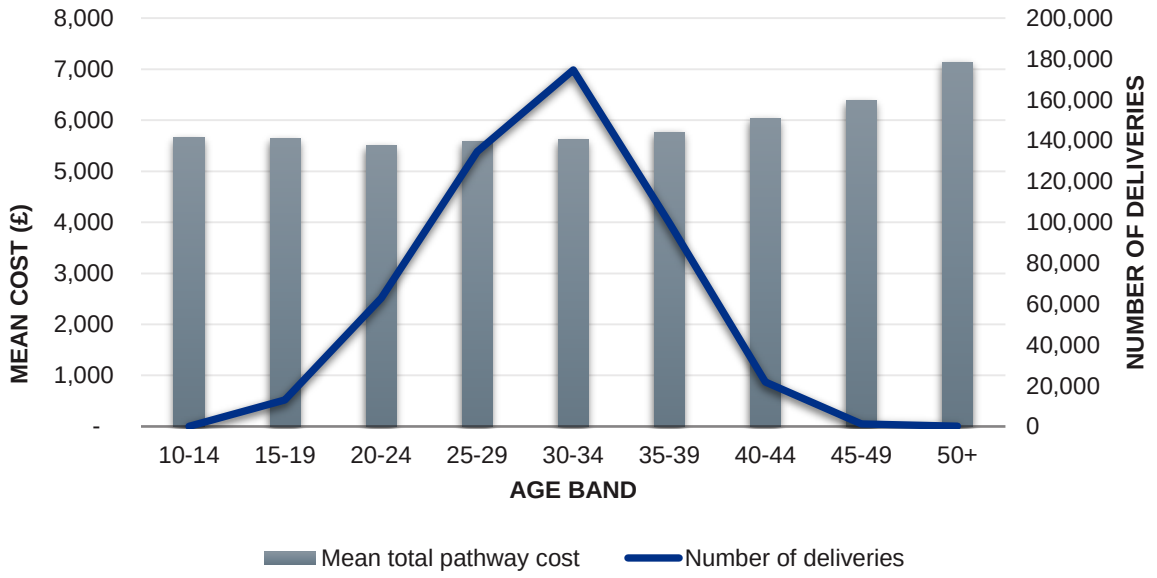
Maternity factor codes are prescribed in MSDS, but for the diagnoses used in SUS+ some judgement has been required. The diagnoses from SUS+ used to identify the ante and postnatal pathways has been discussed with our internal maternity reference group and changes made on their advice to ensure that the diagnoses used align with the maternity factors.

Maternity costs

The average costs of a birth in 2022/23 (including the cost of delivery and antenatal and postnatal care) was £5,417.

The distribution of births and the average costs of births by maternal age band are in figure 1. This shows that, as expected, costs are higher for older age groups with the number of births peaking for the 30 to 34 age group and being lowest at the extremes of the age distribution.

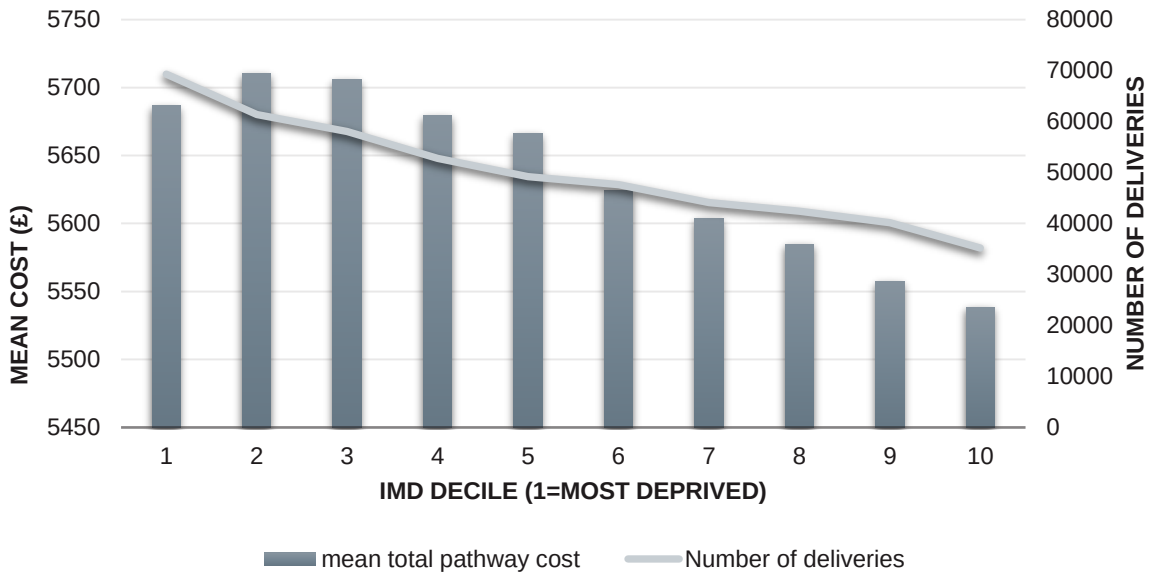
Figure 1: Average cost of births and numbers of deliveries by maternal age band



The distribution of births and the average costs of births by IMD (Index of Multiple Deprivation) decile are in figure 2. This shows that the number of deliveries decreases as deprivation decreases. This may be partly because people living in

more deprived circumstances tend to be younger. With the exception of the most deprived decile, average costs reduce as deprivation reduces. The reduction in average cost between IMD deciles 2 and 1 may also be due to an age interaction.

Figure 2: Average cost of births and numbers of deliveries by IMD decile



Outliers

Analysis of the individual costs revealed some individuals with extremely high costs. These were caused by very long lengths of stay in hospital where maternity was the primary reason for the hospital stay. It was thought these lengths of stay could be data errors or for reasons other than the original maternity admission. Investigation of the outlying costs and testing of capping outliers at different levels was undertaken. This is detailed in Annex D.

Outliers were capped at £25k as this strikes the best balance between retaining as much information in the model that relate to real costs, while capping extremely high costs caused by very long lengths of stay. This results in 82 records being capped.

Explanatory variables

An extensive set of explanatory variables were gathered for testing in the model. The need and supply variables tested in the model are summarised in tables 4 and 5. A full list is in Annex E.

Table 4: Need variables

Explanatory variable	Description
Morbidity flags	Historical diagnosis data were collated for all inpatient episodes and spells in 2021/122 for the cohort of people that gave birth during 2022/23. SUS+ is the Secondary Uses Service dataset that contains patient-level data for hospital activity. These diagnoses data are used to create morbidity flags, indicating a past diagnosis of a condition in one of the World Health Organisation defined sub-chapter of the International Classification of Diseases (ICD).
Age, sex and area of residence	Age, sex and Lower Super Output Area (LSOA) of residence were taken from the GP registrations data Master Patient Index (MPI).
Ethnicity	Matched each individual's ethnic group using a range of patient level health datasets. As the cohort for the maternity model are those that gave birth during 2022/23 and therefore had some contact with health services, the ethnicity coverage is high at 95%. Ethnicity is now included at ethnic group (16 groups).
Household composition	Linking the MPI to the anonymised Unique Property Reference Number (UPRN) allows us to identify all individuals resident in a property and derive a household type variable that indicates the composition of the household as: 8 or more adults, no people aged 16+, 1 adult with children, 1 person household; 2 adults and 1 or more children; 3 to 7 adults with children; 3 to 7 adults aged 20+ with no children, 3 to 7 adults aged under 20, 2 adults of the same gender; 2 adults of different gender; or other.

Explanatory variable	Description
Obstetric variables	A range of obstetric variables are included including birth order, whether there are multiple births during 2022/23 and low birth weight (the proportion of live births with weight <2500g calculated at GP practice level).
Household type and tenure	An interaction of household types and tenures.
Outdoor space	Availability of outdoor space for the household.
Variables from the ONS Census of Population	A range of variables relating to population characteristics from the 2021 census. Only available for small geographical areas (lower layer super output areas - LSOAs) rather than for individuals, so individuals are “attributed” with the value for the LSOA in which they reside.
Coastal and urban or rural flags	Variables indicating whether the LSOA of residence is classified as costal or non-coastal and urban or rural.
Index of Multiple deprivation	The underlying indicators from the Index of Multiple Deprivation. Only available for small geographical areas (lower layer super output areas - LSOAs) rather than for individuals, so individuals are ‘attributed’ with the value for the LSOA in which they reside.
Log population variance	Log of the variance between registered and resident populations for each LSOA. To account for possible list inflation.

Explanatory variable	Description
Department of Work and Pensions	Eligibility for Disability Living Allowance (DLA) or Personal Independence Payment (PIP).
Quality Outcomes Framework prevalence data	Prevalence data from the Quality Outcomes Framework (QOF) were also tested as need variables. Individual flags are not available and so individuals are ‘attributed’ with the value for the practice they are registered with.
GP survey	A range of indicators from the GP survey. Individual flags are not available and so individuals are ‘attributed’ with the value for the practice they are registered with.

Health care use may also be affected by the relative availability of health care services. Variables were tested in the modelling to adjust for this, known as supply variables. While these variables are included in the models as they affect utilisation, they are not included in the formula to calculate weighted populations; instead their value for each area was set to the national average (sterilised). This means if an area has lower use of health care services because of lower capacity or longer distance, this is corrected for in the formula.

