The Cost-Effectiveness of Midwifery Staffing and Skill Mix on Maternity Outcomes

A Report for The National Institute for Health and Care Excellence

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University of Surrey

One of the UK's leading professional, scientific and technological universities in the UK, the University of Surrey ranked 39th in the prestigious Top 100 List of the world's most international universities, part of the Times Higher Education (THE) World University rankings for 2013-14. Actively involved in successive research collaborations with industrial and research partners across Europe since the Fourth Framework Programme, the University of Surrey received funding for 160 projects in the Seventh Framework Programme, including 26 Marie Curie fellowships.

Department of Health Care Management & Policy

The Department of Health Care Management and Policy (DHCMP) at the University of Surrey has been involved in quality improvement interventions over the last 15 years, primarily for long term conditions in the UK and internationally. Our interests are how to measure quality and health outcomes from routine data, quality improvement and technology trials, and integrating the use of the computer into the clinical consultation.

Despite being a small group, we have over 150 full length peer review scientific research publications; in addition to over 100 other peer review journal articles, letters or editorials and in excess of this number of conference abstracts. We have direct links with an excellent group of international collaborators; and links through the primary care informatics working groups of IMIA and EFMI (the International and European informatics organisations).

The Economics group in DHCMP has 10 members and is led by Professor Graham Cookson. The principal focus of the group is on the determinants of health care provider's productivity, the efficiency and effectiveness trade-off in health care, and the role of the health care workforce in this relationship.

Acknowledgements

In November 2013, National Institute for Health and Care Excellence (NICE) was asked by the Department of Health (DH) and NHS England to develop new guideline outputs which focus on safe staffing. In June 2014, NICE commissioned Professor Graham Cookson and his team at the University of Surrey to produce an economic evaluation of the effects of midwifery staffing and skill mix on outcomes of care in maternity settings. This report is the result of that work. GC took overall responsibility for the project, produced the report and conducted the economic evaluation. JvV performed the statistical analysis with assistance from SJ and IL performed the econometric analysis, both contributed to writing the report. SJ was responsible for internal quality assurance. Rachel Byford and David Burleigh were responsible for data management and production, and for information governance. The authors would like to thank: the team at NICE but in particular Jasdeep Hayre and Lorraine Taylor; Dr Chris Bojke (University of York); Professor John Appleby (The King's Fund) and the members of the NICE Safe Staffing Advisory Committee for helpful comments and insights into the production of this report.

Any errors or omissions remain our own.

Disclaimer and Declaration of Interests

Professor Cookson was a co-investigator of an NIHR funded study[1] of staffing and outcomes in maternity services, and was a co-author of the final project report (Sandall et al., 2014) which is referred to in this report as well as in both the Bazian (2014) and Hayre (2014) evidence reviews used by the SSAC. Additionally, he was also one of Vania Gerova's Ph.D. supervisors whose research has been reviewed in Bazian (2014). GC performed the economic evaluation for the acute nursing NICE Safe Staffing Guideline. He currently receives funding from The Leverhulme Trust[2] which is partially supporting research on the healthcare workforce including maternity services. IL also works on this project. JvV and SJ have nothing to declare.

[1] NIHR study HS&DR - 10/1011/94: The efficient use of the maternity workforce and the implications for safety & quality in maternity care: An economic perspective, March 2012-October 2014. Further details are available from: http://www.nets.nihr.ac.uk/projects/hsdr/10101194. The final report can be accessed at: http://www.journalslibrary.nihr.ac.uk/hsdr/volume-2/issue-38#hometab4

[2] Further details can be found at http://www.deliveringbetter.com

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1 Executive Summary

In November 2013, National Institute for Health and Care Excellence (NICE) was asked by the Department of Health (DH) and NHS England to develop new guideline outputs which focus on safe staffing. In July 2014, NICE commissioned this report which aims to estimate the cost-effectiveness of altering midwifery staffing and skill mix on outcomes of care in hospital maternity wards. Following a systematic Evidence Review (Bazian, 2014), the Safe Staffing Advisory Committee (SSAC) set the scope of this report to consider five outcomes: maternal and infant mortality, healthy mother and baby and bodily integrity.

There is limited evidence on the association between midwifery staffing levels, skill mix and clinical outcomes in the UK, and the two studies that provide any economic insights are severely limited. The evidence suggests that increased midwife staffing may be associated with an increased likelihood of delivery with bodily integrity (no uterine damage, 2nd/3rd/4th degree tear, stitches, episiotomy, or Caesarean-section), reduced maternal readmissions within 28 days, and reduced decision-to-delivery times for emergency Caesarean-sections. A number of issues were identified with the extant literature including potential endogeneity. As a result, new statistical analysis was commissioned to produce effectiveness measures for the economic evaluation. This research analysed delivery records from Hospital Episode Statistics from 2003-2013 linked to staffing data from the Workforce Census.

At present, this is the largest and most robust study of maternal outcomes using administrative data. The study found that midwifery staffing levels (FTE midwife per 100 deliveries) was positively and statistically significantly associated with healthy mother and delivery with bodily integrity rates, although the relationships were weak. Most of the variation in outcomes occurred at the individual, patient level rather than at trust level, with clinical risk having the largest effect.

The trust-level intervention considered was an increase in 1 FTE midwife per 100 deliveries. The effectiveness of the intervention was taken from the new statistical analysis. It was not possible to combine the benefits of the intervention into a common metric (e.g. QALYs) therefore it is impossible to ascertain the overall cost-effectiveness of changing midwife staffing or skill mix. Instead a Cost-Effectiveness Analysis was performed and Incremental Cost Effectiveness Ratios (ICERs) were computed separately for each maternity service outcome which was shown to have an association with staffing during the statistical analysis.

The reported ICERs were £85,560 per additional “healthy mother” and £193,426 per mother with “bodily integrity”. No other outcomes were found to be associated with staffing levels. However, despite the findings being based upon the best available evidence, caution should be exercised when using these results as there is great uncertainty as to the benefits of staffing interventions due to potential endogeneity and as a result of aggregate staffing measures. Further research and primary data collection may be required to resolve these issues.

2 Introduction

2.1 The Role of Economic Evaluation in the NICE process

The NHS has limited resources and almost endless uses of those resources. Therefore, when a new intervention or technology is adopted some amount of the existing health care provision will be displaced. This is what economists refer to as the 'opportunity cost' of an intervention. To maximise society's health gain from the NHS's limited budget, and to make decisions on whether to adopt new interventions in a coherent and transparent manner an economic evaluation is performed.

NICE plays a central role in the process by advising the NHS on the (clinical) effectiveness and cost-effectiveness of health care interventions and technologies. An intervention is cost-effective if it generates more health gain than it displaces as a result of the additional costs imposed on the system. Sometimes a new intervention dominates the existing best practice by being both cheaper and more effective, in which case the outcome is clear. More often the proposed intervention is more expensive and may be more effective.

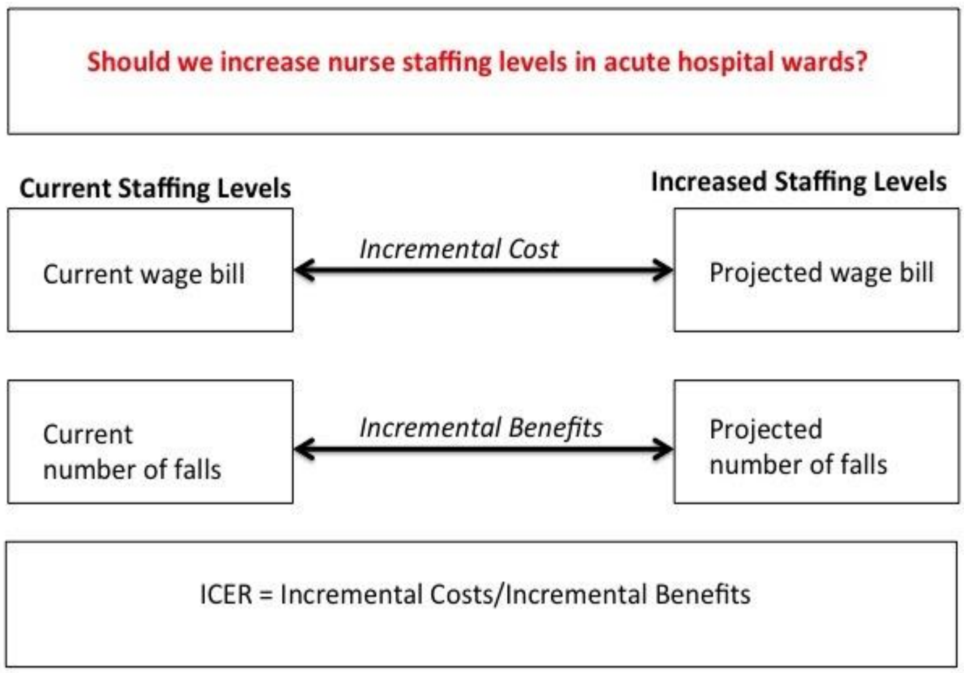
An economic analysis is usually required because the costs and/or benefits of a new intervention are uncertain. There are numerous reasons for this uncertainty. For example, there may be several small-scale studies reporting conflicting levels of effectiveness of a new treatment, or the context or population of these studies may not be wholly representative of the NHS patient population. Alternatively, widespread adoption of a new intervention may alter the market and therefore the price of the intervention. Frequently, the costs of an intervention are borne today but the benefits occur over several years into the future. All of these situations require careful modelling to enable a fair comparison of alternative outcomes. Inevitably, the economist must make assumptions about the most plausible values of the costs and benefits of an intervention based upon the best available evidence.

To illustrate the impact of these assumptions on the results of the economic analysis a sensitivity analysis is performed. This technique varies the main assumptions used to produce the base case to include plausible but extreme values of these assumptions. If varying these assumptions has little effect on the result of the economic analysis then we can be confident that the findings are robust and representative of the truth. If the results of the economic analysis vary considerably during the sensitivity analysis then additional research or evidence may be required to establish the truth, and less weight should be given to the economic evaluation in any decision making process.

NICE prefers that cost-effectiveness is reported as a cost per quality-adjusted life year (QALY) because this enables comparisons across different disease areas, populations or even between service level and disease-specific treatments to be made on a common metric. Additionally, it has the benefit of combining the multiple benefits of an intervention into a single outcome measure. QALYs are measured by estimating the health utility or value of being in different health states (where 1 is equivalent to a notional health state of perfect health and 0 is being dead) and are combined with the length of time spent in each of these health states as a result of the intervention. When it is not possible to measure QALYs, it is appropriate to report the benefits of the intervention in terms of some disease or topic specific outcome. For example, in terms of increasing ward level staffing the outcome may be the number of falls prevented.

Once the costs and benefits of an intervention have been measured, calculating the cost-effectiveness of the proposed intervention is straightforward as **Error! Reference source not found.** illustrates. It is usual to compare the new intervention with current or best practice. Dividing the incremental or additional costs by the incremental or additional benefits produces the Incremental Cost Effectiveness Ratio (ICER).

Figure 1: Incremental Cost-Effectiveness Ratio



As a concrete example, consider a hypothetical situation where the increase in staffing intervention was to add one additional nurse per ward at a cost of £31,867[3] per annum and in one year the only effect was to reduce the number of falls by 4. The ICER in this example would be £7,967 per averted fall.

If the new intervention is less effective *and* more costly than existing practice it is not cost-effective, and if it is more effective *and* cheaper than existing practice it is cost-effective. In these circumstances the outcome is straightforward. Usually however, the new intervention is either less effective but significantly cheaper, or more effective but also more expensive. In these circumstances the ICER is compared to the value of the interventions or treatments which are displaced if the new intervention is adopted: the opportunity cost. This is usually thought to be in the region of £20,000-£30,000 per QALY. There is little guidance available when the ICER is expressed in the original units of effects (e.g. falls prevented) and careful consideration needs to be given as to the value-for-money represented by the intervention in these situations.

2.2 Safe Staffing

Ensuring that staffing levels are sufficient to maximise patient safety and quality of care, whilst optimising the allocation of financial resources, is an important challenge for the NHS. The National Institute for Health and Care Excellence (NICE) has been asked by the Department of Health and NHS England to develop an evidence-based guideline on safe and cost-effective midwifery staffing levels in NHS trusts.

A systematic literature review concluded that the amount of evidence on the relationship between midwifery staffing and outcomes is limited (Bazian, 2014). Their review included 8 studies with most of them using cross-sectional designs, which severely limited their ability to detect potential causality. However, all of the included studies were carried out in the UK and are therefore expected to be applicable to the UK.

Overall few significant associations between midwife staffing levels and outcomes were identified. The evidence suggests that increased midwife staffing may be associated with an increased likelihood of delivery with bodily integrity (no uterine damage, 2nd/3rd/4th degree tear, stitches, episiotomy, or Caesarean-section), reduced maternal readmissions within 28 days, and reduced

[3] This figure calculated by adding the mean annual basic salary (excluding overtime) of an Agenda for Change Band 5 nurse of £25,744 to the mean on-costs of employing the nurse of £6,123 taken from the Personal Social Services Research Unit costings for July 2013-June 2013. It excludes overheads, capital costs, overtime, London weightings or training and qualification costs.

decision-to-delivery times for emergency Caesarean -sections. However, it may not be associated with overall Caesarean -section rates, composite ‘healthy mother’ or ‘health baby’ outcomes, rates of ‘normal’ or ‘straightforward’ births, or stillbirth or neonatal mortality. Interpretation is also complicated by the use of differing, but overlapping, outcomes in different studies. For example, although delivery with bodily integrity was increased in one study, another study suggested a possible reduction in straightforward birth with increasing levels of midwife staffing, and straightforward birth includes some of the same outcomes (no intrapartum Caesarean-section or $3^{rd}/4^{th}$ degree perineal trauma, as well as no birth without forceps or ventouse or blood transfusion).

Only one study formally assessed the interaction between modifying factors (maternal clinical risk and parity) and midwife staffing levels, therefore limited conclusions can be drawn about their effects. No studies were identified which assessed the links between midwife staffing and on maternal mortality or never events (such as maternal death due to post-partum haemorrhage after elective caesarean section, wrongly prepared high-risk injectable medication, intravenous administration of epidural medication, or retained foreign objects post-procedure) or serious fetal/neonatal events such as Erb’s palsy secondary to shoulder dystocia, meconium aspiration syndrome, hypoxic ischaemic encephalopathy (HIE). The SSAC requested that maternal mortality be added to the analysis as none of the included studies in Evidence Review 1 included this outcome (Bazian, 2014).

Limited evidence was identified on potential modifiers of the effect of midwife staffing levels on outcomes, therefore limited conclusions can be drawn about their effects. Only one study (Sandall et al. 2014) formally assessed potential interactions between modifying factors and midwife staffing levels. Its findings suggested that, maternal clinical risk and parity both appear to be modifiers, and to themselves have a large impact on outcomes. This is a serious weakness of the other evidence because it is probable that clinical risk is associated with staffing decisions. Excluding a measure of clinical risk from models may invalidate the findings due to omitted variable bias, which leads to an overestimation of the effect of staffing levels on outcomes.

2.3 Purpose of this report

This report aims to assess the cost-effectiveness of altering midwifery staffing levels and skill mix in the English NHS. It accompanies the Evidence Review produced by the Bazian (2014) and Hayre (2014).

2.4 Structure of this report

The next section details the methodologies and data used for both the economic evaluation and the statistical analysis. Whilst the economic evaluation is the main aim of this report, it was necessary to perform a detailed statistical analysis to determine the effectiveness of staffing on outcomes in maternity services. Section 4 presents the findings and discusses the sensitivity analyses performed. Finally Section 5 discusses the findings alongside the existing evidence base and presents a summary of the limitations of the study. The reference list is found in Section 6 and the appendices contain additional modelling results.

3 Methods

3.1 Economic Model Scope

Following the systematic Evidence Review (Bazian, 2014) performed by Bazian Limited, the Safe Staffing Advisory Committee restricted the scope of the economic analysis to five main outcomes thought to be sensitive to midwifery staffing but for which the evidence base was currently inconclusive. These outcomes were: maternal mortality, maternal health, stillbirth, baby health and bodily integrity[4].

The formal scope of the economic evaluation was agreed as:

Population:	Women who deliver in a obstetric or maternity unit based in an NHS trust
Interventions:	Increasing midwifery staffing levels by 1 FTE per 100 deliveries
Comparators:	“Current” practice – where “current” is defined by the available datasets
Outcomes:	To be performed only where the statistical analysis indicates there is an association between staffing levels and the outcomes: Incremental cost per additional healthy mother ~~Incremental cost per additional maternal death avoided~~ ~~Incremental cost per additional stillbirth avoided~~ ~~Incremental cost per additional healthy baby~~ Incremental cost per additional mother delivered with bodily integrity
Perspective:	National Health Service and Personal Social Services
Evaluation method:	Cost-Effectiveness Analysis (CEA)
Time:	One year. No discounting is required.
Valuing Benefits:	A utility measure (e.g. QALY) is neither available nor appropriate in this setting.
Evidence Synthesis:	The results from the Evidence Review by Bazian (2014) will inform the statistical and economic modelling.

[4] Full definitions and details of how these variables are operationalized are provided in Section 3.4 which details the methodology and data used in the statistical analysis.

3.2 CEA Methodology

The Cost-Effectiveness Analysis (CEA) will estimate the Incremental Cost-Effectiveness Ratio for increasing midwifery staffing by 1 FTE per 100 deliveries maternal mortality, maternal health, stillbirth, baby health and bodily integrity. The 5 outcomes will be considered separately due to a lack of common metric (e.g. QALYs or money). The analysis will be performed at trust level. Whilst a longitudinal/panel dataset will be used for the statistical analysis, the base case values will be taken from the latest available year as they will be most representative.

Table 1 lists the parameters used in the CEA and, taking falls as an example, the CEA uses them in the following steps:

Incremental Cost Effectiveness Ratio: Incremental cost/incremental benefit

Incremental benefit: effectiveness of intervention x exposure

Effectiveness: change in the rate at which the outcome occurs

Exposure: number of deliveries per trust per year

As the intervention is an increase in midwifery numbers, it will only be necessary to calculate the incremental cost and not the baseline cost as the remainder of the cost is still incurred after the intervention. For example, if we consider increasing registered midwifery staffing by 1 FTE per 100 deliveries from 3.34, then the incremental cost is the wage of 46 FTE midwives[5] for the average trust from 143 because both the current practice and intervention will incur the cost of the other 143 FTE midwives.

The following assumptions are also made:

- That the data used in the statistical analysis is representative of English NHS trusts i.e. that there is no selection bias
- That there has been accurate recording of the outcomes
- That any unobserved patient, ward or trust level characteristics do not confound the results
- That the relationships are constant

The importance of these assumptions for the validity of the findings and the likelihood that they hold are discussed in Section 5. The impact of these assumptions on the CEA cannot be modelled through sensitivity analysis. The computer code used to generate the statistical results and the CEA

[5] Based on the average trust employing 143 midwives and having 4620 deliveries per annum.

calculations have been checked by the authors, plus another colleague from the Department of Health Care Management & Policy. Finally, a sensitivity analysis is performed in Section 4 to determine the sensitivity of the findings and conclusions to the values chosen for the parameters in Table 1.

Parameter	Definition	Source and value
Exposure	Number of deliveries (thousands)	HES (2014). Hospital Episode Statistics
Effectiveness	Change in rate of outcome	Odds ratio from results Section 4.1.3.
Midwives	FTE registered midwives per 100 deliveries	HSCIC (2014). Workforce Census
Cost	The cost per FTE Midwife	Public and Social Services Research Unit (2013). Section 3.3

Table 1 Economic Model Parameters and Sources

Table 2: NHS Employment Costs – Source: PSSRU 2013.

Grade	AfC Band	Salary	On-Costs	Total Cost	Total Cost x 0.96	Total Cost x 1.19
Qualified Midwife (Average)	6	£31,752	£7,888	£39,640	£38,054	£47,171
Qualified Midwife (Top of band)	6	£34,530	£8,674	£43,204	£41,476	£51,413
Newly Qualified Midwife (Average)	5	£25,744	£6,188	£31,932	£30,654	£37,999
Newly Qualified Midwife (Bottom of Band)	5	£21,478	£4,980	£26,458	£25,400	£31,485

3.1 Costs

From an NHS perspective, only direct costs are considered. As this is a midwife staffing intervention this is understood to be the wage plus the on-costs (employer's national insurance and pension contributions). Overtime, training costs, and capital costs are excluded. Costs are taken from PSSRU's Unit Cost of Health and Social Care 2013 report (Curtis, 2013) and are national averages in UK pounds for the period July 2012 to June 2013. The employment costs which are reported in Table 2 can be weighted for London trust by multiplying by a factor of 1.19 or reduced for trusts outside London by multiplying by a factor of 0.96. A newly qualified midwife is placed on a band 5 salary raising to band 6 after 12 months or at most after 24 months. As a result, the average band 6 salary is taken as the base case cost in the economic evaluation. The highest and lowest plausible cost are taken as the upper and lower bounds for the sensitivity analysis. These are the bottom of band 5 discounted for being outside London, and the top of band 6 weighted by the inner London cost. These three salary values are highlighted in red in Table 2.

3.2 Evidence of cost-effectiveness of interventions

There are no existing economic evaluations of interventions to alter midwifery staffing levels and/or skill mix that provide suitable estimates of the cost-effectiveness of the interventions (Hayre, 2014). Evidence Review 3 (Hayre, 2014) found two "partially applicable" studies (Allen and Thornton, 2013; Sandall et al., 2014) that provided minimal economic evidence. The studies were reviewed in detail by Hayre (2014) and the findings of the economic evidence review are therefore only summarised below.