Table 5: Supply variables

Explanatory variable	Description
ICB dummy	A flag for each individual indicating which ICB is responsible for commissioning their health care – based on the GP practice at which they are registered.
Quality Outcomes Framework scores and exception rates	Weighted achievement score and vaccination and immunisation rates from the Quality Outcomes Framework (QOF) were also tested as supply variables. Individual flags are not available and so individuals are “attributed” with the value for the practice they are registered with.
GP workforce survey	A range of variables relating to GP workforce. Individual flags are not available and so individuals are “attributed” with the value for the practice they are registered with.
Distance to maternity unit	Gravity weighted distance to maternity units

Due to the high number of attributed need variables, rationalisation of the variables tested in the model was undertaken by splitting the variables into thematic groups and using principal components analysis (PCA) to identify the most important variables. The large number of attributed need variables available to the model requires a large degree of variable selection that is mostly statistically driven through test statistics of coefficients. Preliminary selection using principal components was

used to reduce data and the necessary computational power required in this final variable selection.

The attributed variables were split into thematic groups. For each group of variables, all possible components were created and variables were kept, which on their own captured at least 5% of the variance each or cumulatively captured at least 90% of the variance, whichever condition was met first. For groups that contained more than 10 variables, the 3 most important variables from the first principal component were selected, 2 variables from the second and 1 variable from each subsequent component. For groups of 10 or fewer variables, the 2 most important variables were selected from the first principal component and 1 variable from each subsequent component. If any suggested-to-be-selected variable had already been selected in a previous component we moved one to select the next most important variable of the current component.

Before performing the PCA on each of the groups of variables, the Kaiser-Meyer-Olkin measure of sampling adequacy was calculated, which characterises the appropriateness of the group to be data reduced through PCA. For any groups that fail to meet this criterion PCA is not undertaken and all variables of that group are included in the final model. 10 groups of variables were created:

- QOF prevalence
- QOF scores
- QOF exception rates
- GP immunisation rates
- hospital supply variables
- barriers (subset of IMD variables)
- education (subset of IMD and census variables)
- health (subset of IMD and census variables)
- income (subset of IMD and census variables)
- living environment (subset of IMD variables)

Of the 10 groups, only living environment could not be reduced through PCA. The full set of variables used in the modelling, following this PCA process are listed in Annex E.

Model specification

Age functional form

Following the change made in the 2022/23 general and acute model, age is included in the maternity model using linear splines. The use of splines allows the impact of age on predicted costs to vary within age groups.

Number of diagnostic positions

During the development of the general and acute model for 2022/23 allocations, analysis was undertaken to determine the optimal number of diagnostic positions to use in the creation of the diagnostic flags. In the updated dataset, the number of secondary diagnostic positions that can be recorded increased to 23 (compared to 13 diagnostic positions in the dataset for the 2016/17 model update). As such, the optimal number of positions used to create the morbidity binary flags was examined. Changes in model fit were minimal after the use of 13 secondary positions, although 23 diagnostic positions performed best in terms of model fit.

Considering depth of coding, goodness of fit statistics and provider coding distributions and diagnostics testing, 12 secondary diagnostic positions were chosen as this struck the best balance between making the best use of the available data without introducing bias into the model due to differences in depth of coding by providers.

The diagnostic flags for the maternity model are created based on the primary diagnosis and 12 secondary diagnosis in line with the general acute model.

Interactions of age with household type

Following testing in the model, it was recommended that an interaction of household type with age was included in the maternity model. This allows for heterogenous effects of household type across the age distribution.

Final model selection

The model specification ACRA has now recommended for the maternity model is shown in table 6.

Table 6: Maternity model specification

Model component

Age linear splines
Morbidity flags
Household type
Property type and tenure
ICB dummies
Ethnicity
Interaction of age and household type
Obstetric variables
Attributed need and supply variables

Statistical modelling was used to select the “best fit” drivers of relative costs from the set of explanatory variables at the person level and the relative weights for each driver. The quantified relationships found were taken to be predictors of relative future, cost-weighted need for maternity services, with the exception of the supply variables.

The dataset was partitioned into 2 parts: a training dataset and a validation dataset, with a ratio of 8:2 (that is, 80% of observations were used for the training dataset and 20% for the validation).

Partitioning the dataset allows evidence of “overfitting” to be assessed. In this context, the term overfitting is usually used to express that a model performs well on the training set but fails to achieve good results on additional datasets.

Given the large number of candidate variables in the model and the associated risk of overfitting the model, a variable selection process was conducted to obtain a list of attributed variables that are associated with the costs of maternity services. A stepwise approach as described below is used to select variables for the final model. Variable selection is undertaken on the training sample. The final coefficients for the selected variables are then calculated using the whole dataset. In line with ACRA’s previous recommendations, some groups of variables are treated as a group of variables and if any are significant, the whole group are retained in the model. For the maternity model this is true for age, ethnicity, household type, age and household type interactions, historic diagnoses and ICB dummies.

The variable selection approach involves a “fixed” component and variable selection component. The fixed component includes age, ethnicity, morbidity (diagnostic groups) and ICB dummy variables, which do not enter the variable selection process but are included in the model irrespective of significance. The selection component includes all other candidate variables as set out in Annex E.

The selection component involves fitting all candidate variables into an OLS model and then removing variables using a t test to calculate how significant each variable is in the model. Variables are removed at a certain level of t beginning at t= 0.2, then refitting the model and subsequently removing variables at increasing levels of t until t= 2.58 (significant at 99% level).

The coefficients for the variables selected for the model are in Annex F.

Impact of final model

Calculation of need indices

Once the variables in the model had been determined, weighted populations were produced for GP practices, which were summed to ICBs to reflect relative need for healthcare in each area. As part of this process, the supply variables are “sterilised”.

ACRA has previously recommended that the effect of ethnicity should not be to reduce allocations of resources where the coefficients from the models indicate lower need. In the absence of other evidence, this is assumed to reflect unmet need. In previous models with main effects only for ethnicity, negative coefficients have been set to 0 prior to model predictions to achieve this objective. In the maternity model, all ethnic groups other than Chinese or Any other ethnic group have positive coefficients indicating higher costs for maternity care compared to the White British reference group. As the maternity model is only based on births (rather than being a whole cohort model) and identifies the appropriate ante and postnatal pathway based on the characteristics of the mother (rather than the actual pathway), there is less likely to be unmet need. Therefore, these negative coefficients are retained in the model.

The output of the model is an average cost of birth by GP practice. This is applied to the estimated number of births by GP practice to give a weighted population which is then normalised to the overall number of patients registered with GP practices.

These weighted populations are used to calculate a ‘need index’ for each ICB by dividing the weighted population by the total registered population. A value above 1 indicates higher than average need and a value below one indicates lower than average need. For the maternity model the need index will be influenced both by the number of births and the predicted average costs of births for GP practices.

To allow comparison of the new model to the previous model, the need indices have been calculated for the existing model and the proposed model using the same GP practice birth estimates and 2022/23 populations so that any changes observed are due to the change in the model rather than changes in numbers of births or population.

Impact by age and deprivation

The need indices for age and IMD quintiles are shown in tables 7 to 9. These quintiles are derived by assigning each GP practice to an age (proportion aged over 65 years) and deprivation (IMD score) quintile based on the characteristics of their registered population. In this way it is possible to examine how need indices vary by age and deprivation for different models. Tables 7 and 8 show that both models have the expected pattern of higher need for areas with older, more deprived populations and a lower level of need in areas with younger, less deprived populations.

The main impact of the model is on GP practices serving younger populations, where there is a reduction for the youngest and most deprived but increases for the youngest populations at all other levels of deprivation. Need is still highest for the youngest and most deprived populations.

The changes will be driven by a combination of factors from the updated model, but the shift to younger populations is likely to be influenced by the improved estimate of relative need for ethnic minority groups (who are predicted to have higher than average need) and the shift from 2 to 6 birth tariffs, which allows for more variations in costs. This is also likely to influence the reduction for the youngest most deprived group who may have previously been more likely to attract the higher birth tariff, but under the more graduated tariff system may no longer be as likely to receive the highest tariff.

Table 7: GP practice need indices for previous model by age and IMD quintile

		Age quintile (A1 = youngest quintile, A5 = oldest quintile)					
		A1	**A2**	**A3**	**A4**	**A5**	
Deprivation quintile (D1 = least deprived, D5 = most deprived)	**D1**	**1.01**	**1.02**	**0.95**	**0.85**	**0.71**	**0.86**
	D2	**1.03**	**1.08**	**1.02**	**0.92**	**0.73**	**0.92**
	D3	**1.11**	**1.12**	**1.04**	**0.94**	**0.76**	**1.00**
	D4	**1.16**	**1.16**	**1.07**	**0.96**	**0.80**	**1.08**
	D5	**1.33**	**1.22**	**1.11**	**1.00**	**0.79**	**1.20**
		1.18	**1.14**	**1.04**	**0.92**	**0.73**	

Table 8: GP practice need indices for new model by age and IMD quintile

		Age quintile (A1 = youngest quintile, A5 = oldest quintile)					
		A1	**A2**	**A3**	**A4**	**A5**	
Deprivation quintile (D1 = least deprived, D5 = most deprived)	**D1**	**1.03**	**1.03**	**0.94**	**0.85**	**0.71**	**0.85**
	D2	**1.05**	**1.08**	**1.02**	**0.91**	**0.73**	**0.92**
	D3	**1.19**	**1.12**	**1.03**	**0.94**	**0.76**	**1.01**
	D4	**1.19**	**1.15**	**1.05**	**0.96**	**0.81**	**1.08**
	D5	**1.30**	**1.21**	**1.10**	**1.00**	**0.79**	**1.19**
		1.19	**1.13**	**1.03**	**0.91**	**0.74**	

Table 9: Change in weighted population between previous and new model by age and IMD quintile

		Age quintile (A1 = youngest quintile, A5 = oldest quintile)					
		A1	**A2**	**A3**	**A4**	**A5**	
Deprivation quintile (D1 = least deprived, D5 = most deprived)	**D1**	**0.01**	**0.00**	**-0.01**	**0.00**	**0.00**	**0.00**
	D2	**0.02**	**-0.01**	**0.00**	**-0.01**	**0.00**	**0.00**
	D3	**0.07**	**0.00**	**-0.01**	**0.00**	**0.01**	**0.01**
	D4	**0.02**	**-0.01**	**-0.02**	**0.00**	**0.01**	**0.00**
	D5	**-0.03**	**-0.01**	**-0.01**	**0.01**	**0.00**	**-0.01**
		0.02	**-0.01**	**-0.01**	**0.00**	**0.00**	

Geographical impact

The local authority need indices for the new model and the change in the need indices are shown in the cartograms in figures 3 and 4 below. These show that need is generally higher in urban areas, but that the update to the model has increased predicted need both in London and some peripheral areas. The increase in relative need in London could be driven by the improved estimates of need for ethnic groups. The change from 2 to 6 tariffs will also influence the pattern of change observed.