The applicability criteria rate the applicability of the studies to the NICE reference case (in this study health outcomes in NHS settings). This partially applicable rating means that the studies fail to meet one or more of the applicability criteria, and this would change the conclusions about cost effectiveness. Neither included study performed an incremental cost-effectiveness analysis or considered the relationship between staffing costs and outcomes. In addition the limitations criteria measures the methodological quality of the study. A rating of "potentially serious limitations" indicates that the study fails to meet one or more quality criteria, and *this could change* the conclusions about cost effectiveness. "Very serious limitations" would indicate that the study fails to meet one or more quality criteria, and this is *highly likely to change* the conclusions about cost effectiveness. Such studies should usually be excluded from further consideration.

One partially applicable study (Allen and Thornton, 2013) with very serious limitations suggested a 25% reduction in midwifery overload (the number of women exceed the scheduled workload) could be achieved with a 4% increase in budget. A 15% reduction in midwifery overload could be achieved by reducing staffing on Saturday night and all of Sunday and reapplied at peak weekday times with no increase in costs. The study did not describe the simulation model in detail, the cost perspective, resource estimates, unit cost estimates and sources were not stated. The study also used evidence for one ward in England and may not be generalisable to other wards. The analysis was not a fully incremental analysis and no sensitivity analysis was undertaken to investigate uncertainty. Given the very serious limitations the study should be excluded from further consideration.

The other partially applicable study with potentially serious limitations (Sandall et al, 2014) showed higher midwife staffing levels were associated with higher costs of each delivery. Adding an additional midwife would increase the number of deliveries possible in a trust by approximately 18 deliveries per year. The study also showed that midwives are substitutes (can replace one another) with support workers but complements (should be used in conjunction) with doctors and consultants in terms of the total number of deliveries handled by a trust. Only 1– 2% of the total variation in the outcome indicators was attributable to differences between trusts whereas 98– 99% of the variation was attributable to differences between mothers within trusts, mostly due to clinical risk, parity and age. The linear effects of the staffing variables were not statistically significant for eight indicators. Increased investment in staff did not necessarily have an effect on the outcome and experience measures chosen, although there was a higher rate of intact perineum and also of delivery with bodily integrity in trusts with greater levels of midwifery staffing. The odds of having a delivery with bodily integrity increase by 10 percent per additional midwife per 100 maternities[6]. Adding an additional midwife per 100 maternities is equivalent to adding an additional 46 midwives to the FTE headcount for the average trust[7], representing a 33% increase in the midwifery workforce.

However, the study was considered to have potentially serious limitations because it was unclear if all relevant long terms costs and consequences were considered (i.e. long term implications of mother and baby safety concerns). The analysis was not a fully incremental analysis. The time spent between roles in obstetric versus gynaecology could not be separated, and there was no consideration of bank and agency staff. Multicollinearity (a strong correlation between explanatory variables used in the model) between many variables was identified. Endogeneity (the error term and the explanatory variables are correlated) was also a potential concern. The combination of both multicollinearity and endogeneity could result in potentially biased results, or incorrectly accepting or rejecting a null hypothesis.

[6] The odds ratio was 1.10 so the odds can be calculated as (1.1-1)*100=10%

[7] The mean FTE midwives per 100 maternities was 3.08 in Sandal et al. (2014) and the average number of deliveries was 4,620. See Table 16 on page 32 of the report. This implies an increase of 46.2 FTE midwives moving from 142.3 to 188.5 FTE on average.

Given the limited relevance of the existing literature, alongside the poor quality of the results, it will be necessary to generate effectiveness measures before the cost-effectiveness can proceed. The next section details the data sets and methods used to determine the effects of altering staffing levels and skill mix on outcomes of care in maternity settings.

3.3 Effectiveness of Staffing on Outcomes

Following Evidence Review 1 (Bazian, 2014), the SSAC felt that the extant evidence was not robust enough to inform the guideline development. Certainly, the existing evidence finds only weak or inconsistent evidence of the positive effect of staffing on outcomes, even in highly powered studies. A major limitation of most studies, as discussed in Section 2.2, is the omission of clinical risk measures that may bias the findings. The best available study (Sandall et al., 2014) identified in Evidence Review 1 (Bazian, 2014) which does control for clinical risk, reported a single year, observational study and may suffer from further sources of endogeneity.

Crudely, statistical models attempt to measure the effects of some variables of interest on an outcome of interest. For example, the effect of staffing levels on intrapartum maternal health. A number of conditions must hold for the results of such statistical modelling to be valid for decision-making purposes. Both Evidence Review 1 (Bazian, 2014) and the economists on the SSAC have raised concerns that the extant evidence *may* suffer from endogeneity.

Endogeneity is a technical term that refers to the situation where there is a correlation or relationship between the explanatory variables in a statistical model and the error term. The error term captures the variation in the outcome that isn't explained by the explanatory variables. Whenever this error is correlated with the explanatory variables the problem of endogeneity arises and the estimated relationships between these explanatory variables and the outcome are biased or untrustworthy. The estimated effects may be over or under estimates of the true relationship and this makes decision-making difficult, if not impossible. These are several potential causes of endogeneity, the most common of which are omitted variables and simultaneity.

Endogeneity is most commonly caused by omitted variables. There are may be a relationship between clinical risk and staffing levels; a trust may employ more staff than another trust if a greater proportion of their patients are "higher risk". At the same time we think that both staffing levels and high risk independently effect clinical outcomes. Excluding one of these variables from our model will therefore cause endogeneity because we have omitted a variable. We rarely have all of the potential explanatory variables in a model because either (i) we don't know what all of them are, or

(ii) we haven't observed them. However, omitted variable bias only occurs when the excluded explanatory variables are related to the included explanatory variables. Using longitudinal data where trusts are repeatedly observed over time removes some omitted variable bias, to the extent to which these omitted variables are time invariant. For example, if management quality is potentially correlated with both staffing levels and patient outcomes it could induce endogeneity. However this could be removed if management quality is constant for each trust over time.

Alternatively endogeneity may be caused by simultaneity. This is where the outcome and one (or more) of the explanatory variables a jointly determined. For example, whilst staffing may determine how many deliveries a maternity service can handle, the number (or expected number) of deliveries may determine the amount of staff a provider employs. This indicates that it may be difficult to determine which way the causal relationship flows. This is less of a problem in the estimation of outcomes but more in the estimation of the effects of staffing levels on output (i.e. the number of deliveries). This could be addressed through econometric techniques such as generalized method of moments where historical values of output (deliveries) are included as an explanatory variable.

Sandall et al. (2014) suggests that increased midwife staffing may be associated with an increased likelihood of delivery with bodily integrity (no uterine damage, 2nd/3rd/4th degree perineal tear, stitches, episiotomy, or Caesarean section), but not with a healthy mother or healthy baby. It doesn't explicitly consider maternal mortality. To perform an economic evaluation evidence is needed of the effectiveness of altering staffing or skill mix on these outcomes, but this is evidently missing. NICE therefore commissioned further research into the association between outcomes and staffing. Specifically this work focused on the five outcomes that the SSAC would most benefit their deliberations: maternal and infant mortality, healthy mother and baby and bodily integrity. Whilst the results of the statistical modelling – presented in Section 4.1 – may aid the SSAC in their decision-making they were primarily intended to support the economic evaluation. This subsection details the data and methods used in this new analysis. At present, we believe that this is the largest and most robust observational study of maternity staffing levels, skill mix and outcomes. Yet as with all research, there remain some limitations with this analysis which are discussed in Section 5.1.

3.3.1 Data and Variables

Hospital Episode Statistics (HES) is a pseudo-anonymous patient level administrative database containing details of all admissions, outpatient appointments and Accident & Emergency attendances at all NHS trusts in England, including acute hospitals, primary care trusts and mental health trusts. Each HES record contains details of a single consultant episode: a period of patient care overseen by a consultant or other suitably qualified healthcare professional (e.g. a midwife). It is more common to work with spells or admissions, which is a continuous period of time spent as a patient within a trust. This may include more than one episode.

This study worked with delivery spells as the basic unit of observation, although exploiting the anonymous but unique patient identifiers in the HES records relevant information from previous delivery and non-delivery spells can be appended or derived. For example, parity - the number of live births (over 24 weeks) that a woman has had. This allowed for a more complete picture of a woman's obstetric history to be compiled. Primary care trusts, mental health trusts and private providers were excluded from the dataset.

Attached to a mother's delivery episode is 1-9 baby records for up to 9 babies called the maternity tail. Each baby has its own HES birth record, but this is not linked to the mother's delivery record. Delivery (mother) and birth (baby) records were extracted from the Hospital Episode Statistics database for the period 2003-2013 by The Health and Social Care Information Centre along with non-delivery episodes for these mothers. These were stored in a SQL database on a secure, private network. Full details of data storage, data management and information governance procedures are available upon request. The University of Surrey is compliant with the research and Information Governance frameworks for health and social care in the United Kingdom and is compliant with the University's best practice standards. It adheres to all of the conditions imposed by NHS HSCIC under the HES and ESR data sharing agreements. Information Governance in the Department of Health Care Management & Policy is managed by Dr Tom Chan.

The statistical analysis included NHS hospital deliveries resulting in a registerable birth between 2003 and 2013. A registrable birth occurs when a baby is born alive, or stillborn, after 24 completed weeks. Duplicate delivery and birth records were removed from the dataset. Episodes were converted to spells. The data were cleaned and the variables extracted or derived as defined in Table 3 and

Table 4 following the procedures outlined in Appendix 2 of Sandall et al. (2014).

Table 3: Outcome Variable Names & Definitions

Variable	Values	Definition
Maternal Mortality	1 = dead	Death listed as a discharge destination
Healthy Mother	1= healthy mother	A delivery with bodily integrity, no instrumental delivery, no maternal sepsis, no anaesthetic complication, mother returns home ≤ 2 days, mother not readmitted within 28 days
Stillborn	1 = stillborn	Either an antepartum or intrapartum stillbirth as identified in the "BIRSTAT" field of HES
Healthy Baby	1 = healthy baby	A live baby, with gestational age of between 37-42 weeks, and baby's weight is between 2.5-4.5kg
Delivery with Bodily Integrity	1 = bodily integrity	Delivery without uterine damage, 2nd/3rd/4th degree perineal tear, stitches, or episiotomy

Maternal mortality is generally considered a poor indicator of quality of care due to its rarity[8] and questions about the relationship with factors controlled by care providers. A recently reported study by Knight et al. (2014) showed that two thirds of women who die during pregnancy or shortly afterwards die from non-pregnancy related medical conditions— for instance, heart disease, neurological conditions, or mental health problems — that have deteriorated because they were not well controlled. However as none of the included studies in Evidence Review 1 (Bazian, 2014) covered maternal mortality, the SSAC were keen to include this in the current study. In-hospital maternal death was identified through the discharge destination. Given the time available for the study it was not possible to request data linkage (based upon NHS number[9]) to ONS birth and death records. Therefore it wasn't possible to consider maternal mortality within 42 days – the most commonly used definition – or 1 year of delivery.

Whilst maternal mortality is incredibly rare, unfortunately the same cannot be said for babies. In 2011, 1 in 133 babies were stillborn or died within seven days of birth (NAO, 2013). Whilst this

[8] The maternal death rate is approximately 11 per 100,000 live births, which equates to 60-70 deaths per annum (CMACE, 2011). The rate has been declining steadily over the past decade.
[9] This data linkage requires special permissions and that the NHS number on the ONS data are encrypted with exactly the same algorithm as that used by HSCIC for a recipient's HES extract. Both processes take a long time and due to the severe backlog in data requests at HSCIC this was not feasible within the time constraints of this project.

mortality rate has been historically declining, there is significant variation both across UK countries and across individual trusts within countries. Stillbirth, either antepartum or intrapartum, is therefore an important outcome indicator. It is derived from the birth status field for each baby in the maternity tail.

The SSAC were also interested in a range of other outcomes that were developed in Sandall et al. (2014), and which are replicated here. Whilst mother and baby mortality are important indicators they affect a small fraction of the patient population. Whether or not the mother and/or baby are healthy following the birth are more widely applicable measures of quality of care. The definitions of "healthy" are those adopted in Sandall et al. (2014). A healthy baby is a live, full term (37-42 week) baby weighing more 2.5-4.5 kg. Gestational age and weight are expected to be correlated and themselves important predictors of a live birth. If all three conditions are met then a baby is defined as "healthy." Unfortunately the baby weight and gestational age fields are the most poorly coded in the maternity episodes.

A healthy mother experiences a normal birth with bodily integrity (defined below), without instrumental delivery, maternal sepsis or anesthetic complications, and returns home within 2 days of delivery not to be readmitted within 28 days. The final outcome variable selected by the SSAC was delivery with bodily integrity This term means that, following birth, the woman has not sustained any of the following: an abdominal wound (caesarean), an episiotomy (incision at the vaginal opening to facilitate birth), or a second-, third- or fourth-degree perineal tear[10]. She has therefore not required any stitches.

Although the principal aim of the statistical analysis is to determine the effect of staffing on maternal outcomes, a number of patient level explanatory variables were also extracted or derived from the HES records. These were considered to partially explain the variation in the outcomes between mothers. As the composition of mothers (case-mix) varies from trust to trust, it is important to include these variables to prevent confounding variations in the service user population with variations in the service itself. For example, if clinical risk is an important predictor of outcomes – with higher risk mother's having worse outcomes for themselves and their babies –

[10] A first-degree tear is skin only, often does not require suturing and heals spontaneously; a second-degree tear involves injury to the perineum involving perineal muscles but not involving the anal sphincter; a third-degree tear involves partial or complete disruption of the anal sphincter muscles which may involve both the external and internal anal sphincter muscles; and a fourth-degree tear is where the anal sphincter muscles and anal mucosa have been disrupted.

variation in clinical risk profiles from trust to trust would appear to show trusts with a greater proportion of higher risk woman to have worst outcomes if this variable is excluded from the analysis. This is a problem of confounding. Further as explained in Section 3.3, as these patient level variables may be correlated with the trust level staffing variables omitting them from the analysis could induce bias in the form of endogeneity.

Table 4 lists the included patient level variables. This included maternal age, parity, clinical risk at the end of pregnancy as measured by the NICE guideline for intrapartum care (NICE, 2007), ethnicity, area socioeconomic deprivation as measured by the Index of Multiple Deprivation (IMD) (DCLG, 2011), geographical location (urban/rural) and region. As in other studies, important explanatory variables such as smoking status, drug/alcohol use and maternal obesity are not available. However as they are likely to be correlated with a number of the co-morbidities and conditions included in the clinical risk variable, and because they are unlikely to be correlated with staffing levels their omission is unlikely to bias the results.

This study adopted the innovative method developed in Sandal et al. (2014) to exploit the rich clinical history available in HES records to identify women with "higher risk" pregnancies because of pre-existing medical conditions, a complicated previous obstetric history or conditions that develop during pregnancy. These women and their babies may have different outcomes from women regarded as at "lower risk". They used the NICE (2007) intrapartum care guideline and matched the conditions listed in the guideline to relevant four-alphanumeric digit ICD-10 codes. For certain conditions, other types of codes were matched, such as OPCS-4 or HES Data Dictionary data items, for example to identify breech presentation or multiple pregnancy. See pages 23-24 of Sandal et al. (2014) for further details.

The HES data were extracted to a secure, private R Studio server for statistical analysis where they were matched to the trust level dataset. The trust level dataset was assembled from three distinct sources. The HSCIC provided staffing data for English trusts under a Data Sharing Agreement. The staffing data were Full Time Equivalent (FTE) members by occupational group (e.g. registered midwife). Data provided for 2004 to 2013 are taken from the Non-Medical Workforce Census as at 30 September in each specified year. NHS Hospital and Community Health Service (HCHS) medical staff in Obstetrics and Gynaecology by organisation and grade are taken from the Medical Workforce Census as at 30 September in each specified year. In addition, a dummy (binary) variable for whether the hospital was a University Teaching Hospital was generated from data provided by Association of University Hospital Trusts (2014). Lastly, the number of maternities was included as a proxy for organisation size using data provided by the Office for National Statistics (ONS).

These are the same variables as used in Sandall et al. (2014) with the exception of service configuration. Sandall et al. (2014) included a categorical variable that captured the service configuration (e.g. Midwifery Led Unit) that was provided by BirthChoiceUK. However Sandall et al. (2014) only required data for 2010 whilst this study required data for the decade 2003-2013. In the time that was available, BirthChoiceUK did not have the resources available to provide this information. However, this variable was not found to be statistically significantly related to outcomes in Sandal et al. (2014), and to the extent to which configuration is largely expected to be time invariant the longitudinal nature of this dataset should remove any potential confounding problems. Similarly, any other trust level variables that are fixed over time will be controlled for through the longitudinal nature of the data.

As discussed in Section 3.3, the staffing variable is a proxy variable and may not adequately reflect the staffing levels on a delivery suite at the time of delivery. For example, the staffing numbers are a census figure at 30 September and mask any variation in staffing over a year. Further the numbers do not indicate how staff are split between obstetrics and gynaecology, or between the various wards or units within the maternity service (e.g. antepartum or antenatal care). Finally, it is impossible to determine how mother to staff ratios vary over time in response to changes in demand, staff absence or rotas. If these aspects do not vary across providers then the model remains valid in terms of the strength of the relationship, but the scale of the effect will be wrong.

What was evident from Sandall et al. (2014) was that there was little variation in the ratio of staff to maternities, and weak or non-existent relationships between staffing levels and outcomes. The lack of variation in staffing within trusts may be one explanation for these findings. Therefore a new variable – Hospital Load Ratio[11] – was added as a patient level fixed effect, which is derived from HES and the staffing data. Delivery dates were used to estimate the number of mothers who gave birth on the same day at the same provider: Hospital Load. This is a crude measure of service demand because it ignores the length of delivery and other patients who may be admitted to the maternity service but who did not deliver on that day. However the variable does create significant variation in service demand, as the brief description in Section 4.1.1 illustrate.

This Hospital Load was then divided by the total FTE maternity staff a trust employed that year to give a crude estimate of deliveries per staff that varies by day: Hospital Load Ratio. Obviously all staff are not working at the same time, or even all work on the delivery ward. But if it can be assumed that the rota/shift pattern and split between wards follows the same pattern the relationship should hold. In summary, the variation in service demand has been used to generate greater variation in the staffing variable.

Whilst the quality of HES data has been steadily improving since its introduction a number of key fields are still miscoded or incomplete. For example, gestational age is frequently miscoded because a number of trusts enter the age in days rather than weeks required in HES. This results in a

[11] Thanks to Dr Chris Bojke at Centre for Health Economics, University of York for suggesting this potential solution.

truncation of, for example, a 40-week term pregnancy to a 28-week pre-term pregnancy because the trust entered 280 days (40 x 7) in the patient's gestational age field. These trusts were identified during the data cleaning stage and the gestational age set to "UNKNOWN." A similar practice was applied to the other fields.

An exclusion criterion was therefore applied to the final dataset based upon the quality of clinical coding. Trusts were excluded for a particular outcome in a particular year if their coding completeness was less than 80 per cent for that outcome in that year. This approach maximised the available data for each analysis whilst ensuring generally high quality coding. Other studies have demonstrated that high quality coding trusts are representative of all trusts, and that the results of statistical analyses are not sensitive to the exclusion of low quality coding trusts (Murray et al., 2012; Knight et al., 2013).

Table 4: Explanatory Variables Labels & Definitions

Variable	Categories/definition
Mother's characteristics	
Mother's age (years)	≤ 19, 20–24, 25–29, 30–34, 35–39, 40–44, ≥ 45
Mother's parity[a]	0, 1, 2, 3, 4 or more
Clinical risk[b]	Lower, higher (includes individual assessment)
Ethnicity[a]	Not given/not known/not stated
	English/Welsh/Scottish/Northern Irish/British (white)
	Irish (white)
	Gypsy or Irish traveller
	Any other white background
	White and black Caribbean (mixed)
	White and black African (mixed)
	White and Asian (mixed)
	Any other mixed/multiple ethnic background
	Indian (Asian or Asian British)
	Pakistani (Asian or Asian British)
	Bangladeshi (Asian or Asian British)
	Chinese
	Any other Asian background
	African (black or black British)
	Caribbean (black or black British)
	Any other black/African/Caribbean backgroun
	Arab
	Any other ethnic group, please describe
Postcode-linked data	
IMD[a]	Quintiles 1 = most deprived to 5 = least deprived
Rural/urban classification[a]	No information/other postcode
	Urban ≥ 10,000 – sparse
	Urban ≥ 10,000 – less sparse
	Town and fringe – sparse
	Town and fringe – less sparse
	Village – sparse
	Village – less sparse
	Hamlet and isolated dwelling – sparse
	Hamlet and isolated dwelling – less sparse
Strategic Health Authority[a]	North East
	North West
	Yorkshire and Humber
	East Midlands
	West Midlands
	East of England
	London
	South East Coast
	South Central
	South West

Trust-level data	
Trust size[c]	ONS maternities (in thousands)
Doctors[d]	FTE doctors per 100 maternities
Midwives[e]	FTE midwives per 100 maternities
Support Workers[e]	FTE support workers per 100 maternities
Consultants[d]	FTE consultants per 100 maternities

Data Sources:

a Source: Hospital Episode Statistics with categories defined in Data Dictionary (NHS HSCIC, 2010)
b Derived from NICE Clinical Guideline 55 for intrapartum care (NICE, 2007) following the methods outlined in Sandall et al. (2014) using Hospital Episode Statistics

c Source: ONS Birth Records
d Source: Health and Social Care Information Centre (2003-2013) Medical Workforce Census
e Source: Health and Social Care Information Centre (2003-2013) Non-Medical Workforce Census

3.3.2 Statistical Methodology

A generalised linear mixed model is applied to each of the five outcome variables in turn using R[12]. Generalized linear models are appropriate when the response function is non-linear such as the case of binary (0,1) outcomes such as these. In this case logistic regression is used. A mixed model is used to capture the multilevel or hierarchical nature of the data (patients are nested within trusts). All sorts of data are naturally multilevel, hierarchical or nested. Students nested within classes within schools, and patients nested within wards within hospitals are two examples. Using techniques that are specifically designed for data generated under such hierarchical structures provides many statistical and practical advantages, including:

Correct inferences: As the observations are not independent the standard errors from a traditional will be underestimated leading to an overstatement of statistical significance. This could be corrected for using other methods such as clustered standard errors.

Substantive interest in trust level effects: Multilevel modeling allows researchers to study the residual variation in the outcomes after controlling for patient level factors. It allows us to determine what proportion of the variation in outcomes is determined by patient level factors and which by trust level factors.

[12] The R code used to generate the models is available upon request. The glmer function in the lme4 package was used.

Estimating trust effects simultaneously with the trust of group-level predictors: The effect of staffing, which is a trust level rather than patient level variable, is of substantive interest in the analysis. In a fixed effects model, the effects of group-level predictors are confounded with the effects of the group dummies, i.e. it is not possible to separate out effects due to observed and unobserved group characteristics. In a multilevel (*random effects*) model, the effects of both types of variable can be estimated.

Inference to a population of trusts: In a multilevel model the groups (trusts in this case) in the sample are treated as a random sample from a population of groups/trusts. Using a fixed effects model, inferences cannot be made beyond the groups in the sample. This is particularly relevant in this study where not all trusts are included for all outcomes.

Arguably an ordered multinomial logistic regression could be used instead of the logistic regression adopted here. For example, instead of running two separate models for (i) maternal mortality (0 = alive, 1 = dead), and (ii) healthy mother (0 = unhealthy, 1 = healthy) we could adopt an ordered logistic model with outcomes (1 = dead, 2 = alive but unhealthy, and 3 = alive and healthy). However these can be considered equivalent (Allison, 1984: 46-47) whilst running the simpler logistic model over an ordered logistic model is computational simpler and therefore faster. This is an important consideration with multilevel models applied to large datasets such as this sample because the statistical models can take a long time to run and often experience problems converging at all.

Each of the five outcomes were considered in turn with the set of explanatory variables listed in

Table 4 entered as fixed effects. Patients were nested within years within trusts and these were estimated as random effects. Odds ratios are estimated from the regression results. The standard errors are extracted from the diagonal of the variance-covariance matrix but as these are approximations they are unreliable for performing statistical inference (i.e. for generating p-values for producing confidence intervals). Instead, Likelihood Ratio (hypothesis) tests of the groups of parameters are performed and the statistical significance of these are reported[13].

To facilitate this, the explanatory variables were added in blocks starting with mother-level clinical variables (age, parity and risk), then socio-demographics (ethnicity, deprivation and urban/rural), trust-level variables (trust size and SHA) and finally staffing variables (both the hospital load variable and the staffing levels). The intercept, through a random effect, was the only parameter allowed to vary between trusts, to ensure that clustering of mothers and babies within trusts was properly accounted for in the estimation of the parameter estimate standard errors (SEs). All other variables were entered as fixed effects i.e. the relationship between the variable of interest (e.g. deprivation) was the same for all mothers regardless of which trust she gave birth in.

Commonly used measures of model fit (e.g. R-squared) are largely meaningless with non-linear models such as logistic regressions. A more appropriate measure is the discrimination properties of the model – how often the model correctly predicts the outcome under study. In essence it compares the predicted values with the actual observations. The area under the ROC curve (AUC) statistic indicates how well a model fits the data. An AUC of 0.5 is no better than tossing a coin (which would be correct 50% of the time) whereas an AUC of 1 implies perfect prediction.

3.3.3 Econometric Methodology

Skill mix is an important topic, specifically the questions of the extent to which staff groups and professions are substitutes (can replace each other) or complements (should be used together). Understanding the relationships between staff groups is important for optimising the healthcare workforce to maximise the amount of work that can be done. Changes in healthcare staffing in recent years has implicitly assumed that staff groups are substitutes, at least for certain tasks. For instance, the greater use of healthcare assistants. Production economics can be used to test whether this assumption is correct and could provide important insights into the optimal skill mix for maternity services. This analysis is focused on the amount of output (the total number of deliveries) rather than on the outcomes of this work.

[13] Specifically, the difference in the Log-Likelihood of the two models (one with and one without the parameter(s) of interes) are distributed as a Chi-Squared variable for hypothesis testing.

In economics, a production function describes the mechanism for converting a vector of inputs (e.g. midwives) into output (deliveries). After selecting the appropriate functional form, econometric estimation of the function's parameters allows the output elasticities to be calculated and returns to scale to be found. The output elasticity measures how responsive output is (the number of deliveries) to a change in the amount of input (e.g. staff). Due to the absence of data on input prices at the maternity services level of analysis, we adopted a production (i.e. quantity) function approach. Many healthcare studies using production functions (as opposed to cost functions) have adopted Reinhardt's (1972) specification of the production function, which was the first to include multiple labour inputs (registered nurses, technicians, administrative staff and doctors). However, this function assumes all inputs to be substitutes (solely due to the absence of cross-products) and discounts the possibility that different staff groups could be complements. The advance in production function analysis of the 1970s gave rise to two flexible econometric specifications which allows researchers to relax this overly strict assumption. Berndt and Christensen (1973) introduced the transcendental-logarithmic (translog) production function and Diewart (1971) introduced the generalized linear production function (also known as the Allen, McFadden and Samuelson production function).

Using either of these functions would have allowed us to estimate the relationship between the labour inputs because the regression coefficient on the cross-products (interaction effects) can be simply used to calculate the Hicks (1970) elasticity of complementarity (see Sato and Koizumi (1973) or Syrquin and Hollender (1982), for an explanation). However, an advantage of the Diewart (1971) specification is that it allows zero quantities for some inputs which may be a more realistic assumption when labour inputs are disaggregated as they are in our study. This modelling enabled us to examine the output contribution of the different staff inputs (output elasticities) and their influence upon the productivity of other staff inputs (i.e. whether they are complements or substitutes). With these results available, we were able to investigate the input substitution possibilities available to hospitals under different scenarios.

Following Diewart (1971) we adopted a generalized linear production function defined as:

$$Y = F(X) = F(X_1, \ldots, X_K) = \sum_{i=1}^{K}\sum_{j=1}^{K} \alpha_{ij}\sqrt{X_i}\sqrt{X_j}$$

where in our study K= 4, X = {consultants, doctors, midwives and support staff} and Y = Q, corresponding to the number of deliveries. To examine the q-complementarity (and therefore to answer the question relating to skill mix), we calculated the Hick's elasticity of complementarity[69], η^H defined for any two staffing inputs *i, j* (*i*, $\neq$*j*):

$$\eta_{ij}^{H} = \frac{f f_{ij}}{f_i f_j} \ \forall \ i \neq j$$

where

$$f_{ij} = {\partial^2 f}\Big/{\partial x_i \partial x_j}$$

The elasticities were computed at the means and the standard errors via the delta method.

We used the total number of deliveries within a hospital trust for a given year as the output measure and adopted a generalized linear production function suggested from Diewert (1971) and recently used by Sandall *et al.* (2014) in order to model the output of maternity services in the English NHS. However, instead of using a single cross-section, we use a panel dataset at the trust level so we can control for year effects and unobserved For the purposes of the analysis[14], the decision making unit was the hospital trust at a given year. The data cover the period between the financial years 2004/05 and 2013/14. More specifically, the results are based on matching information extracted from the Maternity Workforce Census for the period 2004/05 to 2013/14 (as at 30 September of each year) and the ONS Birth Registration Records for the period 2004/05 to 2012/13.[15] Merging the data resulting in an unbalanced panel dataset of 352 distinct providers for 10 years, where 228 of them were observed in every year. Table 1 presents some descriptive statistics, regarding the total sample, for the variables used in the subsequent analysis. The output measure was the total number of deliveries within the trust which has a sample mean of 4255.5 maternities and a standard deviation of 2168.2 which indicates a large degree of variation.

From the staffing data, the main focus is on the following four categories: registered midwives, support workers, consultants and all other doctors. The last two categories are considered separately in order to examine their substitutability and complementarity with the rest labour input types. Registered midwives are clearly the largest group with a mean FTE of 110.10, followed by doctors (21.73), consultants (10.03) and support workers (4.73). The mean FTE of support workers

[14] This analysis was performed whilst the research team were waiting for the full HES dataset. We therefore used aggregated (non-patient level) data and the data will therefore be slightly different to the data used in the main analysis. This analysis should therefore be considered subsidiary to the main analysis, but nevertheless it provides interesting insights into the skill mix questions.

[15] Workforce data for 2013/14 is taken from the Provisional NHS Hospital & Community Health Service (HCHS) Monthly Workforce Statistics and is at 31 May 2014.

may seem small, however, a simple descriptive analysis indicates that their use has been following a steadily upward trend during the period under investigation, from a mean FTE of 2.99 in 2004/05 to a mean FTE of 7.31 in 2013/14. The evolution in the use of doctors and consultants has been rather stable throughout the total period while the mean FTE of registered midwives has been increased from 97.37 in 2004/05 to 132.05 in 2013/14. The data are therefore comparable to that used in the main statistical analysis.

4 Results

4.1 Statistical Analysis

The final dataset consisted of 5,753,551 valid deliveries over 10 years from 2004 from 157 trusts. The dataset is an unbalanced panel in that not all trusts are observed for all outcome variables in all years. This was either due to the exclusion criteria (data quality) or because trusts changed provider code (e.g. due to merger or closure).

4.1.1 Descriptive Analysis

The descriptive analysis reports the changing structure of the dataset over the 10-year period. Table 5 presents the descriptive statistics for the outcomes. A universal pattern across the indicators is that there is relatively little variation over time, but high levels of variation across trusts within years. For instance the bodily integrity rate is double that for the top performing trusts when compared to the least performing trust. A similar pattern emerges for healthy mother. There is a prima face case to explore, although these are the raw outcome rates and are not adjusted for clinical risk.

Table 5: Descriptive Statistics of Outcomes

Healthy Mother	Mean	Std.Dev	Min	Max
2004	52%	5.15%	39%	64%
2005	51%	5.12%	38%	67%
2006	50%	5.02%	38%	66%
2007	48%	4.67%	34%	62%
2008	47%	4.81%	34%	60%
2009	47%	5.04%	33%	63%
2010	46%	4.83%	31%	61%
2011	45%	4.99%	29%	57%
2012	45%	4.96%	31%	55%

Maternal Mortality	Mean	Std.Dev	Min	Max
2004	0.005%	0.012%	0.000%	0.049%
2005	0.004%	0.011%	0.000%	0.070%
2006	0.003%	0.008%	0.000%	0.035%
2007	0.002%	0.007%	0.000%	0.035%
2008	0.003%	0.009%	0.000%	0.065%
2009	0.004%	0.009%	0.000%	0.047%
2010	0.003%	0.009%	0.000%	0.047%
2011	0.004%	0.012%	0.000%	0.105%
2012	0.002%	0.007%	0.000%	0.049%

Bodily Integrity	Mean	Std.Dev	Min	Max
2004	38%	7.10%	23%	66%
2005	37%	6.80%	21%	65%
2006	36%	6.25%	23%	56%
2007	35%	6.03%	17%	51%
2008	34%	5.91%	21%	51%
2009	34%	5.77%	22%	50%
2010	32%	5.73%	20%	51%
2011	31%	5.94%	18%	54%
2012	30%	5.60%	15%	45%

Stillbirth	Mean	Std.Dev	Min	Max
2004	0.521%	0.196%	0.000%	1.211%
2005	0.511%	0.166%	0.139%	1.007%
2006	0.548%	0.182%	0.000%	1.184%
2007	0.511%	0.183%	0.039%	1.102%
2008	0.497%	0.169%	0.060%	0.941%
2009	0.513%	0.154%	0.000%	0.954%
2010	0.516%	0.153%	0.126%	1.048%
2011	0.524%	0.151%	0.178%	0.942%
2012	0.485%	0.159%	0.128%	0.899%

Healthy Baby	Mean	Std.Dev	Min	Max
2004	89%	3%	82%	93%
2005	89%	2%	82%	94%
2006	89%	2%	82%	93%
2007	89%	2%	82%	93%
2008	89%	2%	83%	93%
2009	89%	2%	78%	93%
2010	89%	2%	78%	93%
2011	89%	2%	84%	93%
2012	89%	2%	84%	94%

Never event outcomes such as maternal or baby mortality have been steadily declining, although they have always been rare. However there was been a worsening in the healthy mother and bodily integrity variable. As bodily integrity is a component of the healthy mother variable, it is expected that they share the same trend. The worsening of the healthy mother variable could be to increased proportion of the population giving birth and the very slight changes in the demographic profile. This could result in more interventions (e.g. planned caesarean sections), which would affect the healthy mother outcome rate. Alternatively it could simply be the result of an improvement in the quality of clinical coding.

As the statistics in Table 6 illustrate, there is remarkably little variation in the profile of woman giving birth over the past decade with respect to all of the variables except clinical risk which has increased from 41% in 2004 to 53% in 2013. This could, in part, be explained by an improvement in the level of clinical coding of particular conditions or procedures that would render a woman at “higher risk” of a difficult delivery. Further, the age profile has altered very slightly with both a greater proportion of younger and older woman giving birth. Whilst the statistical models will include fixed time effects to test whether there is a time trend in the data (equivalent to estimating a different intercept or baseline for each year), it is unlikely to provide much explanatory power. The SHA of each trusts remains constant over the period and therefore only one observation is presented. However, the substantial variation in outcomes across trends may be the result of variations in the case-mix or by variations in hospital level factors such as staffing. The multilevel modelling introduced in Section 3.3.2 will allow for this to be tested and for the effect of both individual (patient level) and group (trust level) predictors to determine the outcomes.

Table 6: Descriptive Statistics – Hospital Episode Statistics Data

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	All Years
Maternal Age											
<20	3%	3%	4%	4%	4%	4%	4%	4%	4%	4%	4%
20-24	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%	0%
25-29	7%	7%	7%	6%	6%	6%	6%	5%	5%	4%	6%
30-34	19%	19%	19%	19%	19%	19%	19%	19%	18%	17%	19%
35-39	25%	25%	26%	27%	27%	27%	27%	28%	28%	28%	27%
>40	30%	29%	28%	28%	27%	27%	28%	28%	29%	29%	28%
Missing	16%	16%	16%	17%	16%	16%	16%	16%	15%	16%	16%
Parity											
0	49%	48%	48%	49%	48%	44%	44%	43%	42%	41%	46%
1	31%	32%	32%	33%	32%	33%	32%	32%	33%	33%	32%
2	11%	12%	12%	11%	12%	13%	14%	14%	14%	15%	13%
3	5%	5%	5%	4%	4%	5%	5%	6%	6%	6%	5%
4+	4%	4%	4%	3%	4%	5%	5%	5%	5%	5%	4%
Clinical Risk											
Higher Risk	41%	43%	44%	45%	46%	48%	50%	52%	53%	55%	47%
Deprivation (IMD Quintiles)											
1	27%	28%	28%	28%	28%	28%	28%	28%	28%	28%	28%
2	21%	21%	21%	22%	22%	22%	22%	22%	22%	22%	22%
3	18%	18%	18%	18%	18%	18%	18%	18%	18%	18%	18%
4	16%	16%	16%	16%	16%	16%	16%	16%	16%	16%	16%
5	16%	16%	16%	16%	15%	15%	15%	15%	15%	14%	15%
Missing	1%	1%	1%	1%	1%	1%	1%	1%	2%	2%	1%

	2004	2005	2006	2007	2008	2009	2010	2011	2012	20
Ethnicity										
British (White)	65%	65%	66%	65%	66%	66%	66%	65%	65%	6
Irish (White)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0

Any other White background	5%	5%	6%	7%	7%	8%	9%	9%	9%	9
White and Black Caribbean	0%	0%	0%	0%	0%	0%	0%	0%	1%	1
White and Black African	0%	0%	0%	0%	0%	0%	0%	0%	0%	0
White and Asian	0%	0%	0%	0%	0%	0%	0%	0%	0%	0
Any other Mixed background	0%	1%	1%	1%	1%	1%	1%	1%	1%	1
Indian	3%	3%	3%	3%	3%	3%	3%	3%	3%	3
Pakistani	4%	4%	4%	4%	4%	4%	4%	4%	4%	4
Bangladeshi	1%	1%	1%	1%	1%	1%	1%	1%	1%	1
Any other Asian background	1%	1%	2%	2%	2%	2%	2%	2%	2%	2
Caribbean	1%	1%	1%	1%	1%	1%	1%	1%	1%	1
African	3%	3%	3%	3%	3%	4%	3%	3%	3%	3
Any other Black background	1%	1%	1%	1%	1%	1%	1%	1%	1%	1
Chinese	0%	0%	1%	1%	1%	1%	1%	1%	1%	1
Not known	3%	2%	2%	2%	1%	1%	1%	1%	1%	1
Not stated	9%	8%	6%	5%	5%	4%	3%	3%	4%	4
Any other ethnic group	2%	2%	2%	3%	3%	3%	3%	3%	3%	3

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	2004	2005	2006	2007	2008	2009	2010	2011	2012
Rural/Urban Indicator									
Urban =>10K - sparse	0%	0%	0%	0%	0%	0%	0%	0%	0%

Town and Fringe - sparse	0%	0%	0%	0%	0%	0%	0%	0%	0%
Village - sparse	0%	0%	0%	0%	0%	0%	0%	0%	0%
Hamlet and Isolated dwelling - sparse	0%	0%	0%	0%	0%	0%	0%	0%	0%
Urban =>10K - less sparse	85%	85%	85%	85%	85%	86%	86%	85%	85%
Town and Fringe - less sparse	7%	7%	7%	7%	7%	7%	7%	7%	7%
Village - less sparse	5%	5%	5%	5%	4%	4%	4%	4%	4%
Rest of UK	0%	0%	0%	0%	0%	0%	0%	0%	0%
Hamlet and Isolated Dwelling - less sparse	2%	2%	2%	2%	2%	2%	2%	2%	2%
Missing	1%	1%	0%	1%	1%	1%	1%	1%	2%
SHA									
South West									
East Midlands									
East of England									
London									
North East									
North West									
Not known									
South East									
West Midlands									
Yorkshire and The Humber									
Total Records	**568950**	**573957**	**593480**	**611593**	**636564**	**633409**	**654060**	**658566**	**668797**

4.1.1.1 Staffing Trends

Table 7 presents some descriptive statistics on the staffing data. Again, there is relatively little variation in the average number of staff per 100 deliveries for each of the staffing groups over the decade, but greater variation within a year across trusts. The minimum and maximum values, whilst plausible, are very far apart and the standard deviation is relatively high. For example in 2013 the range of registered midwives per 100 deliveries is 1.55-16.71. This points to a fair degree of trust level variation in the staff to patient ratio. Recall, however, that this represents the total number of these staff (e.g. registered midwives) in the whole trust and there may be variation across trusts in how these staff are deployed across different maternity services, wards or between obstetrics and gynaecology. It also doesn't capture differences in service configuration e.g. obstetric-led versus midwife-led units. This is one of the major limitations of these aggregate data.

Comparing the data in Table 6 with those reported in Sandall et al. (2014) they are broadly similar despite the dataset being slightly different. Similarly to the HES patient level data described in the previous section, there is a strong correlation between these figures and those reported in Sandall et al. (2014). For instance, the 2010 FTE midwives per 100 deliveries is 3.10 in this study and 3.08 in Sandall et al. (2014).

A descriptive analysis of trends in staffing levels and skill mix variables over the decade to 2013 provides some interesting insights for the following variables:

1. *FTE doctors per 100 maternities*
2. *FTE midwives per 100 maternities*
3. *FTE support workers per 100 maternities*
4. *FTE all staff per 100 maternities*
5. *FTE managers per 100 maternities*
6. *Doctors to midwives ratio*
7. *Support workers to midwives ratio*
8. *Managers to total staff ratio*

To understand the variation between regions, the trust level data were collapsed by year and Strategic Health Authority Strategic Health Authority (SHA), and each index is plotted separately for each one of the ten SHAs as well as for the as well as for the country as a whole. The yellow curve superimposed on each plot is a 3rd degree polynomial which polynomial which smooths out the general trend. Unlike the data reported in Table 7, the following figures describe the figures describe the full sample of staffing data including trusts which were excluded from the statistical analysis (either statistical analysis (either as a result of poor quality coding or due to a lack of matching) and primary care trusts. Primary care trusts. Primary trusts provide a great deal of community based midwifery care (e.g. antenatal care and home

care and home deliveries), which will distort the representation somewhat. Figure 2: FTE Registered Midwives per 100 Maternities 2003-2013

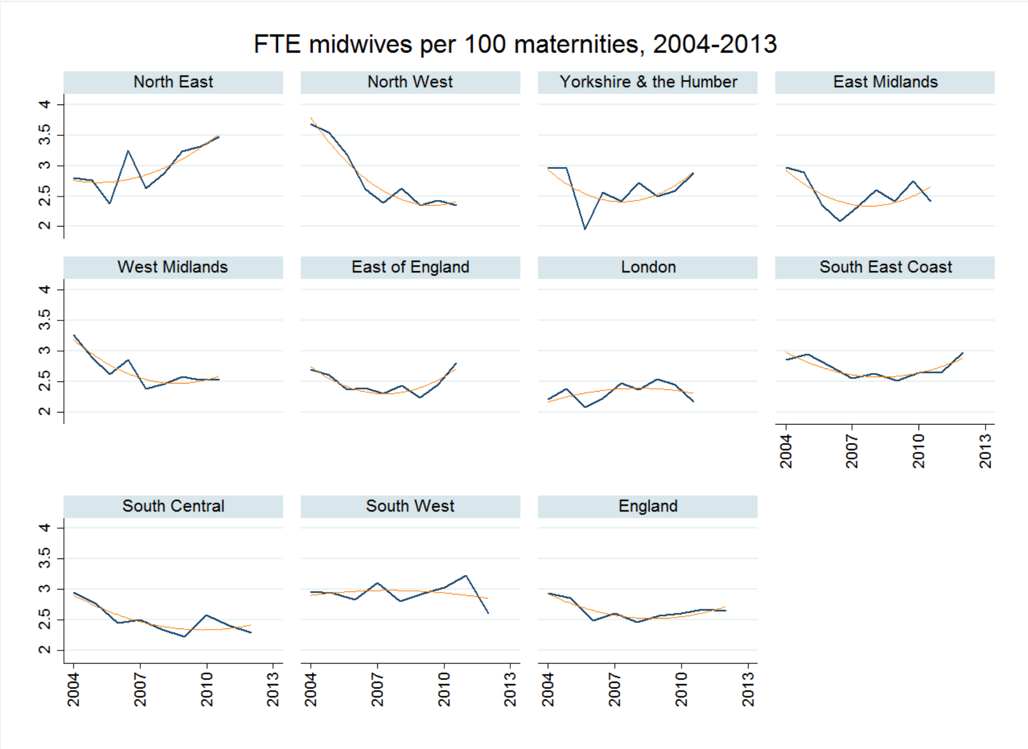


Figure 3: FTE Doctors per 100 maternities 2003-2013

displays the evolution in the doctor to patient ratio captured by the FTE doctors per 100 maternities. It has steadily risen from 0.69 in 2004-05 to 0.76 in 2012-13, yet there is considerable variation at the regional level. Notably, it has decreased, on average, for trusts located in the South West and the South East Central SHAs.