Figure 3: Local authority (LA) need indices for the new maternity model

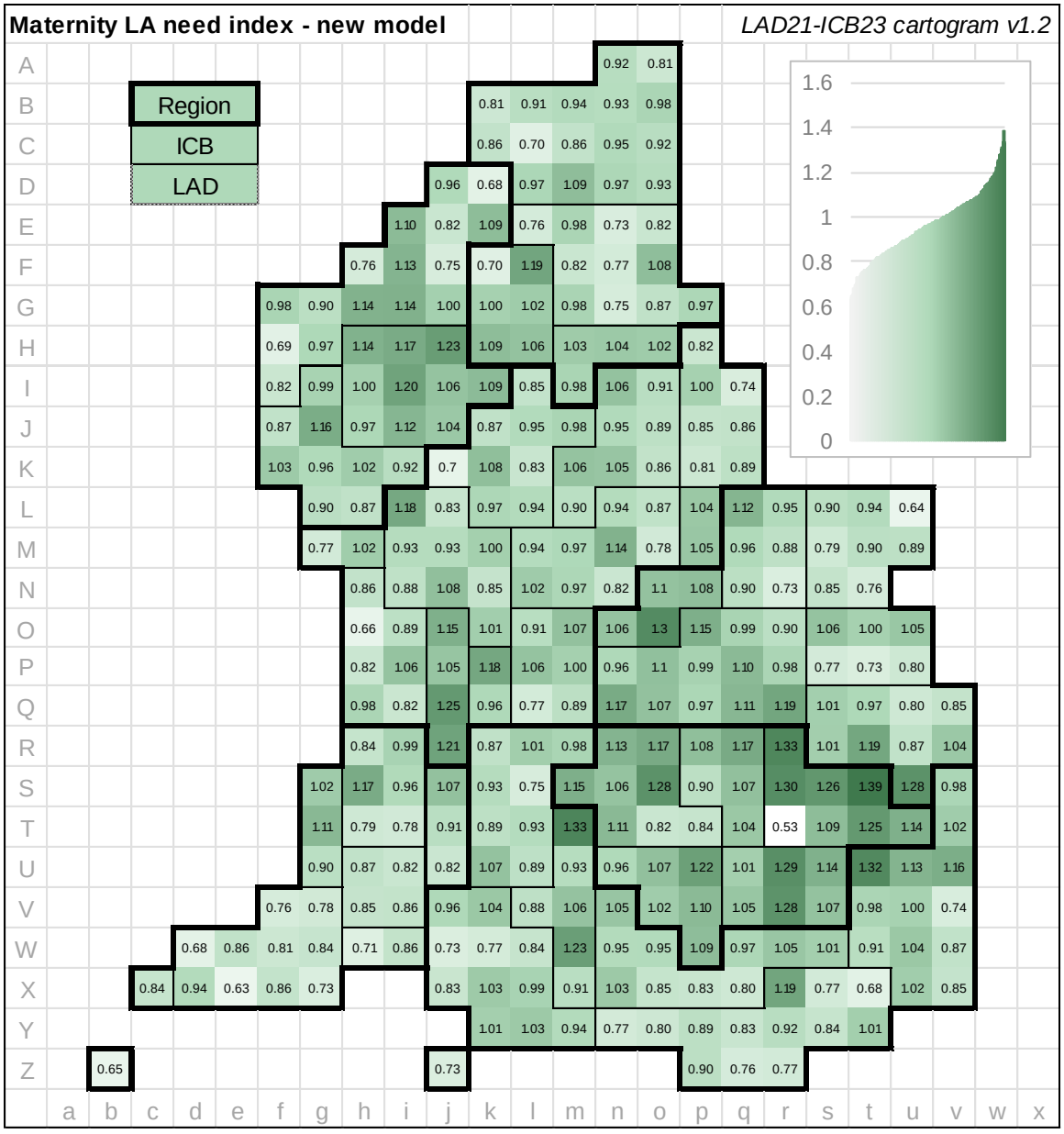
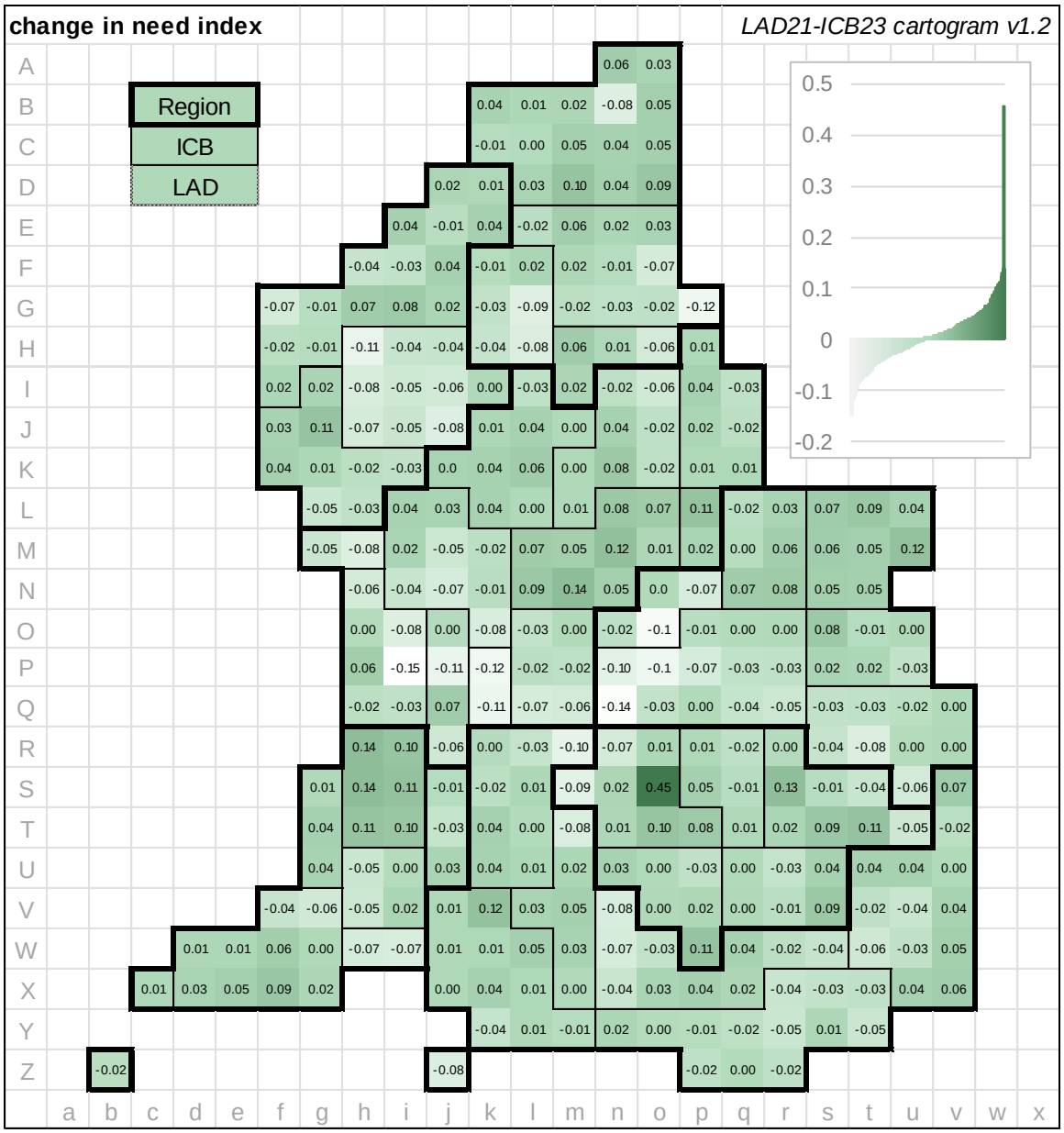


Figure 4: Difference in local authority (LA) need indices between current model and new model



Annex A: ACRA's criteria for assessing formulae

Criteria	Definition
Transparency and simplicity	The construction and application of the formula should aim for simplicity, be well documented and be open to scrutiny.
Comprehensibility	The formula and its derivation should be explainable to non-specialists in plain English and be capable of common sense justification, even if the detail is understood only by specialists.
Evidence base	The formulae are based on the best evidence available.
Technical robustness	The techniques used must be consistent with best practice methods for statistical and econometric modelling and be applied appropriately.
Objectivity	Formula should be based on plausible relationships and there should be tests of bias, robustness, statistical significance and explanatory power.
Flexibility	The recommendations can respond to changes of commissioning responsibilities (for example, coverage of services) and size.
Parsimony	The formula should not include relationships of low materiality. All other things being equal fewer rather than more variables are preferred.
Plausibility	The measures and relationships in the formula should be plausible and have face validity.
Clarity of contribution of indicators	The contribution made by individual components in the formula should avoid ambiguity. Where multiple indicators are used the purpose, weighting and selection must be clear.
Reliability of data	The data are available and consistent for all local areas (units of allocation) where possible and not subject to local variations in reporting.
Freedom from perverse incentives	The methods and data sources used to calculate the formula should not create perverse incentives either for manipulating data or other negative behaviours.
Durability and stability	The relationships used to drive the formula should be durable and the data used to derive the formula should be stable.
Updateable	The scale of the work required to update the formula is manageable within the time constraints of the allocation cycle.