The analysis is repeated for the midwife to patient ratios through the number of FTE registered midwives per 100 midwives per 100 maternities for each SHA and for the whole country. Over the period it has slightly decreased for the decreased for the whole country. A large reduction is observed for trusts located in the North West SHA and only those SHA and only those in the North East SHA display an average increase. A differentiated picture (

Figure 4) emerges for the support work to patient ratio, the number of FTE support workers per 100 maternities, which have been found to be substitutes to midwives, especially in low-risk women. Apart from trusts located in the North West and the East of England, their overall use seems to have increased in the rest of the regions, sharply in some cases, and in the country as a whole as well. This mirrors trends seen in nursing more broadly.

Table 7: Staffing Data Descriptive Statistics – FTE per 100 deliveries

	Midwives			Support Workers			Doctors			Consultants		
Year	**Mean**	**S.D.**	**Range**	**Mean**	**S.D.**	**Range**	**Mean**	**S.D.**	**Range**	**Mean**	**S.D.**	**Range**
2004	3.13	0.72	1.80 - 7.80	0.09	0.16	0.00 - 0.84	0.53	0.21	0.11 - 1.95	0.23	0.09	0.12 - 0.98
2005	3.20	1.08	0.91 - 9.62	0.10	0.17	0.00 - 1.10	0.57	0.20	0.06 - 1.69	0.24	0.11	0.11 - 1.04
2006	2.94	0.82	0.98 - 7.43	0.10	0.19	0.00 - 1.23	0.51	0.15	0.05 - 0.94	0.23	0.10	0.08 - 1.05
2007	2.97	0.75	1.38 - 7.41	0.10	0.18	0.00 - 0.98	0.52	0.19	0.21 - 1.87	0.23	0.10	0.08 - 1.03
2008	3.09	1.75	1.50 - 21.64	0.11	0.21	0.00 - 1.00	0.54	0.21	0.18 - 1.94	0.27	0.36	0.08 - 4.27
2009	3.09	0.90	1.07 - 9.22	0.13	0.23	0.00 - 1.31	0.57	0.19	0.07 - 1.79	0.26	0.17	0.08 - 1.77
2010	3.10	0.92	1.15 - 9.69	0.13	0.22	0.00 - 0.98	0.57	0.22	0.05 - 1.92	0.28	0.16	0.07 - 1.60
2011	3.29	1.70	1.33 - 18.71	0.14	0.22	0.00 - 0.94	0.58	0.30	0.03 - 3.18	0.29	0.22	0.06 - 1.91
2012	3.34	1.65	1.55 - 16.71	0.16	0.27	0.00 - 1.99	0.59	0.31	0.13 - 3.02	0.30	0.20	0.06 - 1.63
All Years	3.13	1.14	0.91 - 21.64	0.12	0.21	0.00 - 1.99	0.55	0.22	0.03 - 3.18	0.26	0.17	0.06 - 4.27

Figure 2: FTE Registered Midwives per 100 Maternities 2003-2013

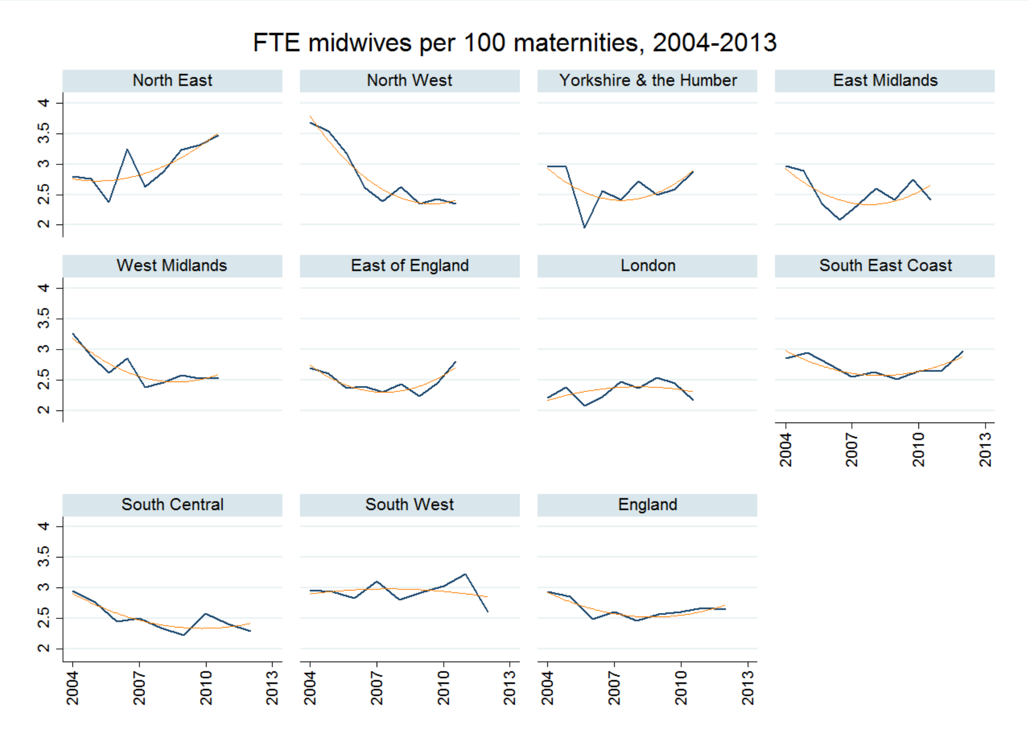


Figure 3: FTE Doctors per 100 maternities 2003-2013

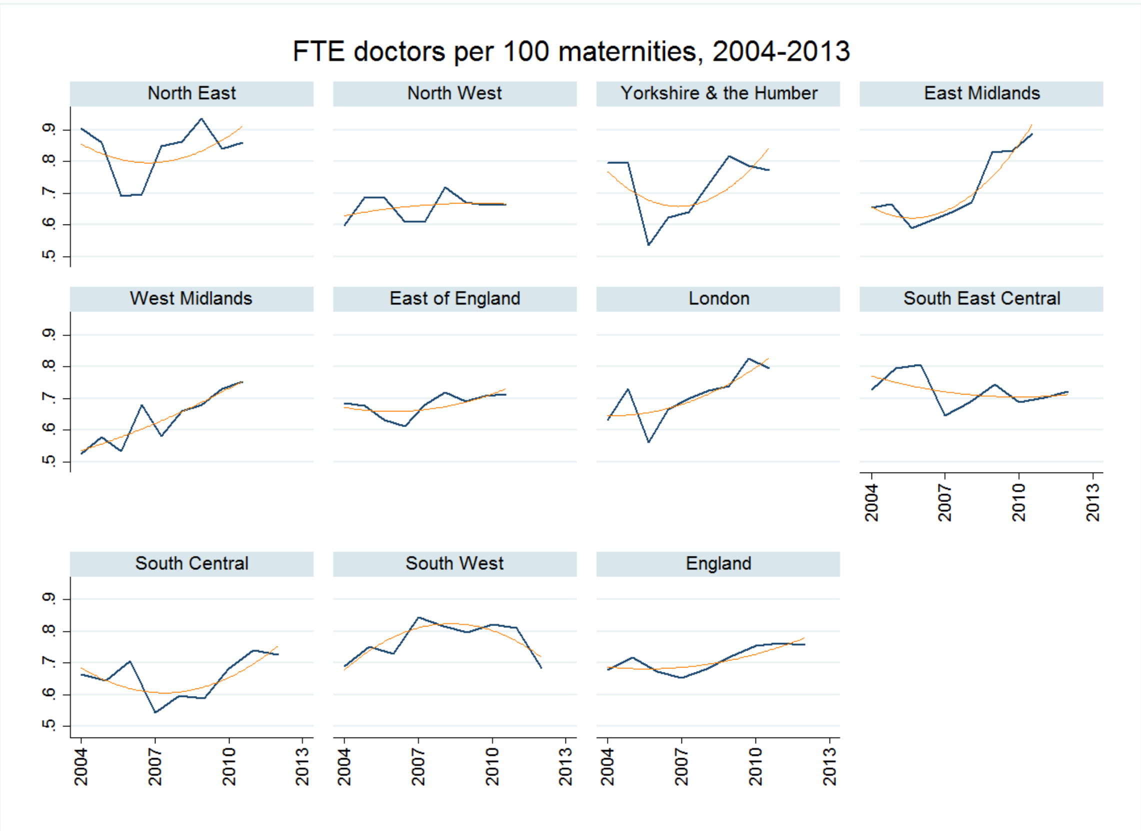
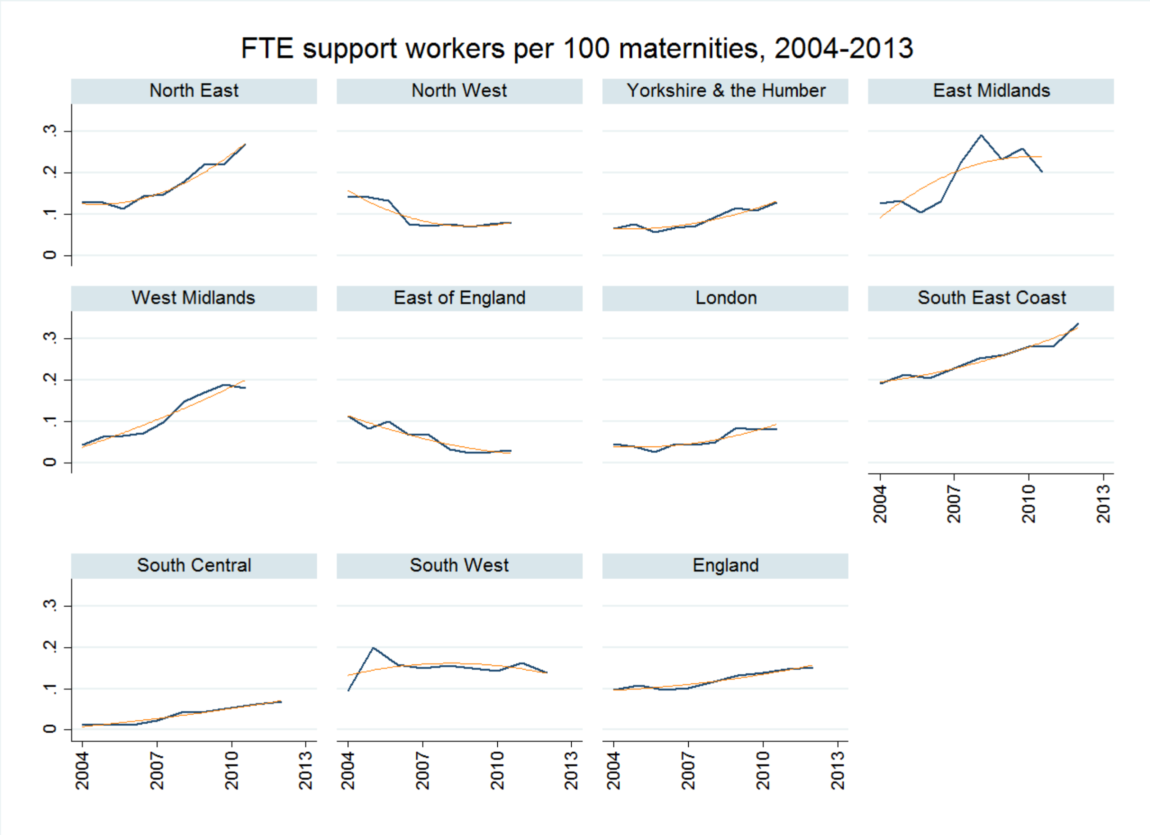


Figure 4: FTE Support Workers per 100 maternities 2003-2013



Aggregating all of the staff groups together, the total number of FTE staff (medical plus clinical) per 100 maternities seems to have followed a rather negative trend during the period under examination, with the exceptions of the North East and, to a lesser extent, the East Midlands SHAs. This is depicted in Figure 5. This trend is most pronounced in the North West where there was a very strong downward trend in the registered midwife to patient ratio.

The next three figures plot the trend in skill mix over the past decade. Figure 6 displays the doctors to midwives ratio, which has increased for the total country on average. Considering each SHA separately, it has either increased or remained relatively stable, except for trusts belonging to the North East SHA for increase between 2007 and 2009). The ratio of support workers to midwives, shown in

Figure 7, has also increased as the substitution of these two labour inputs is generally considered to be quite cost effective. Apart from the North West and East of England SHAs, it seems to have been steadily increasing over the period 2004-2013.

Figure 5: Total Staff per 100 Maternities 2003-2013

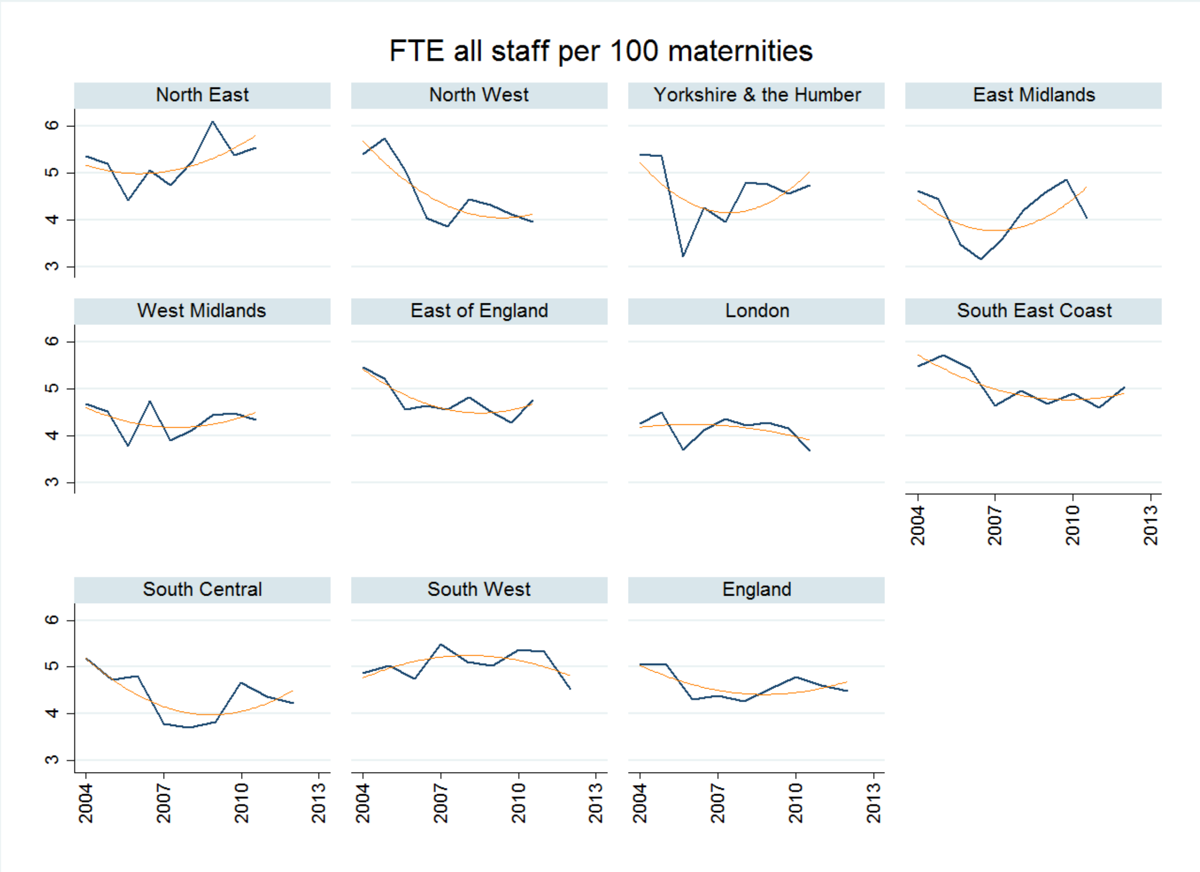


Figure 6: Doctors to Midwives Ratio 2003-2013

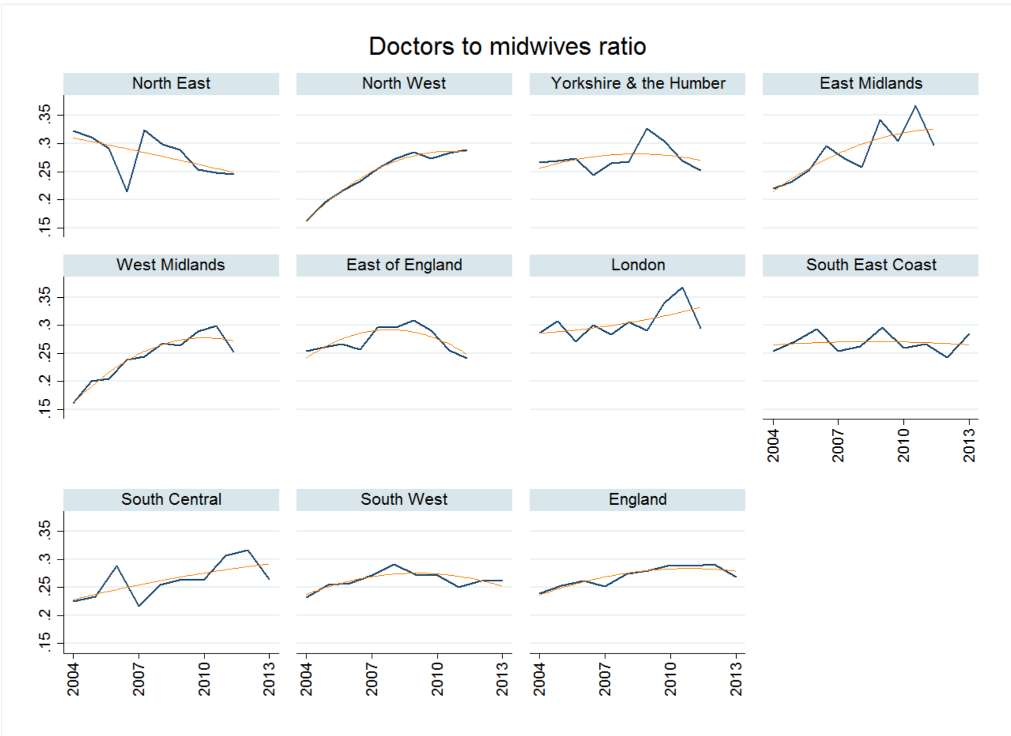
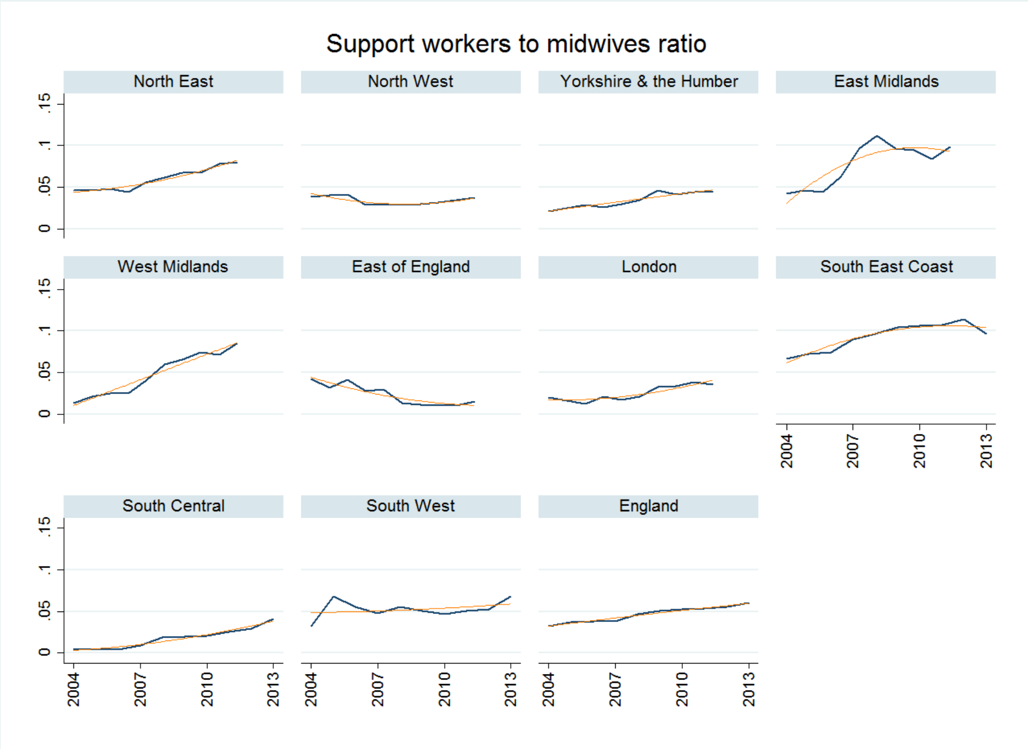
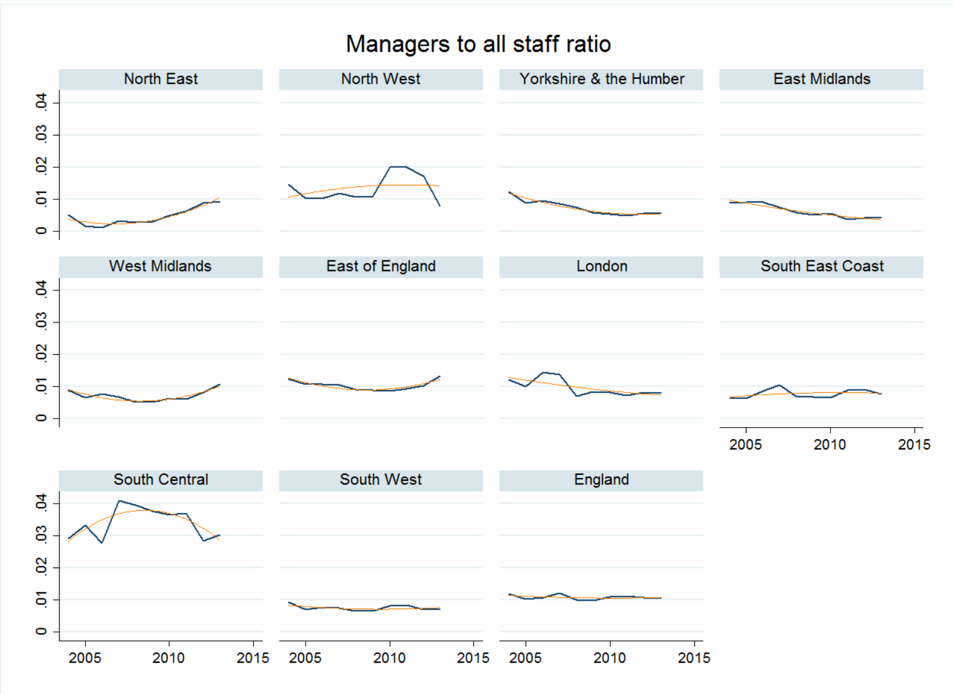


Figure 7: Support Workers to Midwives Ratio 2003-2013



Finally, the trend in the ratio of managers to all staff is presented in Figure 8. Overall it has remained rather stable over the time with small increases and decreases in most SHAs. Only in the North West and the South Central is there a considerable variation over time.