Annex B: 2022/23 delivery tariffs

Table B1: Delivery tariffs (2022/23)

HRG	Description	Payment level	Tariff (£)
	Homebirth		2,062
NZ30C	Normal Delivery with CC Score 0	1	2,014
NZ30A	Normal Delivery with CC Score 2+	2	2,455
NZ30B	Normal Delivery with CC Score 1	2	2,455
NZ31C	Normal Delivery, with Epidural or Induction, with CC Score 0	2	2,455
NZ40C	Assisted Delivery with CC Score 0	2	2,455
NZ31A	Normal Delivery, with Epidural or Induction, with CC Score 2+	3	3,275
NZ31B	Normal Delivery, with Epidural or Induction, with CC Score 1	3	3,275
NZ32B	Normal Delivery, with Epidural and Induction, or with PPSI, with CC Score 1	3	3,275
NZ32C	Normal Delivery, with Epidural and Induction, or with PPSI, with CC Score 0	3	3,275
NZ33B	Normal Delivery, with Epidural or Induction, and with PPSI, with CC Score 1	3	3,275
NZ33C	Normal Delivery, with Epidural or Induction, and with PPSI, with CC Score 0	3	3,275
NZ34C	Normal Delivery, with Epidural, Induction and PPSI, with CC Score 0	3	3,275
NZ40A	Assisted Delivery with CC Score 2+	3	3,275
NZ40B	Assisted Delivery with CC Score 1	3	3,275
NZ41B	Assisted Delivery, with Epidural or Induction, with CC Score 1	3	3,275
NZ41C	Assisted Delivery, with Epidural or Induction, with CC Score 0	3	3,275
NZ42C	Assisted Delivery, with Epidural and Induction, or with PPSI, with CC Score 0	3	3,275

HRG	Description	Payment level	Tariff (£)
NZ43C	Assisted Delivery, with Epidural or Induction, and with PPSI, with CC Score 0	3	3,275
NZ50C	Planned Caesarean Section with CC Score 0-1	3	3,275
NZ32A	Normal Delivery, with Epidural and Induction, or with PPSI, with CC Score 2+	4	4,044
NZ33A	Normal Delivery, with Epidural or Induction, and with PPSI, with CC Score 2+	4	4,044
NZ34A	Normal Delivery, with Epidural, Induction and PPSI, with CC Score 2+	4	4,044
NZ34B	Normal Delivery, with Epidural, Induction and PPSI, with CC Score 1	4	4,044
NZ42B	Assisted Delivery, with Epidural and Induction, or with PPSI, with CC Score 1	4	4,044
NZ43B	Assisted Delivery, with Epidural or Induction, and with PPSI, with CC Score 1	4	4,044
NZ41A	Assisted Delivery, with Epidural or Induction, with CC Score 2+	4	4,044
NZ44B	Assisted Delivery, with Epidural, Induction and PPSI, with CC Score 1	4	4,044
NZ44C	Assisted Delivery, with Epidural, Induction and PPSI, with CC Score 0	4	4,044
NZ50B	Planned Caesarean Section with CC Score 2-3	4	4,044
NZ42A	Assisted Delivery, with Epidural and Induction, or with PPSI, with CC Score 2+	5	4,746
NZ43A	Assisted Delivery, with Epidural or Induction, and with PPSI, with CC Score 2+	5	4,746
NZ44A	Assisted Delivery, with Epidural, Induction and PPSI, with CC Score 2+	5	4,746

HRG	Description	Payment level	Tariff (£)
NZ50A	Planned Caesarean Section with CC Score 4+	5	4,746
NZ51C	Emergency Caesarean Section with CC Score 0-1	5	4,746
NZ51A	Emergency Caesarean Section with CC Score 4+	6	5,977
NZ51B	Emergency Caesarean Section with CC Score 2-3	6	5,977

*PPSI = Post-partum surgical intervention

Annex C: Maternity factors

Table C1: Antenatal maternity factors: intermediate

Maternity factor	Description
Current factors	
Alcohol use	14+ units per week
BMI greater than 35 and less than or equal to 49	
BMI less than 18	
Complex social factors*	
Sensory or physical disabilities	
Substance use	
Medical factors	
Epilepsy requiring anti-convulsants	
Gastrointestinal disorder	Crohns, Ulcerative colitis, malabsorption syndromes, gastric ulcer. Achalasia. Other hepatitis.
Hepatitis B or C	Diagnosed before or during pregnancy
Hypertension	Pre-existing diagnosis requiring medication
Inherited disorder	Requiring active follow up in secondary care
Mental health	Under care of secondary mental health services, previous puerperal psychosis
PAPP-A <0.415 MoM	result of ≤0.415MoM in the current pregnancy
Previous uterine surgery	Previous Caesarean section, myomectomy, septectomy, endometrial ablation

Respiratory disease	Moderate or severe asthma - under secondary care or required a hospital admission in last year, or any ITU admission for asthma in the past. Sarcoidosis, pulmonary fibrosis, chronic obstructive pulmonary disease, tuberculosis
Previous obstetric history	
Abnormally invasive placenta	History of placenta accreta requiring referral to specialist centre
Early pre-term birth (<34 weeks)	
Fetal Loss (12-24 weeks)	In utero death-fetal loss between 12 weeks and 0 days and 23 weeks and 6 days
High weight term baby – more than 4½ kg	
Intrauterine fetal growth restriction	
Low weight term baby – less than 2½ kg	
Miscarriages	History of 3 or more consecutive miscarriages
Neonatal death	History of a neonatal death following a live birth during the first 28 days of life.
Pre-eclampsia, eclampsia or HELLP	
Puerperal psychosis	
Stillbirth	
Other	
Age at booking <20 years	Maternal age at booking <20 years

Table C2: Antenatal maternity factors: intensive

Maternity factor	Description
Current factors	
Expecting twins or more	
Medical factors	
Autoimmune disease	Pre pregnancy diagnosis or diagnosed in current pregnancy-Myasthenia Gravis, Systemic Lupus Erythematosus, rheumatoid arthritis, systemic sclerosis, psoriatic arthropathy, autoimmune hepatitis, autoimmune hypothyroidism, ITP
BMI >49	
Cancer	Current cancer or in past 3 years prior to conception
Cardiac disease	Severe enough to be currently under a secondary care provider
Central Nervous System disorder	Myotonic dystrophy, Multiple sclerosis, Spinal problems (spine bifida/occulta), Generalised neuropathies (for example, Charcot Marie Tooth), Severe migraine, Stroke, Previous history of subarachnoid haemorrhage
Diabetes and other endocrine disorders	Diabetes, Addison's disease, hyperthyroidism, Cushing's syndrome
Haematological condition: Thrombophilia/clotting disorder	Antiphospholipid syndrome, Protein C deficiency, Protein S deficiency, Antithrombin deficiency, factor V Leiden homozygosity, prothrombin gene variant homozygosity, compound heterozygotes von Willebrands disease, haemophilia, thrombocytopenia;
Haemoglobinopathy	Sickle cell disease, thalassaemia,
HIV	
Maternal cystic fibrosis	Maternal history of Cystic fibrosis
Previous organ transplant	Maternal history of transplants in any of: heart, lung, kidney, liver or bone marrow

Renal disease	Chronic renal disease or failure, glomerulonephritis,glomerulosclerosis, Henoch-Schonlein Purpura, Haemolytic uremic syndrome, IgA Nephropathy, Lupus Nephritis,Dysplasia, Nephrotic syndrome, Polycystic kidney disease
Rhesus isoimmunisation	A blood incompatibility disorder where the mother's blood type is not compatible with the fetus
Thromboembolic disorder	Previous venous thrombosis, previous arterial thrombosis, previous pulmonary embolism
Previous obstetric history	
Previous fetal congenital anomaly that required specialist fetal medicine	HRG's NZ71Z, NZ72Z and NZ22Z

Table C3: Postnatal maternity factors: intermediate

Maternity factor	Description
Current factors	
Alcohol use	
BMI greater than 35 and less than or equal to 49	
Complex social factors*	

Substance use	
Medical factors	
Acute fatty liver of pregnancy (AFLP)	Previous history or current pregnancy history of AFLP
Cardiac disease	severe enough to be currently under a secondary care provider during the current pregnancy and /or postnatal period
Diabetes or other endocrine disorder	
Inherited disorder	Maternal inherited disorder requiring active follow up in secondary care
Mental health	Under care of secondary mental health services, previous puerperal psychosis
Neurological disorders	
OASIS/Postnatal bladder dysfunction	Occurred in either a previous or current pregnancy (3rd or 4th degree tears)
Post ITU admission	Maternal history of an ITU admission during the antenatal, birth or postnatal phase of the current pregnancy
Postpartum psychosis (Level 2/3 critical care)	
During this pregnancy	
Deep vein thrombosis or pulmonary embolism	
Gestational diabetes	
Gestational hypertension	
Multiple pregnancy	
Neonatal death	
Pre-eclampsia, eclampsia or HELLP	
Still birth or termination after 24 weeks gestation	

Other	
Age at booking <20 years	Maternal age at booking <20 years

Table C4: Postnatal maternity factors: intensive

Maternity factor	Description
Current factors	
BMI over 50	
Medical factors	
HIV	diagnosed with HIV either prior to or within the current pregnancy
Renal disease	Chronic renal failure, glomerulonephritis, glomerulosclerosis, Henoch-Schonlein Purpura, Haemolytic uremic syndrome, IgA Nephropathy, Lupus Nephritis, Dysplasia, Nephrotic syndrome, Polycystic kidney disease
During this pregnancy	
Fetal anomaly	Fetal anomaly requiring specialist fetal medicine involvement occurring within the current pregnancy

Cystic Fibrosis	Maternal history of cystic fibrosis
Pulmonary Hypertension	Maternal history of pulmonary hypertension, defined as systolic pressure in the pulmonary artery exceeding 30 mm Hg
Peripartum cardiomyopathy	Previous or current pregnancy
Organ transplants	Maternal history of transplants in any of: heart, lung, kidney, liver or bone marrow.

Annex D: Analysis of outliers

Analysis of outliers was undertaken at 3 thresholds – the £20k (136 records) and £25k (82 records) plus a threshold of 75th percentile + 5 interquartile range (IQR) (£14,362 – 372 records). Figures D1 and D2 show the distribution of outliers compared to the overall cohort for delivery tariff and length of stay.

The figures show that for £14.3k and £20k there is a pattern of outliers having the higher delivery tariffs indicating more interventions, complications and comorbidities. For the £25k threshold, the pattern is not as marked, with a higher proportion in the second highest delivery tariff than the highest. Figure D2 indicates that for many of the outliers there is a long length of stay which is leading to the additional costs. The very long lengths of stay are for the outliers above the £25k threshold. ACRA were of the view that these lengths of stay may be due to data errors or for reasons other than the original maternity admission and should be capped.

Figure D1: Distribution of outliers by delivery tariff

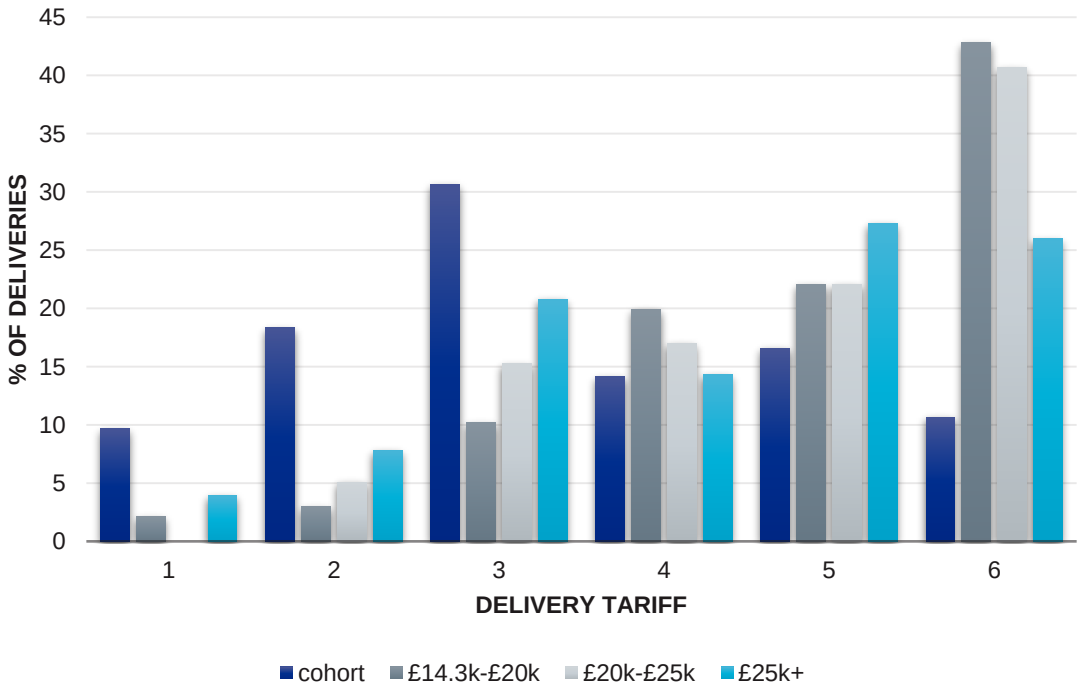
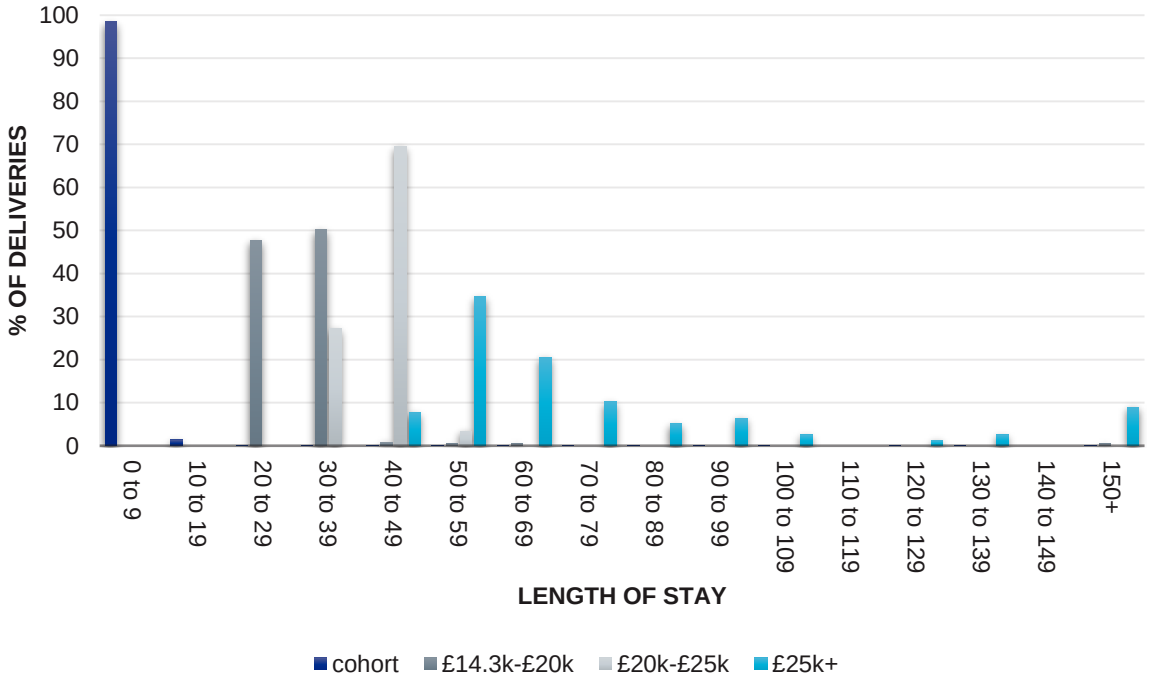


Figure D2: Distribution of outliers by length of stay



Based on this analysis, a threshold of £25k (this is the equivalent of 75th percentile +10 IQR, rounded to the nearest 5k) was recommended as this strikes the best balance between retaining as much information in the model that relate to real costs, while capping very high costs caused by very long lengths of stay which may not be related to maternity need.

Annex E: Variables tested in the model

Individual variables

Age/gender splines	
Age <1	Age 40-44
Age 1-4	Age 45-49
Age 5-9	Age 50-54
Age 10-14	Age 55-59
Age 15-19	Age 60-64
Age 20-24	Age 65-69
Age 25-29	Age 70-74
Age 30-34	Age 75-79
Age 35-39	Age 80-84
Age 40-44	Age 85+
Household type	
Household with 8 or more adults	Household with 3-7 adults aged 20+ without children
Household with no people aged 16+	Household with 3-7 adults aged under 20 without children
Household with 1 adult and children	Household with two adults of different gender
One person household	Household with two adults of same gender
Other household type	Unknown household type
Household with 3-7 adults and children	
Age and household type interactions	
Ethnic Group	
White: Irish	Bangladeshi
White: Other White	Chinese
White and Black Caribbean	Other Asian
White and Black African	African
White and Asian	Caribbean
Other Mixed	Other Black
Indian	Any other ethnic group
Pakistani	
Obstetric variables	

Birth order	Multiple births in 2022/23
Private outdoor space	
Property and tenure type	
Detached and owner occupied	Terraced and owner occupied
Detached and private rented	Terraced and private rented
Detached and social rented	Terraced and social rented
Detached and unknown tenure	Terraced and unknown tenure
Semi-detached and owner occupied	Flat and owner occupied
Semie-detached and private rented	Flat and private rented
Semi-detached and social rented	Flat and social rented
Semi-detached and unknown tenure	Flat and unknown tenure
Other property type	
Educational establishment	Medical establishment
Temporary accommodation	Commercial establishment
Sheltered accommodation	Other
Military establishment	Unknown

Diagnoses – included as individual diagnostic flags

A00-A09 Intestinal infectious diseases	K65-K67 Diseases of peritoneum
A15-A19 Tuberculosis	K70-K77 Diseases of liver
A20-A49 Certain bacterial diseases	K80-K87 Disorders of gall bladder, biliary tract and pancreas
A50-A64 Infections with predominantly sexual mode of transmission	K90-K93 Other diseases of the digestive system
A65-A79 Other infectious and parasitic disorders	L00-L14 L55-L99 Other infections and disorders of the skin
A80-A89 Viral infections of the central nervous system	L20-L30 Dermatitis and eczema
A90-A99 Arthropod-borne viral fevers and viral haemorrhagic fevers	L40-L45 Papulosquamous disorders (including Psoriasis)
B00-B09 Viral infections characterized by skin and mucous membrane lesions	L50-L54 Urticaria and erythema
B15-B19 Viral hepatitis	M00-M25 Arthropathies