Figure 8: Managers to All Staff Ratio 2003-2013

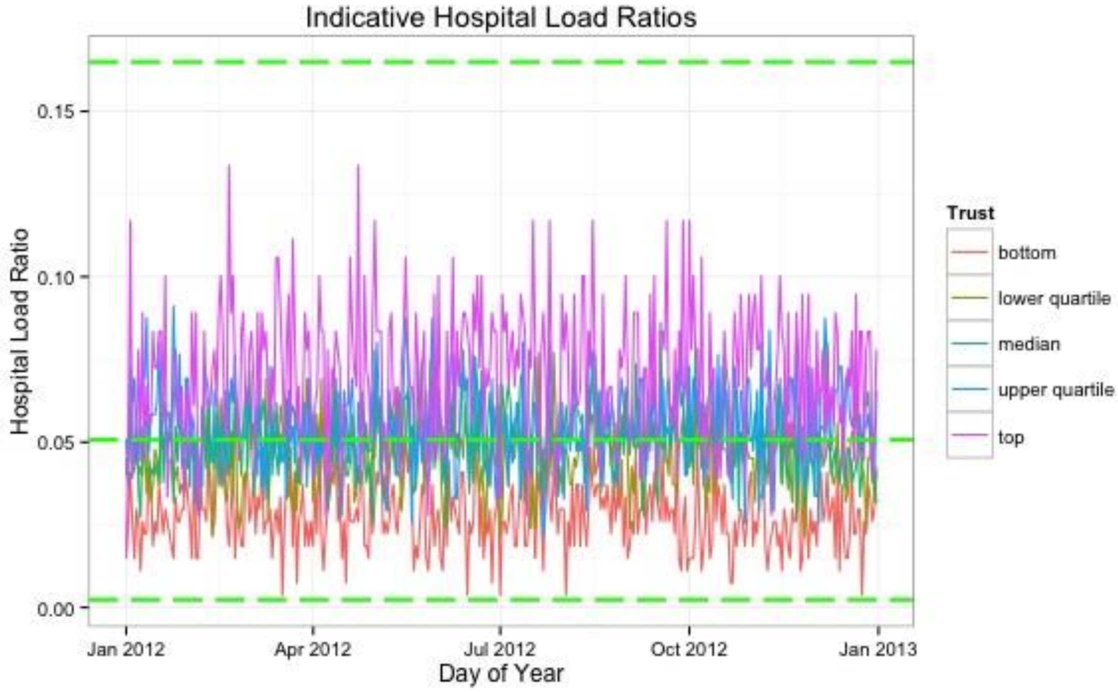


Overall there has been some variation in staffing levels and skill mix both over time and in regional variation. The time trend may provide some useful variation in staffing levels to identify a relationship between staffing and outcomes in the regression models. Whilst these descriptive figures do not control for clinical risk (case-mix) they do control for demand (the number of deliveries), which makes the regional variations of interest for future research. Whilst the SHA is included in the statistical models no substantive interest is paid to the regional trends identified in this section.

The Hospital Load Ratio variable is an interesting addition to the dataset. The staffing data described above are annual census data so provide only one observation per trust per year. As a result there is little variation and few observations to drive the precision of the models. By dividing the Hospital Load – the number of deliveries each day – by the total number of staff the Hospital Load Ratio provides some temporal and intra-trust variation in staffing 'intensity.' For example, if a hospital has 200 staff on the payroll and on a particular day there are 12 deliveries then this variable would be 0.06. If the next day there are only 6 deliveries this variable now falls to 0.03. Therefore an increasing Hospital Load Ratio may be considered an undesirable event.

Displaying the variable is difficult as there are over 0.5 million observations. However to illustrate how the variable captures the variation in staff-patient ratios consider Figure 9. This plots 5 trusts data from 2013. All 157 trusts in the dataset were ordered by their 2013 average Hospital Load Ratio and the trusts at each of the quartiles (0, 25, 50, 75 and 100) were plotted day by day for the whole of 2013. Superimposed onto the plot are the entire sample's minimum, maximum and mean values as dotted horizontal lines.

Figure 9: Hospital Load Ratio Variation 2013



4.1.2 Statistical (Regression) Results

Multilevel models were fitted to the data as described in Section 3.3.2 in detail. Whilst the models took a relatively long time to be estimated due to their complexity and the choice of an optimization algorithm that favoured precision over speed, the fitted models had good convergence properties. The following tables present a simplified set of results for the statistical analysis, presenting the findings of relevance for the economic evaluation. Full results are reserved to the appendix for interested readers.

Logistic regression models to outcomes using the logit function, that is the log of the odds of the outcome. It is more common to exponeniate the regression (beta) coefficients to produce odds ratios. For categorical variables such as clinical risk, the interpretation is easy. The odds ratio is the difference in the odds of the outcomes between the categories of the variable. For instance, if the odds ratio for higher risk for maternal mortality was 2 then mothers in the higher risk category are twice as likely to die than those in the lower risk category. Odds ratios (OR) also provide a way of categorising the strength of association between multiple explanatory variables: strong (OR > 3), moderate (OR = 1.6-3.0), or weak (OR=1.1-1.5). Attention is therefore focused on the odds ratio.

The statistical significance of the variables can be determined in two ways. Firstly, asterisks indicate whether the estimated p-value of each coefficient is less than 10 per cent (*), 5 per cent (**) or 1 per cent (***). The standard errors, t-statistics and actual p-values are reported in full in the appendix. Caution should be used when relying solely on the p-values as the standard errors are unreliable as discussed in the methods section. Secondly, the results of the Likelihood Ratio tests are reported as Chi-Squared tests at the foot of each regression model. This tests the statistical significance of the improvement in the model fit of adding groups of coefficients to the model.

Very few of the explanatory variables were statistically significant in the maternal mortality model, although the AUC was quite high (0.76) indicating that the model was able to discriminate cases. Clinical risk has the largest effect, with mothers in the higher risk category 4.25 times more likely to die than those in the lower risk category. It should be stressed that this is from a very low unconditional probability of death of 0.002% on average. Maternal age was also an important predictor of maternal death, with mothers aged 25-35 approximately half as likely to die than those aged over 40. For women under 25 they were less than a third as likely to die than those aged over 40. Some of the ethnicity categories were statistically significant predictors with large odds ratios. However as they are marginally statistically significant despite their large regression coefficients and given the approximate nature of the standard errors in the model, too much confidence should not be placed in this finding unless strongly supported by theory.

The healthy mother and bodily integrity outcomes have very similar regression results. This is not surprising as bodily integrity is a component indicator of healthy mother. There is a clear time dimension to the results, with each year being strongly significantly related to the outcome. When compared to 2004 (the base year) each year since has a lower rate of healthy mothers and bodily integrity. This was also clear in the descriptive statistics in Section 4.1.1. For instance, a mother giving birth in 2012 is more than 30% less likely to be “healthy” or have “bodily integrity” than those giving birth in 2004.

Patient level factors are clearly very important, with age, ethnicity and parity being associated with both outcomes and deprivation also being associated with bodily integrity. In both cases, the largest odds ratio is for the clinical risk variable. A mother classed as “higher risk” is half as likely to deliver with bodily integrity than a mother classed as “lower risk”.

In terms of the trust level variables, larger trusts have lower healthy mother rates but this effect is weak. The association between support worker staffing levels and both outcomes is marginal both in terms of effect size and statistical significance. There is a stronger relationship between medical staff (both junior doctors and consultants) and both outcomes. This is to be expected but the relationship could be reverse causal. Trusts that perform more planned caesareans for example will require more consultants, ceteris paribus, but will by definition have lower healthy mother and bodily integrity rates due to the procedure. Midwifery levels are positively associated with healthy mother and bodily integrity rates but these relationships are weak (OR: 1.019 and 1.01). The statistical significance of the findings likely comes from the very large dataset and the associated improvement in precision.

All of these findings are congruent with those of the extant literature, especially with Sandall et al. (2014); the difference in the statistical significance of the staffing variables being explained by the larger sample. The most interesting and novel finding is with respect to the Hospital Load Ratio. This variable was included to proxy the effect of shift-by-shift variation in staff to patient ratios. As no staffing data are available at this level or frequency, the variation in "demand" was exploited under the assumption of constant staffing levels to create variation in the staff to patient ratios. Whilst interpretation of the variable is impossible, days in which there are higher patient loads have much worse outcomes. The odds ratio is strong and statistically significant for healthy mother.

This may be the subtle but important difference between staffing levels and skill mix which may be a fruitful avenue for future research. For instance, a low ratio of staff to patients on a shift-by-shift basis, caused either by staff shortage or excess patients, may result in poorer outcomes for mothers. This may lead to complications such as, inter alia, maternal sepsis or other problems that result in longer lengths of stay or readmission. However, skill mix which wasn't captured in this pseudo shift level variable may be the critical factor in outcomes relating to interventionist procedures such as caesarean sections or episiotomy. At present this must be left as a hypothesis for further research but it is a possible explanation for the finding.

Confusingly there is an inverse relationship with both bodily integrity (a subset of healthy mother) and healthy baby outcomes. However, the statistical significance is marginal and these findings may be the result of underestimated standard errors as discussed in the methodology section. The odds ratios are also relatively weak (healthy baby = 1.32; bodily integrity = 1.16). Yet at present the findings cannot be discounted. For these two outcomes therefore a worsening Hospital Load Ratio would improve outcomes.

Neither baby outcomes were significantly associated with midwifery staffing levels. However higher levels of support workers (ceteris paribus) was associated with lower healthy baby rates whilst higher consultant and doctor staffing levels were associated with higher healthy baby rates. As per the maternal outcomes, there was a clear association between maternal age, clinical risk, ethnicity and parity and both baby outcomes. Yet again, clinical risk had the largest odds ratios, with a mother classified as higher risk being 32 times more likely to have a stillborn baby than lower risk mothers. Unlike the other regression models, area deprivation and the geographic variables (SHA and rural/urban classification) were statistically significant predictors of the baby outcomes. Compared to the South West for example, each other SHA was 30-50% more likely to have a healthy baby.

In all cases the AUC statistics indicate that the models had good discriminatory properties and correctly identify outcomes most of the time. With the exception of the healthy mother indicator (AUC = 0.67), the AUC were high (>0.7) and for healthy baby it was very high (AUC = 0.81). In every model the variation in the outcome attributed to the trust is less than 2% with 98-99% of the variance in the outcomes due to mothers' characteristics. Therefore as staffing is determine at the trust level it is unlikely to have a large effect on the outcomes.

Table 8: Simplified Statistical Findings

		Healthy Mother		Maternal Mortality		Healthy Baby		Stillbirth		Bodily Integrity	
		Odds Ratio		Odds Ratio		Odds Ratio		Odds Ratio		Odds Ratio	
Intercept		0.829	***	0.00	***	18.30	***	0.00	***	2.08	***
Maternal Age	**Missing**	1.201	***	0.00		1.15		0.69	***	1.35	***
	<20	0.621	***	0.31	*	0.96	***	0.95		2.81	***
	20-24	0.607	***	0.28	***	1.06	***	0.78	***	2.14	***
	25-29	0.654	***	0.42	***	1.14	***	0.72	***	1.54	***
	30-34	0.718	***	0.47	***	1.15	***	0.70	***	1.20	***
	35-39	0.815	***	0.65		1.10	***	0.80	***	1.06	***
	>40	0.000		0.00		0.00		0.00		0.00	
Higher Risk		2.980	***	4.25	***	0.18	***	32.21	***	0.50	***
Ethnicity	**British (White)**	0.878	***	1.35		0.92	***	0.87	***	1.12	***
	Irish (White)	0.997		0.00		0.99		1.16	*	0.90	***
	Any other White background	0.926	***	0.41		1.02	*	0.88	***	1.05	***
	White and Black Caribbean	1.006		0.00		0.79	***	1.27	***	1.65	***
	White and Black African	1.265	***	0.00		1.03		1.11		1.13	***
	White and Asian	0.951	*	0.00		0.86	***	1.02		1.01	
	Any other Mixed background	0.984		3.37		0.94	*	0.76	***	1.15	***
	Indian	1.098	***	2.21		0.77	***	1.11	*	0.65	***
	Pakistani	1.094	***	1.49		0.87	***	1.38	***	0.95	***
	Bangladeshi	1.087	***	2.94		0.82	***	1.05		0.88	***
	Any other Asian background	1.070	***	4.49	*	0.90	***	1.17	***	0.76	***
	Caribbean	1.197	***	3.30		0.75	***	1.36	***	1.82	***
	African	1.428	***	3.02	*	0.97	*	1.37	***	1.01	
	Any other Black background	1.309	***	0.77		0.85	***	1.33	***	1.24	***
	Chinese	0.948	***	3.09		1.27	***	0.76	***	0.66	***
	Not known	0.846	***	3.87	*	0.97		0.66	***	1.08	***

	Not stated	0.876	***	4.53	*	0.98		0.78	***	1.07	***
	Any other ethnic group	0.000		0.00		0.00		0.00		0.00	
Parity	0	1.863	***	1.38		0.80	***	1.63	***	0.09	***
	1	1.031	***	0.72		1.29	***	0.86	***	0.28	***
	2	0.976	***	1.23		1.25	***	0.85	***	0.52	***
	3	0.963	***	0.90		1.13	***	0.93	*	0.74	***
	4>	0.000		0.00		0.00		0.00		0.00	
IMD	Missing	0.983		0.00		0.65	***	1.65	***	1.30	***
	1	0.995		1.41		0.78	***	1.34	***	1.58	***
	2	0.994	*	1.31		0.84	***	1.24	***	1.36	***
	3	0.996		0.92		0.89	***	1.18	***	1.20	***
	4	0.997		0.84		0.94	***	1.07	***	1.10	***
	5	0.000		0.00		0.00		0.00		0.00	
Rural/Urban	Missing	1.117	***	2009613.00				1.28	*		
	Urban =>10K - sparse	1.022		1.99		0.85	***	0.94		1.04	
	Town and Fringe - sparse	1.199	***	0.00		0.93	*	1.03		1.06	***
	Village - sparse	1.117	***	1.00		1.00		1.08		1.04	*
	Hamlet and Isolated dwelling - sparse	1.157	***	0.00		1.02		1.17		0.95	*
	Urban =>10K - less sparse	0.981	***	0.47	*	0.97	*	0.97		1.03	***
	Town and Fringe - less sparse	0.985	*	0.51		0.96	***	1.00		1.04	***
	Village - less sparse	0.989		0.34		1.01		0.97		1.02	*
	Rest of UK	1.145	*	0.63		0.62	***	1.39		1.14	*
	Hamlet and Isolated Dwelling - less sparse	0.000		0.00		0.00	***	0.00		0.00	***
SHA	East Midlands	1.020		0.81		1.49	***	0.96		1.15	
	East of Englad	0.933		0.70		1.28	***	1.06		0.89	
	London	1.102	*	0.98		1.29	***	1.07		0.79	***
	North East	1.091		1.32		1.33	***	1.04		1.12	
	North West	1.222	***	0.73		1.34	***	0.99		0.90	
	South East	1.032		0.83		1.34	***	1.01		0.86	*

	West Midlands	1.071		0.88		1.33	***	0.92		0.91	
	Yorkshire & Humberside	1.086		0.47	*	1.24	***	1.09		1.08	
	South West	0.000	***	0.00		0.00		0.00		0.00	***
Maternities (thousands)		0.988	***	1.03		1.00		1.01		1.00	***
Staffing	**Midwives**	1.019	***	1.17		1.00		1.01		1.01	***
	Support Workers	0.983	*	0.83		0.95	***	1.03		0.91	***
	Doctors	0.961	***	0.84		0.97		0.92		0.99	
	Consultants	0.878	***	0.26		1.10	*	0.94		0.84	***
Hospital Load Ratio		0.485	***	0.07		1.32	*	0.68		1.16	*
Year	**2004**	0.000		0.00		0.00		0.00		0.00	***
	2005	0.945	***	0.75		1.05	***	0.95	*	0.95	***
	2006	0.887	***	0.61	*	1.06	***	0.94	*	0.92	***
	2007	0.801	***	0.52	**	1.10	***	0.88	***	0.91	***
	2008	0.777	***	0.69		1.14	***	0.84	***	0.86	***
	2009	0.776	***	0.64		1.14	***	0.84	***	0.78	***
	2010	0.726	***	0.63		1.19	***	0.82	***	0.74	***
	2011	0.680	***	0.77		1.24	***	0.81	***	0.71	***
	2012	0.673	***	0.32	***	1.28	***	0.72	***	0.68	***
N (trusts)		157		157		147		156		154	
AUC		1		1		1		1		1	
Random	**Null model**	0	0	0	0	0	0	0	0	0	0
variance	**plus Year**	0	0	0	0	0	0	0	0	0	0
	plus Mother's covariates	0	0	0	0	0	0	0	0	0	0
	plus Socioeconomic covariates	0	0	0	0	0	0	0	0	0	0
	plus Trust covariates	0	0	0	0	0	0	0	0	0	0
	plus Staffing covariates	0	0	0	0	0	0	0	0	0	0
Chi-squared	**Null model**	-	-	-	-	-	-	-	-	-	-
tests	**plus Year**	10804	***	14	.	56	***	14	.	13269	***

plus Mother's covariates	420220	***	109	***	224406	***	35515	***	608798	***
plus Socioeconomic covariates	13975	***	93	***	25174	***	5438	***	74671	***
plus Trust covariates	553704	***	7	1	32	***	11	0	67	***
plus Staffing covariates	21009	***	3	1	6979	***	630	***	11507	***

4.2 Econometric Analysis

The following tables report the results from the estimation of the production function for maternity services in the English NHS. The total number of deliveries within a hospital trust for a given year was used as the output measure and a generalized linear production function was adopted following Sandall et al. (2014). However, instead of using a single cross-section, a panel dataset at the trust level was created which can control for year/time effects as well as unobserved heterogeneity at the trust level. The panel data structure may alleviate some sources of endogeneity. The main advantage of adopting the generalized linear production function is that it allowed us to examine the effects of both the staffing levels and the skill mix through the use of the interaction terms. Given its flexible form, it does not force all staff groups to be substitutes but it allows us to examine whether some labour inputs are complements. Moreover, it also allows for some inputs to have zero values.

The presentation of our results begins with Table 9 which reports some basic Ordinary Least Squares estimates of the specified production function. The vector of explanatory variables is gradually augmented with different labour inputs (i.e. the staffing levels), their cross-products (i.e. the skill-mix), year and Strategic Health Authority (SHA) fixed effects in order to assess the sensitivity of the results to different model specifications. These fixed effects help in controlling for factors which are common across trusts for each year and for each SHA region. Finally, a lagged dependent variable is also inserted into the model in order to account for the past behaviour of hospital trusts with respect to the total number of maternities. Even if not of primarily interest and not being easily interpreted within this context, controlling for dynamics can help into removing some bias from the estimated coefficients of the rest dependent variables. In order to produce more precise estimates, the standard errors have been corrected for clustering at the trust level in order to account for any unobserved factors which cannot be attributed to the explanatory variables.