B20-B24 Human immunodeficiency virus [HIV] disease	M30-M36 Systemic connective tissue disorders
B25-B34 Other viral diseases	M40-M54 Dorsopathies
B35-B49 Mycoses	M60-M79 Soft tissue disorders
B50-B64 Protozoal diseases	M80-M94 Osteopathies and chondropathies
B65-B83 Helminthiases	M95-M99 Other disorders of the musculoskeletal system and connective tissue
B85-B99 Other infectious and parasitic diseases	N00-N08, N10-N16 Diseases of the kidney
C00-C14 Malignant neoplasm of liporal cavity and pharynx	N17-N19 Renal failure
C15-C26 Malignant neoplasm of digestive organs	N20-N23 Urolithiasis
C30-C39 Malignant neoplasms of respiratory and intrathoracic organs	N25-N29 Other disorders of kidney and ureter
C40-C41 Malignant neoplasm of bone and articular cartilage	N30-N39 Other diseases of the urinary system
C43-C44 Malignant neoplasms of skin	N40-N51 Diseases of male genital organs
C45-C49 Malignant neoplasms of mesothelial and soft tissue	N60-N64 Disorders of breast
C50 Malignant neoplasm of breast	N70-N77 Inflammatory diseases of female pelvic organs
C51-C58 Malignant neoplasms of female genital organs	N80-N98 Noninflammatory disorders of female genital tract
C60-C63 Malignant neoplasms of male genital organs	N99 Other disorders of the genitourinary system
C64-C68 Malignant neoplasms of urinary tract	O00-O08 Pregnancy with abortive outcome
C69-C72 Malignant neoplasms of eye, brain and other parts of central nervous system	O10-O75, O85-O92, O94-O99 Complications of labour and delivery
C73-C80, C97 Malignant neoplasm. of thyroid and other endocrine glands	O80-O84 Delivery
C81-C96 Malignant neoplasms of lymphoid, haematopoietic and related tissue	P00-P04 Complications of foetus/neonate affected by maternal
D00-D48 In situ and benign neoplasms and others of uncertainty	P05-P96 Other conditions originating in the perinatal period
D50-D64 Anaemias	Q00-Q89 Congenital malformations

D65-D89 Diseases of the blood and blood-forming organs	Q90-Q99 Chromosomal abnormalities
E00-E07 Disorders of thyroid gland	R00-R09 Symptoms and signs involving the circulatory/respiratory system
E10-E14 Diabetes Mellitus	R10-R19 Symptoms and signs involving the digestive system and abdomen
E15-E90 Endocrine nutritional and metabolic diseases	R20-R23 Symptoms and signs involving the skin and subcutaneous tissue
F00-F03 Dementia	R25-R29 Symptoms and signs involving the nervous and musculoskeletal system
F04-F09 Other organic including symptomatic mental disorders	R30-R39 Symptoms and signs involving the urinary system
F10-F19 Mental and behavioural disorders due to psychoactive substances	R40-R46 Symptoms and signs involving cognition, perception, emotional state and behaviour
F20-F29 Schizophrenia, schizotypal and delusional disorders	R47-R49 Symptoms and signs involving speech and voice
F30-F39 Mood [affective] disorders	R50-R68 General symptoms and signs
F40-F69 Neurotic, behavioural and personality disorders	R69 Unknown and unspecified causes of morbidity
F70-F79 Mental retardation	R70-R89 Abnormal findings of bodily fluids or samples without diagnosis
F80-F99 Other mental and behavioural disorders	R90-R94 Abnormal findings on diagnostic imaging/function studies
G00-G09 Inflammatory diseases of the central nervous system	R95-R99 Ill-defined and unknown causes of mortality
G10-G14, G30-G32 Other degenerative diseases (including Alzheimer's)	S00-S09 Injuries to the head
G20-G26 Extrapyramidal and movement disorders (including Parkinsonism)	S10-S19 Injuries to the neck
G35-G37 Demyelinating diseases (including Multiple Sclerosis) of the central nervous system	S20-S29 Injuries to the thorax
G40-G47 Epilepsy, migraine and other episodic disorders	S30-S39 Injuries to abdomen, lower back, lumbar spine and pelvis

G50-G73 G90-G99 Other diseases and disorders of the nervous system	S40-S49 Injuries to the shoulder and upper arm
G80-G83 Cerebral palsy and other paralytic syndromes	S50-S59 Injuries to the elbow and forearm
H00-H06, H15-H22, H30-H36, H43-H59 Other disorders of the eye	S60-S69 Injuries to the wrist and hand
H10-H13 Disorders of conjunctiva (including conjunctivitis)	S70-S79 Injuries to the hip and thigh
H25-H28 Disorders of lens (including cataracts)	S80-S89 Injuries to the knee and lower leg
H40-H42 Glaucoma	S90-S99 Injuries to the ankle and foot
H60-H95 Diseases of the ear and mastoid process	T00-T07 Injuries involving multiple body regions
I00-I09 Rheumatic heart disease	T08-T14 Injuries to unspecified part of trunk limb or body
I10-I15 Hypertensive diseases	T15-T19 Effects of foreign body entering through natural orifice
I20-I25 Ischaemic heart diseases	T20-T32 Burns and corrosions
I26-I28 Pulmonary heart disease and diseases of pulmonary circulation	T33-T35 Frostbite
I30-I52 Other forms of heart disease	T36-T50 Poisonings by drugs medicaments and biological substances
I60-I69 Cerebrovascular diseases	T51-T65 Toxic effects of substances chiefly non-medicinal as to source
I70-I79 Diseases of arteries, arterioles and capillaries	T66-T78 Other and unspecified effects of external causes
I80-I89 Diseases of veins and lymphatic system nec.	T79 Certain early complications of trauma
I95-I99 Other and unspecified disorders of the circulatory system	T80-T88 Complications of surgical and medical care not elsewhere classified
J00-J06 Acute upper respiratory infections	T90-T98 Sequelae of injuries of poisoning and other consequences
J09-J18 Influenza and pneumonia	VVV
J20-J22 Other acute lower respiratory infections	WWW

J30-J39 Other diseases of upper respiratory tract	XXX
J40-J47 Chronic lower respiratory diseases	YYY
J60-J70 Lung diseases due to external agents	Z00-Z13 Examination and investigation
J80-J99 Other diseases of the respiratory system	Z20-Z29 Potential health hazards related to communicable diseases
K00-K14 Diseases of oral cavity, salivary glands and jaws	Z30-Z39 Health services in circumstances related to reproduction
K20-K31 Diseases of oesophagus, stomach and duodenum	Z40-Z54 Persons encountering health services for specific care
K35-K38 Diseases of appendix	Z55-Z65 Potential health hazards related to socioeconomic and psychosocial circumstances
K40-K46 Hernia	Z70-Z76 Persons encountering health services in other circumstances
K50-K52 Noninfective enteritis and colitis	Z80-Z99 Persons with potential health hazards related to family
K55-K64 Other diseases of intestines	U Unclassified

LSOA attributed variables

Variable	Source
% DLA/PIP	DWP
Log population variance	NHS E/ONS
Coastal flag	CMO report
Rural/urban flags	ONS
Crime score	IMD
Income score**	IMD
Employment score**	IMD
% never worked or unemployed**	2021 Census
% in higher managerial or professional occupations**	2021 Census
Disabled persons (age standardised rate per 100,000)**	2021 Census
Disabled people in poor health (age standardised per 100,000)**	2021 Census
Years of potential life lost indicator**	IMD
Mood and anxiety disorders indicator**	IMD
% aged 16-74 with no qualifications (age standardised)	2021 Census
Staying on post 16 indicator	IMD
Entry to higher education indicator	IMD
Adult skills and English language proficiency indicator	IMD
Road distance to a post office indicator (km)**	IMD
Road distance to a primary school indicator (km)**	IMD
Road distance to general store or supermarket indicator (km)**	IMD
Road distance to a GP surgery indicator (km)**	IMD
Homelessness indicator**	IMD
Housing affordability indicator**	IMD
Housing in poor condition indicator	IMD
Houses without central heating indicator	IMD
Air quality indicator	IMD
Road traffic accidents indicator	IMD
% single (never married)	2021 Census
% widowed divorced or separated (marriage or civil partnership)	2021 Census
% single pensioner households	2021 Census
% students in population	2021 Census
% unpaid carers	2021 Census

*** variable from PCA*

GP practice attributed variables

Variable	Source
% with GP appointment in last 3 months	GP patient survey
% with long term condition	GP patient survey
% with a long term condition that impacts on day to day activities a lot	GP patient survey
Average number of long term medical conditions for those with at least 1	GP patient survey
Coronary heart disease prevalence**	QOF
Hypertension prevalence**	QOF
Stroke and transient ischaemic attack prevalence**	QOF
Learning disability prevalence**	QOF
Mental health prevalence**	QOF
Osteoperosis prevalence**	QOF

*** variable from PCA*

Supply variables

Variable	Source
Gravity weighted distance between LSOA centroid and maternity units	
ICB dummy variables	
Road distance to a GP surgery indicator (km)**	IMD
Patients per GP FTE	GP workforce survey
Patients per nurse FTE	GP workforce survey
Patient per direct patient care FTE	GP workforce survey
% points achieved for overall achievement score	QOF
% with Diptheria, tetanus and pertussis by 8 months	QOF
% with MMR by 18 months	QOF
% with MMR and DTa/IPV by 5 years	QOF
% 80 year olds with shingles vaccine	QOF

Annex F: Coefficients for the prescribing model

Variable	Coefficient	Significance
Constant	7071.61	0
High cost (above £25k)	18914.23	0

Age and gender

Variable	Coefficient	Significance
Age under 20	-101.03	0
Age 20-24	115.90	0
Age 25-29	5.56	0.539
Age 30-34	8.45	0.142
Age 35-39	26.56	0
Age 40-44	2.72	0.845
Age 45-49	102.16	0.08
Age 50-54	-30.09	0.866

Birth order (reference group first)

Variable	Coefficient	Significance
Second	-82.36	0.00
Third	-122.81	0.00
Four or more	-10.67	0.62
Unknown	-44.71	0.81

Other obstetric variables

Variable	Coefficient	Significance
Multiple births	-294.68	0.00
Low birth weight	0.58	0.00

Household type main effects (reference group – 2 adults with children)

Variable	Coefficient	Significance
8 or more adults	-4.86	0.99
1 adult with children	-232.07	0.56
1 person household	878.45	0.18
Other	-288.42	0.65
3-7 adults with children	78.00	0.80
3-7 adults aged 20+ with no children	1298.04	0.00
3-7 adults aged under 20	-161.71	0.83
2 adults - different gender	820.22	0.32
2 adults - same gender	1462.96	0.05

Household type and age interactions

Variable	Coefficient	Significance
Age<20		
8 or more adults	3.77	0.91
1 adult with children	7.75	0.71
1 person household	-36.64	0.28
Other	24.10	0.47
3-7 adults with children	1.69	0.92
3-7 adults aged 20+ with no children	-57.67	0.01
3-7 adults aged under 20	17.94	0.65
2 adults - different gender	-30.82	0.46
2 adults - same gender	-65.13	0.09
Age 20-24		
8 or more adults	11.57	0.79
1 adult with children	2.18	0.94
1 person household	52.31	0.18
Other	-28.16	0.51
3-7 adults with children	-6.91	0.75
3-7 adults aged 20+ with no children	87.76	0.00
3-7 adults aged under 20	-8.21	0.87
2 adults - different gender	43.47	0.36
2 adults - same gender	81.88	0.09
Age 25-29		
8 or more adults	2.91	0.88

1 adult with children	-5.63	0.69
1 person household	-11.61	0.43
Other	11.47	0.61
3-7 adults with children	5.37	0.65
3-7 adults aged 20+ with no children	-24.18	0.06
3-7 adults aged under 20	12.57	0.56
2 adults - different gender	-14.45	0.31
2 adults - same gender	0.20	0.99
Age 30-34		
8 or more adults	-21.05	0.24
1 adult with children	-1.52	0.88
1 person household	8.92	0.44
Other	-25.03	0.17
3-7 adults with children	-4.63	0.60
3-7 adults aged 20+ with no children	9.68	0.38
3-7 adults aged under 20	-26.03	0.09
2 adults - different gender	16.87	0.07
2 adults - same gender	-3.60	0.88
Age 35-39		
8 or more adults	-2.90	0.91
1 adult with children	-8.74	0.48
1 person household	-3.99	0.79
Other	29.52	0.19
3-7 adults with children	-8.09	0.41
3-7 adults aged 20+ with no children	-41.89	0.01
3-7 adults aged under 20	-1.11	0.96
2 adults - different gender	-9.27	0.40
2 adults - same gender	-49.72	0.11
Age 40-44		
8 or more adults	74.94	0.18
1 adult with children	16.47	0.62
1 person household	-68.98	0.05
Other	-27.94	0.61
3-7 adults with children	-14.20	0.51
3-7 adults aged 20+ with no children	15.94	0.67
3-7 adults aged under 20	39.95	0.40

2 adults - different gender	-17.00	0.52
2 adults - same gender	4.38	0.95
Age 45-49		
8 or more adults	-414.49	0.05
1 adult with children	-16.74	0.89
1 person household	113.18	0.38
Other	351.73	0.06
3-7 adults with children	-25.83	0.76
3-7 adults aged 20+ with no children	-102.72	0.45
3-7 adults aged under 20	29.31	0.84
2 adults - different gender	-184.96	0.05
2 adults - same gender	-217.31	0.49
Age 50+		
8 or more adults	1028.80	0.07
1 adult with children	-359.02	0.52
1 person household	613.02	0.03
Other	-938.76	0.29
3-7 adults with children	-27.24	0.92
3-7 adults aged 20+ with no children	0.45	1.00
3-7 adults aged under 20	-453.72	0.14
2 adults - different gender	307.96	0.26
2 adults - same gender	1028.80	0.07

Ethnicity (reference group – White British)

Variable	Coefficient	Significance
Bangladeshi	243.39	0.00
Chinese	-76.67	0.00
Indian	176.22	0.00
Pakistani	161.48	0.00
Other Asian heritage	117.93	0.00
African	319.32	0.00
Caribbean	213.21	0.00
Other Black heritage	290.41	0.00
Mixed heritage White and Asian	38.81	0.20
Mixed heritage White and Black	201.91	0.00

Mixed heritage White and Caribbean	95.22	0.00
Other mixed heritage	44.96	0.03
White Irish	101.65	0.00
Other White heritage	-42.33	0.00
Any other ethnic group	-38.43	0.03

Diagnoses

Variable	Coefficient	Significance
a00_a09 Intestinal infectious diseases	-8.71	0.67
a15_a19 Tuberculosis	593.61	0.04
a20_a49 Certain bacterial diseases	97.87	0.06
a50_a64 Infections with predominantly sexual mode of transmission	-1534.51	0.06
a65_a79 Other infectious and parasitic disorders	-1202.46	0.04
a80_a89 Viral infections of the central nervous system	-308.03	0.09
a90_a99 Arthropod-borne viral fevers and viral haemorrhagic fevers	3201.80	0.02
b00_b09 Viral infections characterized by skin and mucous membrane lesions	-25.12	0.79
b15_b19 Viral hepatitis	465.68	0.00
b25_b34 Other viral diseases	-77.46	0.20
b35_b49 Mycoses	53.18	0.18
b50_b64 Protozoal diseases	-305.83	0.37
b65_b83 Helminthiases	-564.08	0.12
b85_b99 Other infectious and parasitic diseases	31.11	0.15
c00_c14 Malignant neoplasm of liporal cavity and	1103.07	0.12
c15_c26 Malignant neoplasm of digestive organs	1114.70	0.05
c30_c39 Malignant neoplasms of respiratory and intrathoracic organs	1616.19	0.05
c40_c41 Malignant neoplasm of bone and articular	1999.30	0.05
c43_c44 Malignant neoplasms of skin	1255.23	0.00
c45_c49 Malignant neoplasms of mesothelial and soft tissue	2478.51	0.00
c50 Malignant neoplasm of breast	1627.14	0.00
c51_c58 Malignant neoplasms of female genital organs	694.46	0.07
c64_c68 Malignant neoplasms of urinary tract	1313.84	0.04

c69_c72 Malignant neoplasms of eye, brain and other parts of central nervous system	1493.91	0.00
c73_c80 Malignant neoplasm of thyroid and other endocrine glands	279.53	0.23
c81_c96 Malignant neoplasms of lymphoid, haematopoietic and related tissue	1297.45	0.00
d00_d48 In situ and benign neoplasms and others of uncertainty	136.76	0.00
d50_d64 Anaemias	371.87	0.00
d65_d89 Diseases of the blood and blood-forming organs	827.10	0.00
e00_e07 Disorders of thyroid gland	260.40	0.00
e10_e14 Diabetes Mellitus	1879.84	0.00
e15_e90 Endocrine nutritional and metabolic diseases	433.38	0.00
f00_f03 Dementia	-593.66	0.55
f04_f09 Other organic including symptomatic mental disorders	-510.82	0.14
f10_f19 Mental and behavioural disorders due to psychoactive substances	9.06	0.37
f20_f29 Schizophrenia, schizotypal and delusional disorders	331.26	0.00
f30_f39 Mood disorders	83.54	0.00
f40_f69 Neurotic, behavioural and personality disorders	66.31	0.00
f70_f79 Mental retardation	253.44	0.00
f80_f99 Other mental and behavioural disorders	211.29	0.00
g00_g09 Inflammatory diseases of the central nervous system	-76.66	0.59
g10_g14 Other degenerative diseases (including Alzheimer's).	121.24	0.61
g20_g26 Extrapyramidal and movement disorders (including Parkinsonism)	8.82	0.94
g35_g37 Demyelinating diseases (including Multiple Sclerosis) of the central nervous system	1207.92	0.00
g40_g47 Epilepsy, migraine and other episodic disorders	178.37	0.00
g50_g73 Other diseases and disorders of the nervous system	252.44	0.00
g80_g83 Cerebral palsy and other paralytic syndromes	506.45	0.00
h00_h06 Other disorders of the eye.	95.20	0.00
h10_h13 Disorders of conjunctiva (including conjunctivitis)	-350.64	0.05