Despite the fact that all the models appear to have a high adjusted R-squared, the estimated regression coefficients are rather unhelpful in examining the impact of staffing levels and skill mix on the total output measure. Instead, the elasticities of substitution and complementarity reported in Table 10 can be more informative. The marginal productivities are calculated using the estimated regression coefficients and the sample means from the estimation sample and they inform us about the number of additional deliveries that would be expected, on average, if the FTE of a particular staffing group was marginally increased, *ceteris paribus*. More specifically, the following formula was used in order to obtain the estimated marginal productivities for each labour type:

$$Marginal\ productivity_i = a_i + \frac{1}{2}\sum_{j=2}^{K} a_{ij}\sqrt{\frac{X_j}{X_i}}$$

Table 9: Baseline parameter results for a generalized linear production function (Ordinary Least Squares estimates). The total number of deliveries is used as the output measure

Variable name	*[1]*	*[2]*	*[3]*	*[4]*	*[5]*	*[6]*	*[7]*	*[8]*
Number of deliveries$_{t-1}$	-	-	-	-	-	-	-	.550[a] (.073)
Registered Midwife	32.024[a] (1.059)	23.490[a] (1.432)	22.614[a] (1.817)	22.562[a] (1.809)	36.336[a] (10.884)	36.842[a] (10.616)	39.592[a] (8.378)	22.707[a] (6.762)
Doctor	-	47.933[a] (8.034)	44.326[a] (8.138)	44.636[a] (7.947)	128.650[b] (51.480)	124.46[b] (51.972)	92.266[c] (51.534)	37.917 (25.083)
Consultant	-	-	19.364 (17.715)	18.266 (18.168)	140.200 (121.01)	152.671 (107.35)	149.755[c] (83.011)	80.578[c] (43.444)
Support worker	-	-	-	1.976 (5.090)	13.128 (13.225)	12.775 (13.283)	5.618 (14.564)	3.313 (7.451)
Reg. midwife$^{1/2}$ X Sup. worker$^{1/2}$	-	-	-	-	-34.804 (23.637)	-34.194 (23.939)	-44.325[b] (22.573)	-24.200[b] (12.068)
Reg. midwife$^{1/2}$ X Consultant$^{1/2}$	-	-	-	-	-25.587 (69.446)	-31.314 (64.985)	-46.190 (54.328)	-37.901 (30.249)
Reg. midwife$^{1/2}$ X Doctor$^{1/2}$	-	-	-	-	-38.607 (37.081)	-37.507 (36.177)	-28.227 (31.241)	-20.305 (17.168)
Sup. worker$^{1/2}$ X Consultant$^{1/2}$	-	-	-	-	54.702 (80.206)	50.345 (80.160)	86.374 (73.906)	27.848 (43.353)
Sup. worker$^{1/2}$ X Doctor$^{1/2}$	-	-	-	-	33.271 (46.479)	35.712 (46.397)	47.116 (27.229)	37.857 (26.383)
Consultant$^{1/2}$ X Doctor$^{1/2}$	-	-	-	-	-124.621 (110.02)	-119.937 (109.43)	-95.861 (93.309)	-17.163 (59.379)
Year fixed effects	*No*	*No*	*No*	*No*	*No*	*Yes*	*Yes*	*Yes*
SHA fixed effects	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*Yes*
Adjusted R-squared	.784	.804	.804	.804	.806	.811	.828	.865
Observations	1260	1231	1231	1231	1231	1231	1229	1060

Source: ONS Birth registration Records (2004/05 – 2012/13); Maternity Workforce Census (2004-2014).

Notes: Standard errors are corrected for clustering by trust. [a], [b] and [c] denote statistical significance at the 1%, 5% and 10% level, respectively.

These marginal products are reported in Table 10 based on the columns 7 and 8 of Table 9. The upper panel of Table 10 reports the marginal productivities based on the model that does not account for dynamics (column 7) while in the lower part we have calculated the marginal productivities of each labour type based on the model which controls for inertia in the delivery of total maternities at the trust level. The marginal productivities are all positive, indicating that increasing any staffing level would increase the total number of deliveries in a given provider. The marginal productivities are highest for the doctors (38 additional deliveries), followed by consultants (28 additional deliveries), registered midwives (23 additional deliveries) and support workers (6 additional deliveries). Repeating the same exercise based on the model which incorporates dynamics, seems to remove a significant degree of bias, however, the same pattern remains. A marginal increase in the FTE of doctors would result in 17 additional deliveries, while the marginal products for consultants, registered midwives and support workers are 12, 10 and 3, respectively.

Table 10 also reports the Hicks elasticities of complementarity between the different staffing groups in the production of deliveries within a given hospital trust each year. A positive elasticity indicates that the two labour inputs are complements (i.e. they need to be used together) while a negative elasticity indicates that the two staffing groups are substitutes (i.e. one can be used in the place of another). The elasticities were obtained using the following formula (again using the estimated regression coefficients and the sample means from the estimation sample):

$$Hicks\ elasticity_{ij} = \frac{a_{ij}}{4\sqrt{X_i}\sqrt{X_j}}$$

Regardless from the incorporation of any dynamics, the results indicate that doctors and consultants are quantity-complements with support workers, while all other combination of labour inputs are quantity-substitutes. The elasticity of substitution between registered midwives and support workers is the highest one.

Table 10 Estimates of marginal productivities and Hicks elasticities of complementarity

Panel A: Based on the results of Column 7 of Table 9					
		Reg. midwives	Support workers	Consultants	Doctors
Marginal productivity		22.582	5.798	28.091	37.883
Hicks elasticities	Support workers	-14.146	-	-	-
	Consultants	-2.176	78.051	-	-
	Doctors	-0.664	21.251	-6.382	-
Panel B: Based on the results of Column 8 of Table 9					
		Reg. midwives	Support workers	Consultants	Doctors
Marginal productivity		10.487	2.807	11.624	17.405
Hicks elasticities	Support workers	-33.876	-	-	-
	Consultants	-9.278	123.400	-	-
	Doctors	-2.240	75.400	-5.978	-

However, a major problem with the OLS estimates is that they do not account for any unobserved factors at the trust level. Not controlling for trust-level unobserved heterogeneity may lead to the estimation of biased estimates. Given that the matching of different data sources enabled us to construct a trust-level panel, we adopted a fixed effects estimator which can tackle this important issue. Table 11 and Table 12 report the results for the estimated parameters of the generalized linear production function as well as the marginal productivities alongside the elasticities of complementarity, respectively. The marginal productivities are once again all positive. However, consultants now appear to have the highest marginal productivity (32.4 additional deliveries based on the model not incorporating dynamics), followed by doctors (12.8 additional deliveries), registered midwives (6 additional deliveries) and support workers (3.3 additional deliveries). The results have the same pattern, however their magnitude is lower, when the marginal product of each labour input is calculated based on the model incorporating dynamics (lower panel of Table 5). Once again, we find that registered midwives are quantity-substitutes with all the other three labour types. Still, the elasticity of substitution is higher in the case of registered midwives and support workers. Yet, based on the regression coefficients obtained from the fixed effects model, we find that doctors and support workers are quantity-substitutes while there is evidence that doctors and consultants can be used together in the production of deliveries in the English NHS.

Table 11: Baseline parameter results for a generalized linear production function (Fixed Effects estimates). The total number of deliveries is used as the output measure

Variable name	*[1]*	*[2]*	*[3]*	*[4]*	*[5]*	*[6]*	*[7]*	*[8]*
Number of deliveries$_{t-1}$	-	-	-	-	-	-	-	.0229
								(.063)
Registered Midwife	10.117[a]	8.735[a]	6.771[b]	6.662[b]	25.016[a]	25.520[c]	25.506[c]	23.077[a]
	(2.512)	(2.510)	(2.826)	(2.879)	(14.206)	(14.437)	(14.445)	(15.574)
Doctor	-	22.835[a]	19.007[a]	18.701[a]	54.364[a]	39.322[c]	39.459[c]	35.211[c]
		(5.346)	(5.197)	(5.168)	(20.641)	(20.615)	(20.705)	(23.821)
Consultant	-	-	43.959[b]	42.805[b]	40.875	4.675	4.479	-10.111
			(18.298)	(18.250)	(118.93)	(134.62)	(134.69)	(155.80)
Support worker	-	-	-	3.912	3.501	0.437	0.433	-2.719
				(5.001)	(10.199)	(10.078)	(10.077)	(13.448)
Reg. midwife$^{1/2}$ X Sup. worker$^{1/2}$	-	-	-	-	-19.056	-15.641	-15.658	-14.404
					(16.215)	(15.357)	(15.360)	(18.784)
Reg. midwife$^{1/2}$ X Consultant$^{1/2}$	-	-	-	-	-43.532	-49.509	-49.342	-41.206
					(70.633)	(76.272)	(76.357)	(87.516)
Reg. midwife$^{1/2}$ X Doctor$^{1/2}$	-	-	-	-	-51.528[b]	-51.507[c]	-51.776[c]	-51.756
					(26.043)	(29.374)	(29.378)	(32.867)
Sup. worker$^{1/2}$ X Consultant$^{1/2}$	-	-	-	-	86.123	82.984	83.054	63.461
					(55.858)	(54.855)	(54.872)	(63.938)
Sup. worker$^{1/2}$ X Doctor$^{1/2}$	-	-	-	-	-11.760	-15.980	-15.982	-2.200
					(24.149)	(24.213)	(24.210)	(29.068)
Consultant$^{1/2}$ X Doctor$^{1/2}$	-	-	-	-	82.253	114.739	114.543	115.263
					(90.206)	(91.720)	(91.802)	(101.92)
Year fixed effects	*No*	*No*	*No*	*No*	*No*	*Yes*	*Yes*	*Yes*
SHA fixed effects	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*Yes*
Adjusted R-squared	.060	.083	.093	.093	.100	.154	.153	.091
Observations	1260	1231	1231	1231	1231	1231	1229	1061

Source: ONS Birth registration Records (2004/05 – 2012/13); Maternity Workforce Census (2004-2014).

Notes: Standard errors are corrected for clustering by trust. [a], [b] and [c] denote statistical significance at the 1%, 5% and 10% level, respectively.

Table 12: Estimates of marginal productivities and Hicks elasticities of complementarity

Panel A: Based on the results of Column 7 of Table 11					
		Reg. midwives	Support workers	Consultants	Doctors
Marginal productivity		5.992	3.343	32.367	12.789
Hicks elasticities	Support workers	-32.669	-	-	-
	Consultants	-7.603	112.988	-	-
	Doctors	-13.591	-37.041	19.606	-
Panel B: Based on the results of Column 8 of Table 11					
		Reg. midwives	Support workers	Consultants	Doctors
Marginal productivity		4.470	4.404	26.185	12.454
Hicks elasticities	Support workers	-30.993	-	-	-
	Consultants	-9.907	86.503	-	-
	Doctors	-17.653	-4.254	24.906	-

4.3 Cost-Effectiveness Analysis

4.3.1 Economic Model Parameters

The results of the economic evidence review 3 (Hayre, 2014) identified two economic studies of midwifery staffing and outcomes. To reiterate, only one study reported findings for delivery with bodily integrity but the study was rated as having potentially serious weakness. This study therefore used a larger dataset and attempted to fix the limitations identified in Hayre (2014), namely: endogeneity and the staffing variables. The results of this analysis can be summarised as:

- The results of this analysis are broadly similar to those from Sandall et al. (2014). However, the inclusion of more years of data increased the precision of the regression estimates. The result was that an additional outcome indicator was shown to be associated with staffing levels – healthy mother – although the effect size was small. This was also true of bodily integrity. In both cases the odds ratios were barely over 1 but with incredibly small standard errors.
- Midwifery staffing levels were shown to affect a minority of the outcomes considered. The statistically significant relationships were with healthy mother (OR: 1.02) and bodily integrity (OR: 1.01). These results imply that increasing the number of registered midwives per 100 deliveries by one FTE would increase the odds of these outcomes by 2% and 1% respectively.

- There was no statistically significant relationship between any of the staffing groups and maternal mortality, stillborn of healthy baby so these outcomes were not considered further.
- Besides reducing the uncertainty of the parameter estimates, the use of longitudinal data in this study has also allowed for the control of time invariant unobserved heterogeneity which may have confounded earlier studies. This combined with the inclusion of a patient level risk measure should reduce the risk of omitted variable bias but it is impossible to guarantee this. Attempts to econometrically solve the problem were unsuccessful.
- The addition of the Hospital Load Variable provided inconsistent results. Worsening staff to patient ratios had a strong and statistically significant effect on the healthy mother outcome, but had positive but weak and marginally significant effects on both the healthy baby and bodily integrity. There is no practical interpretation of the odds ratio. These contradictory findings are confusing but indicate that further work around improving the measurement of the staffing variables may be fruitful.

Table 13 presents the parameter values that will be used as the base case for the analysis alongside the upper and lower values to be used in the sensitivity analysis, which are derived from the descriptive and inferential statistical analysis reported in Section 4. The lower and upper values are based upon a plausible range of values.

For staff costs, the lower value is set to the bottom of the relevant Agenda for Change band (e.g. Band 5) discounted by the out of London factor of 0.96, and for the upper value the top of the relevant Agenda for Change band (e.g. band 6) is used, multiplied by the London weighting factor used by PSSRU of 1.19. In both cases the employer's on-costs (14% pension contributions and 13.8% national insurance contributions above £146 per week) are included to make this comparable to the national mean wages reported by PSSRU (Curtis, 2013). This provides an average cost of £39,640 for per additional midwife, with a range of £25,400 to £51,413. The base case level of staffing was set at the average number of midwives per 100 deliveries in 2013, which was 3.34. The minimum staffing ratio that year was 1.55 and the maximum 16.71. These values are highly unlikely but provide a good test of the sensitivity of the model to the underlying assumptions.

The number of expected cases of, for example, healthy mother in the average trust is determined by their rate and the number of deliveries. The base case number of deliveries (4,620) is set at the sample mean for the most recent year of data (2013), and the upper (10,680) and lower values (1,210) are set at the maximum and minimum values. Similarly, the current (before intervention) rate of occurrence is set at the 2013 sample average for the base case and the minimum and maximum values for the lower and upper values of the sensitivity analysis. For example for bodily integrity that would be an average trust rate of 30% in 2013 with a range of 15% to 45%.

Due to the nature of the odds ratio that is calculated from a logistic regression, the most natural intervention to consider is increasing the staffing variable by one unit at a time. That corresponds to 1 FTE midwife per 100 deliveries, and for the average trust that is equivalent to increasing the midwifery workforce by 46 FTE or roughly 33%: a substantial intervention. Against this a lower bound of 0.5 units and an upper bound of 2 were chosen for comparison.

Table 13: Sensitivity Modelling Parameters

	Healthy Mother			Bodily Integrity		
Parameters	**Base**	**Lower**	**Upper**	**Base**	**Lower**	**Upper**
Deliveries (Thousands)	4.62	1.21	10.68	4.62	1.21	10.68
Current Outcome Rate (%)	45	31	55	30	15	45
Effectiveness (Odds Ratio)	1.02	1.01	1.02	1.01	1	1.2
Midwifery Cost	£39,640	£25,400	£51,413	£39,640	£25,400	£51,413
Midwifery FTE per 100 deliveries	3.34	1.55	16.71	3.34	1.55	16.71
Intervention	1	0.5	2	1	0.5	2

Table 14: ICER for Maternal Outcomes

	Healthy Mother			Bodily Integrity		
Cost	**Before**	**After**	**Increment**	**Before**	**After**	**Increment**
FTE Midwives per 100 deliveries	3.34	4.34	1	3.34	4.34	1
FTE Midwives	154.308	200.508	46.2	154.308	200.508	46.2
Total Cost	£6,116,769	£7,987,777	£1,871,008	£6,116,769	£7,987,777	£1,871,008
Effectiveness	**Before**	**After**	**Increment**	**Before**	**After**	**Increment**
Outcome Rate (%)	45.00	45.47	0.47	30.00	30.21	0.21
Total Outcomes	2079.00	2100.87	21.87	1386.00	1395.67	9.67
ICER			**£85,560**			**£193,426**

4.3.2 Cost-Effectiveness

The incremental cost of increasing the number of midwives by 1 FTE per 100 deliveries is the same irrespective of the outcome under consideration. The incremental cost is £1.8 million for the average trust as Table 14 illustrates. This represents an approximate expansion of the midwifery workforce of a third, whilst the statistical analysis predicted an improvement in the outcomes of 1-2% in the odds.

The Incremental Cost Effectiveness Ratios (ICERs) are therefore £85,560 per healthy mother and £193,426 per mother with bodily integrity. This is in comparison to current practice i.e. the current level of staffing and skill mix. ICERs were not calculated for the remaining outcomes as there is no evidence that they are effective at present.

As we cannot express this ICER in a universal 'currency' such as QALYs, it is difficult to establish whether this represents value for money: whether it generates more health benefit than another intervention it may displace. However, taking a broad threshold of cost-effectiveness of £20-30,000 per QALY then a 'healthy mother' would need to generate 2.9-4.3 QALYs to be in the borderline region and over 4.3 to be cost-effective. Similarly, each mother with bodily integrity would need to generate QALYs equivalent to 6.4-9.7.

However this underestimates the cost-effectiveness in a number of ways. First, it hasn't been possible to net off the NHS savings from the intervention e.g. reduced overnight stays associated with a healthy mother. Second, one intervention (increasing the number of midwives by 1 FTE per 100 deliveries) generates both positive outcomes and they need to be combined some how to give a fairer representation of the true cost-effectiveness. In the absence of a common metric this is not possible.

4.3.3 Sensitivity Analysis

A one-way sensitivity analysis was performed whereby each of the parameters in Table 13 were varied from the base case to their upper and lower values. The sensitivity analysis demonstrates to what extent the results of the CEA are influenced by the assumptions that have been made, and allow the uncertainty in the parameter values to be illustrated. Table 15 presents the results of the sensitivity analysis for the ICER for all outcomes.

As there is an assumption that the effect of increasing staffing levels on the outcome is constant across all levels of the staffing variable then altering the assumptions around the size of the intervention, the current level of staffing or the number of deliveries per trust does not alter the ICERs. The assumptions that alter the ICER are the cost of staffing (cost), the effect of staffing on the outcomes in question (effectiveness) and the current level of the outcome (baseline).

If the assumption is that all midwives regardless of grade ‘produce’ the same effect on the outcomes, ceteris paribus, then it is fairly obvious that employing lower grade and therefore cheaper staff as part of the intervention will be more cost-effective. This report has not considered the impact on the supply of midwives of an introduction of the proposed intervention across all providers simultaneously. There are unanswered questions surrounding the availability of additional midwives (especially at the lower grades) and the effect on market conditions of an increase in demand for midwives.

It is clear that the effectiveness is the most important assumption with respect to the cost-effectiveness of the intervention. For example, as the odds ratio on bodily integrity is weak (1.01) this assumption is both fragile and important. A small change in this assumption can have dramatic effects on the ICER as Table 15 clearly illustrates.

Table 15: Sensitivity Analysis Results

	Healthy Mother			Bodily Integrity		
ICER	**Base**	**Lower**	**Upper**	**Base**	**Lower**	**Upper**
Deliveries (Thousands)	£83,747	£83,747	£83,747	£189,328	£189,328	£189,328
Current Outcome Rate (%)	£83,747	£96,643	£83,907	£189,328	£311,368	£160,882
Effectiveness (Odds Ratio)	£83,747	£111,410	£67,083	£189,328	£1,831,368	£10,004
Midwifery Cost	£83,747	£53,662	£108,620	£189,328	£121,315	£245,558
Midwifery FTE per 100 deliveries	£83,747	£83,747	£83,747	£189,328	£189,328	£189,328
Intervention	£83,747	£83,747	£83,747	£189,328	£189,328	£189,328

5 Discussion

Generally, staffing levels (per 100 deliveries) were not related to the outcomes under consideration. The exception was midwifery staffing levels (per 100 deliveries), which were associated with the healthy mother (OR: 1.02) and bodily integrity (OR: 1.01) outcomes. However, these relationships were weak; the odds ratios imply that increasing the number of registered midwives per 100 deliveries by one FTE would increase the odds of these outcomes by 2% and 1% respectively.

Based upon these measures of effectiveness Incremental Cost Effectiveness Ratios were estimated: £85,560 per healthy mother and £193,426 per mother with bodily integrity. This is in comparison to current practice i.e. the current level of staffing and skill mix. ICERs were not calculated for the remaining outcomes as there was no evidence that they were effective at present.

The econometric modelling attempted to model the effect of skill mix on hospital production. It did not consider the outcomes. The results were very similar with or without the inclusion of dynamic effects which indicates that endogeneity is not biasing the results. The econometric results indicate that doctors and consultants are quantity-complements with support workers, while all other combination of labour inputs are quantity-substitutes.

The data and results are consistent with the extant literature. For instance comparing the descriptive statistics produced from the HES data in Table 6 with those reported in Sandall et al. (2014), they are broadly similar despite the current analysis expanding the dataset from one to ten years. Similarly to the HES patient level data, there is a strong correlation between the trust level data (e.g. staffing) and those reported in Sandall et al. (2014). For instance, the 2010 FTE midwives per 100 deliveries is 3.10 in this study and 3.08 in Sandall et al. (2014).

5.1 Statistical Analysis Limitations

The outcome analyses presented here have the limitation present in all observational studies in that they do not test causal associations. We are therefore unable to conclude that alteration of staffing skill mix or any of the other predictor variables will have a beneficial (or detrimental) impact on patient outcomes. A cluster-randomised controlled trial may be required to identify causal associations and the impact of staffing changes. Finally, there may be an endogeneity problem in that trusts with better patient outcomes may also have higher levels of staffing or richer skill mixes for another reason (e.g. high quality management) which is excluded from the models. Some of the potential causes of omitted variable bias have been removed through the use of longitudinal data, to the extent to which these factors are fixed over time. Early attempts have been made to tackle the potential endogeneity problem through econometric means but further research with more time could make more headway. This was only possible with the econometric models which tackled the issue of skill mix and staffing levels on the number of deliveries. It was not possible to make similar progress with the statistical modelling of the outcomes.

Secondary data analysis is always dependent upon the quality of the data. A full census of women’ s deliveries from HES (2003-2013) was used so there was no bias caused by non-response. Instead, biases could be caused by missing data, poorly coded data or omitted variables from the clinical risk model. Extensive data cleaning was conducted to remove duplicate records and records which did not relate to a delivery episode. Trusts were excluded where fewer than 80% of women could be coded for a particular indicator, which limited the dataset for some potential indicators.