h25_h28 Disorders of lens (including cataracts)	345.48	0.06
h40_h42 Glaucoma	-101.10	0.57
h60_h95 Diseases of the ear and mastoid process	225.78	0.00
i00_i09 Rheumatic heart disease	1141.70	0.00
i10_i15 Hypertensive diseases	1198.31	0.00
i20_i25 Ischaemic heart diseases	692.12	0.00
i26_i28 Pulmonary heart disease and diseases of pulmonary circulation	1078.42	0.00
i30_i52 Other forms of heart disease	1169.37	0.00
i60_i69 Cerebrovascular diseases	763.49	0.00
i70_i79 Diseases of arteries, arterioles and capillaries	982.84	0.00
i80_i89 Diseases of veins and lymphatic system not elsewhere classified	288.42	0.00
i95_i99 Other and unspecified disorders of the circulatory system	-84.52	0.08
j00_j06 Acute upper respiratory infections	46.44	0.16
j09_j18 Influenza and pneumonia	-36.92	0.23
j20_j22 Other acute lower respiratory infections	-62.36	0.07
j30_j39 Other diseases of upper respiratory tract	-1.43	0.95
j40_j47 Chronic lower respiratory diseases	98.76	0.00
j60_j70 Lung diseases due to external agents	-163.90	0.69
j80_j99 Other diseases of the respiratory system	-39.09	0.52
k00_k14 Diseases of oral cavity, salivary glands and jaws	31.49	0.56
k20_k31 Diseases of oesophagus, stomach and duodenum	-7.50	0.74
k35_k38 Diseases of appendix	-19.98	0.77
k40_k46 Hernia	-4.47	0.91
k50_k52 Noninfective enteritis and colitis	313.26	0.00
k55_k64 Other diseases of intestines	-22.81	0.12
k65_k67 Diseases of peritoneum	13.68	0.85
k70_k77 Diseases of liver	295.57	0.00
k80_k87 Disorders of gall bladder, biliary tract and pancreas	106.93	0.00
k90_k93 Other diseases of the digestive system	17.00	0.59
l00_l14 Other infections and disorders of the skin	53.91	0.06
l20_l30 Dermatitis and eczema	37.68	0.03
l40_l45 Papulosquamous disorders (including Psoriasis)	-19.33	0.61
l50_l54 Urticaria and erythema	-11.90	0.88

m00_m25 Arthropathies	224.05	0.00
m30_m36 Systemic connective tissue disorders	1066.91	0.00
m40_m54 Dorsopathies	-17.54	0.17
m60_m79 Soft tissue disorders	27.03	0.13
m80_m94 Osteopathies and chondropathies	-8.30	0.88
m95_m99 Other disorders of the musculoskeletal system and connective tissue	108.36	0.73
n00_n08 Diseases of the kidney	205.07	0.00
n17_n19 Renal failure	569.57	0.00
n20_n23 Urolithiasis	79.22	0.15
n25_n29 Other disorders of kidney and ureter	960.00	0.00
n30_n39 Other diseases of the urinary system	26.72	0.40
n60_n64 Disorders of breast	-85.99	0.26
n70_n77 Inflammatory diseases of female pelvic organs	-28.41	0.45
n80_n98 Noninflammatory disorders of female genital tract	-50.48	0.00
n99 Other disorders of the genitourinary system	197.98	0.42
o00_o08 Pregnancy with abortive outcome	86.69	0.00
o10_o75 Complications of labour and delivery	126.80	0.00
p05_p96 Other conditions originating in the perinatal period	514.21	0.42
q00_q89 Congenital malformations	414.65	0.00
q90_q99 Chromosomal abnormalities not elsewhere classified	175.99	0.23
r00_r09 Symptoms and signs involving the circulatory/respiratory system	124.84	0.00
r10_r19 Symptoms and signs involving the digestive system and abdomen	22.83	0.00
r20_r23 Symptoms and signs involving the skin and subcutaneous tissue	-74.53	0.02
r25_r29 Symptoms and signs involving the nervous and musculoskeletal system	10.25	0.82
r30_r39 Symptoms and signs involving the urinary system	-19.56	0.49
r40_r46 Symptoms and signs involving cognition, perception, emotional state and behaviour	-56.42	0.01
r47_r49 Symptoms and signs involving speech and voice	-79.82	0.17
r50_r68 General symptoms and signs	-19.88	0.12
r69 Unknown and unspecified causes of morbidity	105.06	0.56

r70_r89 Abnormal findings of bodily fluids or samples without diagnosis	-12.65	0.61
r90_r94 Abnormal findings on diagnostic imaging/function studies	56.31	0.12
s00_s09 Injuries to the head	-29.71	0.68
s10_s19 Injuries to the neck	-20.84	0.93
s20_s29 Injuries to the thorax	10.83	0.96
s30_s39 Injuries to abdomen, lower back, lumbar spine and pelvis	89.96	0.24
s40_s49 Injuries to the shoulder and upper arm	60.12	0.71
s50_s59 Injuries to the elbow and forearm	84.81	0.44
s60_s69 Injuries to the wrist and hand	1.11	0.99
s70_s79 Injuries to the hip and thigh	-230.14	0.16
s80_s89 Injuries to the knee and lower leg	50.27	0.58
s90_s99 Injuries to the ankle and foot	-254.62	0.04
t00_t07 Injuries involving multiple body regions	-53.08	0.78
t08_t14 Injuries to unspecified part of trunk limb or body	-388.28	0.05
t15_t19 Effects of foreign body entering through natural orifice	14.72	0.94
t20_t32 Burns and corrosions	80.40	0.74
t33_t35 Frostbite	-2513.38	0.07
t36_t50 Poisonings by drugs medicaments and biological substances	1.74	0.98
t51_t65 Toxic effects of substances chiefly non-medicinal as to source	25.25	0.84
t66_t78 Other and unspecified effects of external causes	347.35	0.00
t79 Certain early complications of trauma	-460.95	0.39
t80_t88 Complications of surgical and medical care not elsewhere classified	93.82	0.10
t90_t98 Sequelae of injuries of poisoning and other consequences	-175.21	0.25
VVV	-71.15	0.26
WWW	0.53	0.99
XXX	153.61	0.00
YYY	67.24	0.09
z00_z13 Examination and investigation	15.60	0.30

z20_z29 Potential health hazards related to communicable diseases	47.98	0.00
z30_z39 Health services in circumstances related to reproduction	-2.58	0.66
z40_z54 Persons encountering health services for specific care	35.45	0.09
z55_z65 Potential health hazards related to socioeconomic and psychosocial circumstances	115.61	0.00
z70_z76 Persons encountering health services in other circumstances	85.86	0.01
z80_z99 Persons with potential health hazards related to family	198.56	0.00
U Unclassified	-44.59	0.00

Attributed need variables

Variable	Coefficient	Significance
The difference between the logged registered population and the logged resident population	-99.82	0.00
QOF prevalence – learning disability	38.40	0.00
IMD – crime score	10.33	0.00
Census - % in higher management role	-452.80	0.00
Census - % never worked or long term unemployed	-387.12	0.00
IMD - Mood and anxiety disorders indicator	25.01	0.00
IMD – Housing in poor condition indicator	-111.97	0.00

Property type and tenure

Variable	Coefficient	Significance
Property type/tenure interaction		
Detached and owner occupied	-105.56	0.00
Detached and private rented	-79.06	0.00
Detached and social rented	51.97	0.20
Detached and unknown tenure	-100.38	0.00
Semi-detached and owner occupied	-69.52	0.00
Semie-detached and private rented	-27.34	0.09

Semi-detached and social rented	0.79	0.96
Semi-detached and unknown tenure	8.58	0.76
Terraced and owner occupied	-46.50	0.00
Terraced and private rented	-5.89	0.67
Terraced and social rented	31.68	0.03
Terraced and unknown tenure	35.81	0.20
Flat and owner occupied	-1.73	0.91
Flat and private rented	24.03	0.10
Flat and social rented	64.66	0.00
Flat and unknown tenure	61.47	0.01
Other property types		
Educational establishment	-5.52	0.95
Temporary Accommodation	-3.01	0.94
Sheltered Accommodation	444.18	0.00
Military establishment	431.19	0.66
Medical establishment	231.28	0.14
Commercial establishment	-24.01	0.46

Attributed supply variables

Variable	Coefficient	Significance
IMD - Road distance to a GP surgery indicator (km)	-8.31	0.00
Gravity weighted distance between LSOA centroid and maternity units	11.24	0.02

ICBs (reference group Kent and Medway ICB)

Variable	Coefficient	Significance
Bath and North East Somerset, Swindon and Wiltshire ICB	-196.39	0.00
Bedfordshire, Luton and Milton Keynes ICB	-66.13	0.00
Birmingham and Solihull ICB	-31.80	0.09
Black Country ICB	-324.70	0.00
Bristol, North Somerset and South Gloucestershire ICB	-238.30	0.00
Buckinghamshire, Oxfordshire and Berkshire West ICB	-127.38	0.00
Cambridgeshire and Peterborough ICB	-34.62	0.07

Cheshire and Merseyside ICB	-158.60	0.00
Cornwall and The Isles Of Scilly ICB	-183.62	0.00
Coventry and Warwickshire ICB	-204.01	0.00
Derby and Derbyshire ICB	-242.69	0.00
Devon ICB	-152.49	0.00
Dorset ICB	67.13	0.00
Frimley ICB	-67.38	0.04
Gloucestershire ICB	-407.74	0.00
Greater Manchester ICB	-131.87	0.00
Hampshire and Isle Of Wight ICB	-21.05	0.19
Herefordshire and Worcestershire ICB	43.66	0.05
Hertfordshire and West Essex ICB	35.95	0.05
Humber and North Yorkshire ICB	-130.45	0.00
Lancashire and South Cumbria ICB	-198.87	0.00
Leicester, Leicestershire and Rutland ICB	17.89	0.36
Lincolnshire ICB	-7.91	0.72
Mid and South Essex ICB	-43.80	0.01
Norfolk and Waveney ICB	-89.72	0.00
North Central London ICB	55.14	0.00
North East London ICB	-75.37	0.00
North East and North Cumbria ICB	-77.55	0.00
North West London ICB	9.88	0.58
Northamptonshire ICB	-5.49	0.80
Nottingham and Nottinghamshire ICB	-86.69	0.00
Shropshire, Telford and Wrekin ICB	-296.06	0.00
Somerset ICB	-231.95	0.00
South East London ICB	-12.73	0.47
South West London ICB	-30.20	0.10
South Yorkshire ICB	104.91	0.00
Staffordshire and Stoke-on-Trent ICB	-205.55	0.00
Suffolk and North East Essex ICB	-10.73	0.58
Surrey Heartlands ICB	-6.58	0.74
Sussex ICB	-47.61	0.01
West Yorkshire ICB	-283.31	0.00