A problem when using routinely collected data is that analysis is limited to variables that are (reliably) collected. For example, body mass index and smoking or drug use were excluded from the models because of data quality issues, although they are known to be important risk factors. Only a limited set of trust-level variables were used. Organisational variables (e.g. organisational climate), service configuration (e.g. Obstetric led unit) and models of care that could be important predictors were not available. The models may also have omitted other variables, either known or unknown, that are predictive of outcome.

Staffing data were available only at trust level so we could not explore the effects of staffing at the unit level. The data for trusts that have multiple units could not be disaggregated. Aggregated trust-level data makes the assumption that unit-level effects within a trust are similar, which may not be true. The staffing data are taken from a census undertaken every September. This single-point estimate will hide any fluctuations that may occur over time. We analysed data that were aggregated over a period of a year. These data will therefore miss those occasions when the service is placed under stress, or reaching a critical point, because of excess deliveries, low staffing levels or other factors. Further it was not possible to divide the staffing numbers between obstetric and gynaecology services.

An attempt was made to create variation in staffing levels by creating a new Hospital Load Ratio variable. This divided the approximate number of deliveries each day by the total staffing numbers to create variation in staffing driven by changes in service demand. As not all staff will be working on any particular day on the delivery ward this is a particularly crude proxy. Despite this, the variable provided some important insights being a statistically significant predictor of the outcomes. This is significant improvement over existing studies. However, interpreting the coefficient on this variable for practical purposes is impossible. Instead it underlines the importance of collecting better ward level staffing data on a daily or shift basis, as well as being able to link these back to patient's and therefore their outcomes.

Finally, whilst the significantly larger dataset used here made previously insignificant relationships statistically significant, the effect sizes were marginal. A large change (circa a third of the workforce) would be required to generate a very small change in the outcome (typically 10-20 cases per annum).

5.2 Cost-Effectiveness Analysis limitations

The economic evaluation was stymied by the lack of clear evidence on the effectiveness of the intervention i.e. on the relationship between staffing levels, skill mix and outcomes in maternity services. The limitations described in the previous section indicate that the current statistical analysis is imperfect. However, it is a significant improvement over the existing evidence base and short of an experiment (natural, quasi, or real) it is difficult to imagine how better evidence could be assembled. As a result, a cost-effectiveness analysis could only be performed for healthy mother and bodily integrity.

No universal outcome measure (e.g. QALY) was available to aggregate all of the possible benefits of altering staffing levels. When calculating the cost-effectiveness of the interventions other potential effects have been omitted. Thus, while it is uncertain, the estimate of the cost-effectiveness could be an underestimate of the true benefit of increasing nurse staffing or skill mix changes.

As a result of poor staffing variables that do not adequately measure the true patient-staff ratio and its variation over time and provider, the resulting statistical findings were marginal. This study found more of the outcomes to be statistically significantly related to staffing but this was driven by the size of the dataset which improves the precision of the estimates. However, the effect sizes like in previous studies are practically very small. The findings of this study are therefore congruent with the extant evidence.

5.3 Recommendations for Future Research

There are three main areas for future research. First, improving the collection of ward level staffing data that could be linked to patients and their outcomes is important. A major weakness of this and existing research is the aggregate nature of the staffing data. The progress made through the inclusion of the Hospital Load Ratio demonstrates that this would be a fruitful avenue of research.

Second, designing the implementation of a Maternity Safe Staffing guideline or other staffing intervention in such a way as to create a quasi or natural experiment would be invaluable. At present there is no casual link between staffing and outcomes and the best available evidence does not support a strong relationship between these variables. An experimental design would enable researchers to answer the question conclusively but randomising the numerous omitted variables. Finally, in the absence of an experimental research design more work could be done to find econometric solutions to the endogeneity problem. Early steps were taken in this study to address the issue but time constraints limited the progress that could be made. Future research could adopt the approach used in this study (generalized methods of moments to exploit the time dimension in the data) or careful consideration could be given to instruments for the staffing variables that would remove any potential endogeneity. A good instrument would need to be strongly correlated with the staffing variable of interest (e.g. midwife numbers) but uncorrelated with the outcome directly.

5.4 Evidence Summary

This report complements the systematic Evidence Reviews [1-3] produced by Bazian Ltd and NICE, and aimed to produce a cost-effectiveness analysis of increasing midwife staffing levels on five maternity outcomes: maternal and infant mortality, healthy mother and baby and bodily integrity. The evidence contained in this report can be summarised as follows:

- Due to a lack of published applicable studies, the relationship between midwifery staffing levels and a range of outcomes were analysed using HES data from English NHS trusts 2003-2014.
- The results were largely consistent with the existing evidence, although this work corrected a number of issues with the extant literature.
- Midwifery staffing levels were shown to affect a minority of the outcomes considered. The statistically significant relationships were with healthy mother (OR: 1.02) and bodily integrity (OR: 1.01). These results imply that increasing the number of registered midwives per 100 deliveries by one FTE would increase the odds of these outcomes by 2% and 1% respectively.
- There was no statistically significant relationship between any of the staffing groups and maternal mortality, stillborn of healthy baby so these outcomes were not considered further.
- Based upon these measures of effectiveness Incremental Cost Effectiveness Ratios were estimated as £85,560 per healthy mother and £193,426 per mother with bodily integrity.

- Decision making in the absence of a universal measure, such as QALYS, is difficult but if the outcomes were each generating 2-3 QALYs they *could* be considered cost-effective. This is not currently known. Ultimately, the cost-effectiveness will depend upon the NHS's willingness to pay for these particular outcomes.
- The econometric results indicate that doctors and consultants are quantity-complements with support workers, while all other combination of labour inputs are quantity-substitutes. The elasticity of substitution between registered midwives and support workers is the highest one. All marginal productivities are positive. The econometric findings were robust to the inclusion of dynamic effects.
- Most variation in the outcomes was accounted for at the individual, patient level (within trust level) rather than between trusts. Regression models explain the variation in the outcome variable by the variation in the explanatory variables. As the staffing variables did not vary within trusts they were unable to explain much of the variation in the outcomes.
- The addition of the Hospital Load Variable provided inconsistent results. Worsening staff to patient ratios had a strong and statistically significant effect on the healthy mother outcome, but had positive but weak and marginally significant effects on both the healthy baby and bodily integrity.
- The last two points indicate that further works needs to be done on collecting unit level data that varies over time (e.g shift by shift), especially where this can be matched to patient demand data.
- Patient level factors are clearly very important, with age, ethnicity and parity being associated with both outcomes and deprivation also being associated with bodily integrity. In both cases, the largest odds ratio is for the clinical risk variable. A mother classed as "higher risk" is half as likely to deliver with bodily integrity than a mother classed as "lower risk".
- There is a clear time dimension to the results, with each year being strongly significantly related to the outcome. When compared to 2004 (the base year) each year since has a lower rate of healthy mothers and bodily integrity. This was also clear in the descriptive statistics in Section 4.1.1.
- In terms of the trust level variables, larger trusts have lower healthy mother rates but this effect is weak.
- This is the largest study on this topic to date. The use of longitudinal data combined with the inclusion of a patient level risk measure should reduce the risk of omitted variable bias

but it is impossible to guarantee this. Attempts to econometrically solve the problem were largely unsuccessful.

- Trusts should be encouraged to monitor both planned and actual staffing levels at ward level and to match these to outcomes of care. The adoption of Safe Staffing tools that include the monitoring of staffing and patient acuity data should be welcomed.
- Future research should concentrate on (i) improving the collection of staffing data to allow for within trust variation in staffing, (ii) tackling the inherent problem of endogeneity most likely through innovative research designs, and (iii) measuring the utility of the outcomes to enable the calculation of QALYs and the aggregation of the outcomes into a single measure.

6 References

Allen M, and Thornton S (2013) Providing one-to-one care in labour. Analysis of 'Birthrate Plus' labour ward staffing in real and simulated labour ward environments *BJOG: An International Journal of Obstetrics & Gynaecology,* 120 (1): 100-107

Allison, P. (1984). *Event history analysis*. Newbury Park, CA: Sage Publications.

Association of University Hospital Trusts (2014) *List of AUKUH Members*. URL: http://www.aukuh.org.uk/index.php/members/aukuh-members (Accessed 10 November 2014)

Bazian Ltd (2014) *Evidence review 1: An evidence review on the association between midwifery staffing at a local level and maternal and neonatal outcomes, and factors affecting these requirements*, Report for NICE Safe Staffing Advisory Committee, July 2014, Bazian Ltd, London: UK.

Berndt E, and Christensen L. (1973) The Translog Function and the Substitution of Equipment, Structures and Labour in U.S. Manufacturing, *Journal of Econometrics*, 1 (1): 81–114.

CMACE (2011) Saving Mothers' Lives. Reviewing maternal deaths to make motherhood safer: 2006-2008; Centre for Maternal and Child Enquiries (CMACE), *BJOG: An International Journal of Obstetrics & Gynaecology*, 118(1): Supplement

Curtis, L. (2013) [Ed.] *Unit Costs for Health and Social Care 2013*, Personal Social Services Research Unit, Canterbury: UK

DCLG (2011) The English Indices of Deprivation 2010, Neighbourhood Statistics Release . 2011. URL: http://webarchive.nationalarchives.gov.uk/20120919132719/http://www.communities.gov.uk/documents/statistics/pdf/1871208.pdf (Accessed 10 December 2014).

Diewert WE. (1971) An Application of the Shephard Duality Theorem: A Generalized Leontif Production Function, *Journal of Political Economy*, 79 (3):507.

Hayre, J (2014) *Evidence review 3: Economic Evidence Review in Safe Staffing for Maternity Settings*, Report for NICE Safe Staffing Advisory Committee, August 2014, NICE, London: UK.

Hicks JR. (1970) Elasticities of Substitution Again: Substitutes and Complements, *Oxford Economic Papers,* 22 (3): 289–96.

HSCIC (2010) Hospital Episode Statistics Data Dictionary – Inpatients, NHS Health and Social Care Information Centre. URL: http://www.hscic.gov.uk/media/1358/HES-Hospital-Episode-Statistics-HES-Admitted-Patient-Data-Dictionary/pdf/HES_Inpatients_DD_Sept10.pdf (Accessed 15 December 2014)

Knight HE, Gurol-Urganci I, Mahmood TA, Templeton A, Richmond D, van der Meulen JH, et al. (2013) Evaluating maternity care using national administrative health datasets: how are statistics affected by the quality of data on method of delivery? *BMC Health Services Research*, 13: 200.

Knight M, Kenyon S, Brocklehurst P, Neilson J, Shakespeare J, Kurinczuk JJ, eds [on behalf of MBRRACE-UK] (2014) *Saving lives, improving mothers' care—lessons learned to inform future maternity care from the UK and Ireland Confidential Enquiries into Maternal Deaths and Morbidity 2009-12.* Dec 2014. http://www.npeu.ox.ac.uk/mbrrace-uk/reports (Accessed 14 December, 2014)

Murray J, Saxena S, Modi N, Majeed A, Aylin P, Bottle A. (2012) Quality of routine hospital birth records and the feasibility of their use for creating birth cohorts. *Journal of Public Health*, 35: 298–307.

NICE (2007) Intrapartum Care: Care of Healthy Women and Their Babies During Childbirth . NICE Clinical Guideline 55. URL: www.nice.org.uk/guidance/cg55/resources/guidance-intrapartum-carepdf (Accessed 10 September 2014)

Reinhardt U. (1972) A Production Function for Physician Services, *Review of Economics and Statistics*, 54 (1): 55–66.

Sandall J, Murrells T, Dodwell M, Gibson R, Bewley S, Coxon K, Bick D, Cookson G, Warwick C, and Hamilton-Fairley D. (2014) The efficient use of the maternity workforce and the implications for safety & quality in maternity care, *Health Service and Delivery Research*, 2 (38): October 2014

Sato R, Koizumni T (1973) On the Elasticities of Substitution and Complementarity, *Oxford Economic Papers,* 25 (1): 44–56.

Syrquin M, Hollender G. (1982) Elasticities of Substitution and Complementarity: The General Case. *Oxford Economic Papers*, 34 (3): 515–9.

7 Appendix A: Full Statistical Results

For clarity and for ease of interpretation, only a summary of the statistical findings are presented in the main report in Section 4.1.2. This Appendix contains all of the relevant regression output.

Table 16: Healthy Mother Full Regression Results

							Odds Ratio	
		Beta	Std. Error	t-statistic	p-value	Odds Ratio	Lower CI	Upper CI
Intercept		-0.188	0.045	0.045	0.000	0.829	0.758	0.906
Maternal Age	**Missing**	0.183	0.021	0.021	0.000	1.201	1.153	1.251
	<20	-0.476	0.006	0.006	0.000	0.621	0.614	0.629
	20-24	-0.499	0.005	0.005	0.000	0.607	0.601	0.614
	25-29	-0.425	0.005	0.005	0.000	0.654	0.647	0.660
	30-34	-0.331	0.005	0.005	0.000	0.718	0.711	0.726
	35-39	-0.205	0.005	0.005	0.000	0.815	0.807	0.824
	>40	0.000		0.000		0.000		0.000
Higher Risk		1.092	0.002	0.002	0.000	2.980	2.969	2.992
Ethnicity	**British (White)**	-0.130	0.006	0.006	0.000	0.878	0.867	0.888
	Irish (White)	-0.003	0.015	0.015	0.839	0.997	0.969	1.026
	Any other White background	-0.077	0.007	0.007	0.000	0.926	0.914	0.938
	White and Black Caribbean	0.006	0.015	0.015	0.678	1.006	0.976	1.037
	White and Black African	0.235	0.018	0.018	0.000	1.265	1.221	1.310
	White and Asian	-0.050	0.020	0.020	0.013	0.951	0.914	0.990
	Any other Mixed background	-0.016	0.014	0.014	0.230	0.984	0.958	1.010
	Indian	0.094	0.008	0.008	0.000	1.098	1.081	1.116
	Pakistani	0.090	0.008	0.008	0.000	1.094	1.078	1.110
	Bangladeshi	0.084	0.010	0.010	0.000	1.087	1.066	1.109
	Any other Asian background	0.067	0.009	0.009	0.000	1.070	1.051	1.088

	Caribbean	0.180	0.011	0.011	0.000	1.197	1.173	1.222
	African	0.356	0.008	0.008	0.000	1.428	1.407	1.450
	Any other Black background	0.270	0.011	0.011	0.000	1.309	1.281	1.339
	Chinese	-0.053	0.013	0.013	0.000	0.948	0.924	0.973
	Not known	-0.167	0.010	0.010	0.000	0.846	0.830	0.862
	Not stated	-0.133	0.007	0.007	0.000	0.876	0.863	0.888
	Any other ethnic group	0.000		0.000		0.000		0.000
Parity	**0**	0.622	0.005	0.005	0.000	1.863	1.845	1.881
	1	0.031	0.005	0.005	0.000	1.031	1.022	1.041
	2	-0.024	0.005	0.005	0.000	0.976	0.966	0.986
	3	-0.037	0.006	0.006	0.000	0.963	0.952	0.975
	4>	0.000		0.000		0.000		0.000
IMD	**Missing**	-0.017	0.022	0.022	0.450	0.983	0.941	1.027
	1	-0.005	0.004	0.004	0.173	0.995	0.988	1.002
	2	-0.006	0.003	0.003	0.060	0.994	0.987	1.000
	3	-0.004	0.003	0.003	0.219	0.996	0.989	1.002
	4	-0.003	0.003	0.003	0.413	0.997	0.991	1.004
	5	0.000		0.000		0.000		0.000
Rural/Urban	**Missing**	0.110	0.027	0.027	0.000	1.117	1.060	1.177
	Urban =>10K - sparse	0.022	0.025	0.025	0.380	1.022	0.974	1.072
	Town and Fringe - sparse	0.182	0.017	0.017	0.000	1.199	1.159	1.241
	Village - sparse	0.110	0.018	0.018	0.000	1.117	1.078	1.157
	Hamlet and Isolated dwelling - sparse	0.146	0.023	0.023	0.000	1.157	1.105	1.211
	Urban =>10K - less sparse	-0.020	0.007	0.007	0.005	0.981	0.967	0.994
	Town and Fringe - less sparse	-0.016	0.008	0.008	0.044	0.985	0.970	1.000
	Village - less sparse	-0.011	0.008	0.008	0.174	0.989	0.973	1.005
	Rest of UK	0.135	0.059	0.059	0.021	1.145	1.020	1.284
	Hamlet and Isolated Dwelling - less sparse	0.000		0.000		0.000		0.000
SHA	**East Midlands**	0.019	0.070	0.070	0.783	1.020	0.889	1.170

	East of England	-0.069	0.061	0.061	0.256	0.933	0.829	1.051
	London	0.097	0.054	0.054	0.071	1.102	0.992	1.225
	North East	0.087	0.075	0.075	0.249	1.091	0.941	1.264
	North West	0.200	0.057	0.057	0.000	1.222	1.092	1.367
	South East	0.031	0.057	0.057	0.583	1.032	0.923	1.153
	West Midlands	0.068	0.062	0.062	0.267	1.071	0.949	1.208
	Yorkshire & Humberside	0.083	0.064	0.064	0.193	1.086	0.959	1.231
	South West	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maternities (thousands)		-0.012	0.001	0.001	0.000	0.988	0.986	0.991
FTE per 100 maternities	**Midwives**	0.019	0.002	0.002	0.000	1.019	1.014	1.024
	Support Workers	-0.017	0.009	0.009	0.054	0.983	0.966	1.000
	Doctors	-0.039	0.010	0.010	0.000	0.961	0.943	0.981
	Consultants	-0.130	0.025	0.025	0.000	0.878	0.837	0.921
Hospital Load Ratio		-0.724	0.061	0.061	0.000	0.485	0.430	0.546
Year	**2004**	0.000	0.000	0.000		0.000	0.000	0.000
	2005	-0.056	0.004	0.004	0.000	0.945	0.938	0.952
	2006	-0.120	0.004	0.004	0.000	0.887	0.879	0.894
	2007	-0.222	0.004	0.004	0.000	0.801	0.795	0.808
	2008	-0.252	0.004	0.004	0.000	0.777	0.771	0.784
	2009	-0.254	0.004	0.004	0.000	0.776	0.770	0.782
	2010	-0.320	0.004	0.004	0.000	0.726	0.720	0.733
	2011	-0.386	0.004	0.004	0.000	0.680	0.674	0.686
	2012	-0.396	0.004	0.004	0.000	0.673	0.668	0.679

Table 17: Maternal Mortality Full Results

							Odds Ratio	
		Beta	Std. Error	t-statistic	p-value	Odds Ratio	Lower CI	Upper CI
Intercept		-9.84	0.94	0.94	0.00	0.00	0.00	0.00
Maternal Age	**Missing**	-16.07	1410.63	1410.63	0.99	0.00	0.00	Inf
	<20	-1.18	0.47	0.47	0.01	0.31	0.12	0.77
	20-24	-1.29	0.35	0.35	0.00	0.28	0.14	0.54
	25-29	-0.86	0.30	0.30	0.00	0.42	0.24	0.76
	30-34	-0.76	0.29	0.29	0.01	0.47	0.27	0.83
	35-39	-0.43	0.29	0.29	0.14	0.65	0.36	1.15
	>40	0.00				0.00		
Higher Risk		1.45	0.18	0.18	0.00	4.25	2.97	6.09
Ethnicity	**British (White)**	0.30	0.59	0.59	0.61	1.35	0.42	4.34
	Irish (White)	-14.71	1261.13	1261.13	0.99	0.00	0.00	Inf
	Any other White background	-0.90	0.82	0.82	0.27	0.41	0.08	2.02
	White and Black Caribbean	-14.54	1321.07	1321.07	0.99	0.00	0.00	Inf
	White and Black African	-14.74	1574.28	1574.28	0.99	0.00	0.00	Inf
	White and Asian	-14.57	1791.14	1791.14	0.99	0.00	0.00	Inf
	Any other Mixed background	1.21	0.91	0.91	0.18	3.37	0.56	20.17
	Indian	0.79	0.68	0.68	0.24	2.21	0.58	8.37
	Pakistani	0.40	0.70	0.70	0.57	1.49	0.38	5.86
	Bangladeshi	1.08	0.73	0.73	0.14	2.94	0.70	12.42
	Any other Asian background	1.50	0.66	0.66	0.02	4.49	1.23	16.33
	Caribbean	1.19	0.73	0.73	0.10	3.30	0.79	13.87
	African	1.10	0.64	0.64	0.08	3.02	0.86	10.55
	Any other Black background	-0.26	1.16	1.16	0.82	0.77	0.08	7.43
	Chinese	1.13	0.91	0.91	0.22	3.09	0.52	18.53
	Not known	1.35	0.71	0.71	0.06	3.87	0.96	15.68

	Not stated	1.51	0.62	0.62	0.01	4.53	1.34	15.27
	Any other ethnic group	0.00				0.00		
Parity	**0**	0.32	0.33	0.33	0.33	1.38	0.72	2.66
	1	-0.33	0.35	0.35	0.34	0.72	0.37	1.42
	2	0.20	0.35	0.35	0.56	1.23	0.61	2.46
	3	-0.10	0.44	0.44	0.82	0.90	0.38	2.13
	4>	0.00				0.00		
IMD	**Missing**	-15.10	1703.88	1703.88	0.99	0.00	0.00	Inf
	1	0.34	0.27	0.27	0.20	1.41	0.83	2.40
	2	0.27	0.26	0.26	0.30	1.31	0.79	2.20
	3	-0.08	0.28	0.28	0.77	0.92	0.53	1.60
	4	-0.18	0.29	0.29	0.54	0.84	0.47	1.49
	5	0.00				0.00		
Rural/Urban	**Missing**	14.51	1703.88	1703.88	0.99	2009613.00	0.00	Inf
	Urban =>10K - sparse	0.69	1.09	1.09	0.53	1.99	0.23	16.82
	Town and Fringe - sparse	-15.54	1393.68	1393.68	0.99	0.00	0.00	Inf
	Village - sparse	0.00	1.09	1.09	1.00	1.00	0.12	8.37
	Hamlet and Isolated dwelling - sparse	-15.64	1937.45	1937.45	0.99	0.00	0.00	Inf
	Urban =>10K - less sparse	-0.76	0.43	0.43	0.08	0.47	0.20	1.08
	Town and Fringe - less sparse	-0.67	0.51	0.51	0.19	0.51	0.19	1.39
	Village - less sparse	-1.07	0.61	0.61	0.08	0.34	0.11	1.13
	Rest of UK	-0.46	5047.15	5047.15	1.00	0.63	0.00	Inf
	Hamlet and Isolated Dwelling - less sparse	0.00				0.00		
SHA	**East Midlands**	-0.21	0.40	0.40	0.60	0.81	0.37	1.77
	East of England	-0.35	0.37	0.37	0.34	0.70	0.34	1.46
	London	-0.02	0.34	0.34	0.95	0.98	0.51	1.89
	North East	0.28	0.40	0.40	0.49	1.32	0.60	2.89
	North West	-0.32	0.34	0.34	0.35	0.73	0.37	1.42
	South East	-0.18	0.34	0.34	0.59	0.83	0.43	1.62

	West Midlands	-0.13	0.35	0.35	0.71	0.88	0.44	1.75
	Yorkshire & Humberside	-0.76	0.42	0.42	0.07	0.47	0.21	1.06
	South West	0.00				0.00		
Maternities (thousands)		0.03	0.03	0.03	0.42	1.03	0.96	1.10
FTE per 100 maternities	**Midwives**	0.16	0.13	0.13	0.21	1.17	0.91	1.51
	Support Workers	-0.18	0.39	0.39	0.64	0.83	0.39	1.79
	Doctors	-0.18	0.60	0.60	0.77	0.84	0.26	2.70
	Consultants	-1.33	1.40	1.40	0.34	0.26	0.02	4.11
Hospital Load Ratio		-2.61	4.49	4.49	0.56	0.07	0.00	483.07
Year	**2004**	0.00				0.00		
	2005	-0.29	0.28	0.28	0.30	0.75	0.44	1.29
	2006	-0.50	0.30	0.30	0.10	0.61	0.34	1.09
	2007	-0.65	0.32	0.32	0.04	0.52	0.28	0.98
	2008	-0.37	0.29	0.29	0.20	0.69	0.39	1.22
	2009	-0.45	0.29	0.29	0.12	0.64	0.36	1.12
	2010	-0.46	0.30	0.30	0.13	0.63	0.35	1.14
	2011	-0.26	0.28	0.28	0.36	0.77	0.44	1.35
	2012	-1.15	0.38	0.38	0.00	0.32	0.15	0.66

1492 **Table 18: Bodily Integrity Full Regression Results**

		Beta	Std. Error	t-statistic	p-value	Odds Ratio	Odds Ratio Lower CI	Odds Ratio Upper CI
Intercept		0.73	0.07	0.07	0.00	2.08	1.81	2.40
Maternal Age	**Missing**	0.30	0.05	0.05	0.00	1.35	1.21	1.50
	<20	1.03	0.01	0.01	0.00	2.81	2.77	2.85
	20-24	0.76	0.01	0.01	0.00	2.14	2.11	2.16
	25-29	0.43	0.01	0.01	0.00	1.54	1.52	1.56
	30-34	0.19	0.01	0.01	0.00	1.20	1.19	1.22
	35-39	0.05	0.01	0.01	0.00	1.06	1.04	1.07
	>40	0.00				0.00		
Higher Risk		-0.69	0.00	0.00	0.00	0.50	0.50	0.50
Ethnicity	**British (White)**	0.11	0.01	0.01	0.00	1.12	1.10	1.13
	Irish (White)	-0.10	0.02	0.02	0.00	0.90	0.87	0.93
	Any other White background	0.05	0.01	0.01	0.00	1.05	1.03	1.06
	White and Black Caribbean	0.50	0.02	0.02	0.00	1.65	1.60	1.70
	White and Black African	0.12	0.02	0.02	0.00	1.13	1.09	1.18
	White and Asian	0.01	0.02	0.02	0.76	1.01	0.96	1.05
	Any other Mixed background	0.14	0.01	0.01	0.00	1.15	1.12	1.19
	Indian	-0.43	0.01	0.01	0.00	0.65	0.64	0.66
	Pakistani	-0.05	0.01	0.01	0.00	0.95	0.94	0.97
	Bangladeshi	-0.13	0.01	0.01	0.00	0.88	0.86	0.89
	Any other Asian background	-0.27	0.01	0.01	0.00	0.76	0.75	0.78
	Caribbean	0.60	0.01	0.01	0.00	1.82	1.78	1.86
	African	0.01	0.01	0.01	0.20	1.01	0.99	1.03
	Any other Black background	0.21	0.01	0.01	0.00	1.24	1.21	1.27
	Chinese	-0.42	0.02	0.02	0.00	0.66	0.64	0.68
	Not known	0.08	0.01	0.01	0.00	1.08	1.06	1.11

	Not stated	0.07	0.01	0.01	0.00	1.07	1.05	1.09
	Any other ethnic group	0.00				0.00		
Parity	**0**	-2.38	0.01	0.01	0.00	0.09	0.09	0.09
	1	-1.28	0.01	0.01	0.00	0.28	0.28	0.28
	2	-0.65	0.01	0.01	0.00	0.52	0.52	0.53
	3	-0.29	0.01	0.01	0.00	0.74	0.74	0.75
	4>	0.00				0.00		
IMD	**Missing**	0.26	0.02	0.02	0.00	1.30	1.24	1.36
	1	0.46	0.00	0.00	0.00	1.58	1.56	1.59
	2	0.30	0.00	0.00	0.00	1.36	1.35	1.37
	3	0.19	0.00	0.00	0.00	1.20	1.19	1.21
	4	0.10	0.00	0.00	0.00	1.10	1.09	1.11
	5	0.00				0.00		
Rural/Urban	**Missing**							
	Urban =>10K - sparse	0.04	0.03	0.03	0.15	1.04	0.99	1.09
	Town and Fringe - sparse	0.06	0.02	0.02	0.00	1.06	1.02	1.10
	Village - sparse	0.04	0.02	0.02	0.06	1.04	1.00	1.08
	Hamlet and Isolated dwelling - sparse	-0.05	0.03	0.03	0.04	0.95	0.90	1.00
	Urban =>10K - less sparse	0.03	0.01	0.01	0.00	1.03	1.01	1.05
	Town and Fringe - less sparse	0.04	0.01	0.01	0.00	1.04	1.03	1.06
	Village - less sparse	0.02	0.01	0.01	0.02	1.02	1.00	1.04
	Rest of UK	0.13	0.06	0.06	0.04	1.14	1.00	1.29
	Hamlet and Isolated Dwelling - less sparse	0.00				0.00		
SHA	**East Midlands**	0.14	0.11	0.11	0.20	1.15	0.93	1.42
	East of England	-0.12	0.09	0.09	0.20	0.89	0.74	1.07
	London	-0.24	0.08	0.08	0.01	0.79	0.67	0.93
	North East	0.11	0.12	0.12	0.33	1.12	0.89	1.41
	North West	-0.10	0.09	0.09	0.26	0.90	0.76	1.08
	South East	-0.15	0.09	0.09	0.08	0.86	0.72	1.02

	West Midlands	-0.10	0.10	0.10	0.30	0.91	0.75	1.09
	Yorkshire & Humberside	0.08	0.10	0.10	0.41	1.08	0.89	1.32
	South West	0.00				0.00		
Maternities (thousands)		0.00	0.00	0.00	0.00	1.00	1.00	1.01
FTE per 100 maternities	**Midwives**	0.01	0.00	0.00	0.00	1.01	1.00	1.02
	Support Workers	-0.09	0.01	0.01	0.00	0.91	0.89	0.93
	Doctors	-0.01	0.01	0.01	0.21	0.99	0.96	1.01
	Consultants	-0.18	0.03	0.03	0.00	0.84	0.79	0.89
Hospital Load Ratio		0.15	0.07	0.07	0.02	1.16	1.02	1.32
Year	**2004**	0.00				0.00		
	2005	-0.06	0.00	0.00	0.00	0.95	0.94	0.95
	2006	-0.08	0.00	0.00	0.00	0.92	0.92	0.93
	2007	-0.10	0.00	0.00	0.00	0.91	0.90	0.91
	2008	-0.15	0.00	0.00	0.00	0.86	0.85	0.87
	2009	-0.24	0.00	0.00	0.00	0.78	0.78	0.79
	2010	-0.30	0.00	0.00	0.00	0.74	0.74	0.75
	2011	-0.35	0.00	0.00	0.00	0.71	0.70	0.71
	2012	-0.39	0.00	0.00	0.00	0.68	0.67	0.68

Table 19: Stillborn Full Regression Results

							Odds Ratio	
		Beta	Std. Error	t-statistic	p-value	Odds Ratio	Lower CI	Upper CI
Intercept		-7.80	0.11	0.11	0.00	0.00	0.00	0.00
Maternal Age	**Missing**	-0.37	0.10	0.10	0.00	0.69	0.57	0.84
	<20	-0.05	0.04	0.04	0.20	0.95	0.89	1.02
	20-24	-0.25	0.03	0.03	0.00	0.78	0.74	0.83
	25-29	-0.33	0.03	0.03	0.00	0.72	0.68	0.76
	30-34	-0.36	0.03	0.03	0.00	0.70	0.66	0.74
	35-39	-0.23	0.03	0.03	0.00	0.80	0.75	0.84
	>40	0.00				0.00		
Higher Risk		3.47	0.03	0.03	0.00	32.21	30.30	34.23
Ethnicity	**British (White)**	-0.14	0.04	0.04	0.00	0.87	0.81	0.94
	Irish (White)	0.15	0.09	0.09	0.10	1.16	0.97	1.38
	Any other White background	-0.13	0.04	0.04	0.00	0.88	0.80	0.96
	White and Black Caribbean	0.24	0.09	0.09	0.01	1.27	1.07	1.50
	White and Black African	0.10	0.10	0.10	0.33	1.11	0.90	1.36
	White and Asian	0.02	0.13	0.13	0.87	1.02	0.79	1.31
	Any other Mixed background	-0.28	0.10	0.10	0.01	0.76	0.62	0.92
	Indian	0.11	0.05	0.05	0.03	1.11	1.01	1.23
	Pakistani	0.32	0.05	0.05	0.00	1.38	1.26	1.51
	Bangladeshi	0.05	0.06	0.06	0.43	1.05	0.93	1.18
	Any other Asian background	0.16	0.05	0.05	0.00	1.17	1.05	1.30
	Caribbean	0.31	0.06	0.06	0.00	1.36	1.21	1.52
	African	0.31	0.05	0.05	0.00	1.37	1.25	1.50
	Any other Black background	0.28	0.06	0.06	0.00	1.33	1.18	1.50
	Chinese	-0.27	0.10	0.10	0.01	0.76	0.63	0.93
	Not known	-0.41	0.07	0.07	0.00	0.66	0.57	0.77

	Not stated	-0.25	0.05	0.05	0.00	0.78	0.71	0.86
	Any other ethnic group	0.00				0.00		
Parity	**0**	0.49	0.03	0.03	0.00	1.63	1.54	1.72
	1	-0.15	0.03	0.03	0.00	0.86	0.81	0.91
	2	-0.16	0.03	0.03	0.00	0.85	0.80	0.90
	3	-0.08	0.04	0.04	0.03	0.93	0.86	0.99
	4>	0.00				0.00		
IMD	**Missing**	0.50	0.13	0.13	0.00	1.65	1.29	2.11
	1	0.29	0.02	0.02	0.00	1.34	1.28	1.41
	2	0.22	0.02	0.02	0.00	1.24	1.18	1.30
	3	0.16	0.02	0.02	0.00	1.18	1.12	1.23
	4	0.07	0.02	0.02	0.01	1.07	1.02	1.13
	5	0.00				0.00		
Rural/Urban	**Missing**	0.24	0.15	0.15	0.10	1.28	0.95	1.71
	Urban =>10K - sparse	-0.06	0.17	0.17	0.72	0.94	0.67	1.32
	Town and Fringe - sparse	0.03	0.12	0.12	0.81	1.03	0.81	1.31
	Village - sparse	0.08	0.12	0.12	0.54	1.08	0.85	1.37
	Hamlet and Isolated dwelling - sparse	0.15	0.15	0.15	0.30	1.17	0.87	1.57
	Urban =>10K - less sparse	-0.04	0.05	0.05	0.49	0.97	0.87	1.07
	Town and Fringe - less sparse	0.00	0.06	0.06	0.97	1.00	0.90	1.11
	Village - less sparse	-0.03	0.06	0.06	0.64	0.97	0.87	1.09
	Rest of UK	0.33	0.28	0.28	0.24	1.39	0.81	2.39
	Hamlet and Isolated Dwelling - less sparse	0.00				0.00		
SHA	**East Midlands**	-0.04	0.08	0.08	0.60	0.96	0.81	1.13
	East of England	0.06	0.07	0.07	0.41	1.06	0.92	1.22
	London	0.07	0.07	0.07	0.31	1.07	0.94	1.22
	North East	0.04	0.09	0.09	0.67	1.04	0.87	1.24
	North West	-0.01	0.07	0.07	0.90	0.99	0.87	1.13
	South East	0.01	0.07	0.07	0.84	1.01	0.88	1.16

	West Midlands	-0.08	0.07	0.07	0.25	0.92	0.79	1.06
	Yorkshire & Humberside	0.08	0.08	0.08	0.28	1.09	0.94	1.26
	South West	0.00				0.00		
Maternities (thousands)		0.01	0.01	0.01	0.17	1.01	1.00	1.02
FTE per 100 maternities	**Midwives**	0.01	0.02	0.02	0.52	1.01	0.98	1.04
	Support Workers	0.03	0.05	0.05	0.57	1.03	0.93	1.14
	Doctors	-0.09	0.06	0.06	0.18	0.92	0.81	1.04
	Consultants	-0.07	0.15	0.15	0.67	0.94	0.69	1.27
Hospital Load Ratio		-0.39	0.40	0.40	0.33	0.68	0.31	1.49
Year	**2004**	0.00				0.00		
	2005	-0.05	0.03	0.03	0.05	0.95	0.90	1.00
	2006	-0.06	0.03	0.03	0.03	0.94	0.89	0.99
	2007	-0.12	0.03	0.03	0.00	0.88	0.84	0.93
	2008	-0.17	0.03	0.03	0.00	0.84	0.80	0.89
	2009	-0.17	0.03	0.03	0.00	0.84	0.80	0.89
	2010	-0.19	0.03	0.03	0.00	0.82	0.78	0.87
	2011	-0.22	0.03	0.03	0.00	0.81	0.76	0.85
	2012	-0.33	0.03	0.03	0.00	0.72	0.68	0.76

Table 20: Full Results Healthy Baby Regression

		Beta	Std. Error	t-statistic	p-value	Odds Ratio	Odds Ratio Lower CI	Odds Ratio Upper CI
Intercept		2.91	0.06	0.06	0.00	18.30	16.38	20.46
Maternal Age	**Missing**	0.14	0.09	0.09	0.11	1.15	0.97	1.36
	<20	-0.04	0.01	0.01	0.00	0.96	0.94	0.98
	20-24	0.06	0.01	0.01	0.00	1.06	1.04	1.08
	25-29	0.13	0.01	0.01	0.00	1.14	1.12	1.16
	30-34	0.14	0.01	0.01	0.00	1.15	1.13	1.17
	35-39	0.09	0.01	0.01	0.00	1.10	1.08	1.12
	>40	0.00				0.00		
Higher Risk		-1.72	0.00	0.00	0.00	0.18	0.18	0.18
Ethnicity	**British (White)**	-0.09	0.01	0.01	0.00	0.92	0.90	0.94
	Irish (White)	-0.01	0.03	0.03	0.73	0.99	0.94	1.05
	Any other White background	0.02	0.01	0.01	0.09	1.02	1.00	1.05
	White and Black Caribbean	-0.24	0.03	0.03	0.00	0.79	0.75	0.83
	White and Black African	0.03	0.03	0.03	0.38	1.03	0.96	1.10
	White and Asian	-0.16	0.04	0.04	0.00	0.86	0.80	0.92
	Any other Mixed background	-0.06	0.03	0.03	0.03	0.94	0.90	0.99
	Indian	-0.27	0.01	0.01	0.00	0.77	0.75	0.79
	Pakistani	-0.14	0.01	0.01	0.00	0.87	0.85	0.90
	Bangladeshi	-0.20	0.02	0.02	0.00	0.82	0.79	0.85
	Any other Asian background	-0.10	0.02	0.02	0.00	0.90	0.87	0.93
	Caribbean	-0.28	0.02	0.02	0.00	0.75	0.73	0.78
	African	-0.03	0.01	0.01	0.03	0.97	0.94	1.00
	Any other Black background	-0.16	0.02	0.02	0.00	0.85	0.82	0.89
	Chinese	0.24	0.03	0.03	0.00	1.27	1.21	1.34
	Not known	-0.03	0.02	0.02	0.18	0.97	0.94	1.01
	Not stated	-0.02	0.01	0.01	0.15	0.98	0.95	1.01
	Any other ethnic group	0.00				0.00		

Parity	**0**	-0.22	0.01	0.01	0.00	0.80	0.79	0.82
	1	0.25	0.01	0.01	0.00	1.29	1.27	1.31
	2	0.22	0.01	0.01	0.00	1.25	1.23	1.27
	3	0.12	0.01	0.01	0.00	1.13	1.11	1.15
	4>	0.00				0.00		
IMD	**Missing**	-0.42	0.03	0.03	0.00	0.65	0.61	0.70
	1	-0.25	0.01	0.01	0.00	0.78	0.77	0.79
	2	-0.17	0.01	0.01	0.00	0.84	0.83	0.86
	3	-0.11	0.01	0.01	0.00	0.89	0.88	0.90
	4	-0.06	0.01	0.01	0.00	0.94	0.93	0.95
	5	0.00				0.00		
Rural/Urban	**Missing**							
	Urban =>10K - sparse	-0.16	0.05	0.05	0.00	0.85	0.78	0.93
	Town and Fringe - sparse	-0.07	0.03	0.03	0.02	0.93	0.87	0.99
	Village - sparse	0.00	0.03	0.03	0.96	1.00	0.94	1.07
	Hamlet and Isolated dwelling - sparse	0.02	0.04	0.04	0.66	1.02	0.94	1.11
	Urban =>10K - less sparse	-0.03	0.01	0.01	0.01	0.97	0.94	0.99
	Town and Fringe - less sparse	-0.04	0.01	0.01	0.01	0.96	0.93	0.99
	Village - less sparse	0.01	0.02	0.02	0.41	1.01	0.98	1.04
	Rest of UK	-0.47	0.08	0.08	0.00	0.62	0.53	0.73
	Hamlet and Isolated Dwelling - less sparse	0.00				0.00		
SHA	**East Midlands**	0.40	0.08	0.08	0.00	1.49	1.28	1.74
	East of England	0.25	0.07	0.07	0.00	1.28	1.12	1.46
	London	0.26	0.06	0.06	0.00	1.29	1.15	1.46
	North East	0.28	0.08	0.08	0.00	1.33	1.13	1.56
	North West	0.29	0.06	0.06	0.00	1.34	1.18	1.52
	South East	0.29	0.06	0.06	0.00	1.34	1.18	1.52
	West Midlands	0.28	0.07	0.07	0.00	1.33	1.16	1.52
	Yorkshire & Humberside	0.21	0.07	0.07	0.00	1.24	1.08	1.42
	South West	0.00				0.00		
Maternities (thousands)		0.00	0.00	0.00	0.34	1.00	1.00	1.01

FTE per 100 maternities	**Midwives**	0.00	0.00	0.00	0.92	1.00	0.99	1.01
	Support Workers	-0.05	0.02	0.02	0.00	0.95	0.92	0.98
	Doctors	-0.03	0.02	0.02	0.19	0.97	0.94	1.01
	Consultants	0.09	0.05	0.05	0.07	1.10	0.99	1.21
Hospital Load Ratio		0.28	0.11	0.11	0.02	1.32	1.05	1.65
Year	**2004**	0.00				0.00		
	2005	0.05	0.01	0.01	0.00	1.05	1.04	1.07
	2006	0.06	0.01	0.01	0.00	1.06	1.04	1.07
	2007	0.10	0.01	0.01	0.00	1.10	1.09	1.12
	2008	0.13	0.01	0.01	0.00	1.14	1.12	1.16
	2009	0.13	0.01	0.01	0.00	1.14	1.13	1.16
	2010	0.17	0.01	0.01	0.00	1.19	1.17	1.21
	2011	0.21	0.01	0.01	0.00	1.24	1.22	1.26
	2012	0.25	0.01	0.01	0.00	1.28	1.26	1.30

Table 21: Healthy Baby Full Regression Results

		Beta	Std. Error	t-	p-	Odds Ratio	Odds Ratio Lower	Upper

				statistic	value		CI	CI
Intercept		2.91	0.06	0.06	0.00	18.30	16.38	20.46
Maternal Age	**Missing**	0.14	0.09	0.09	0.11	1.15	0.97	1.36
	<20	-0.04	0.01	0.01	0.00	0.96	0.94	0.98
	20-24	0.06	0.01	0.01	0.00	1.06	1.04	1.08
	25-29	0.13	0.01	0.01	0.00	1.14	1.12	1.16
	30-34	0.14	0.01	0.01	0.00	1.15	1.13	1.17
	35-39	0.09	0.01	0.01	0.00	1.10	1.08	1.12
	>40	0.00				0.00		
Higher Risk		-1.72	0.00	0.00	0.00	0.18	0.18	0.18
Ethnicity	**British (White)**	-0.09	0.01	0.01	0.00	0.92	0.90	0.94
	Irish (White)	-0.01	0.03	0.03	0.73	0.99	0.94	1.05
	Any other White background	0.02	0.01	0.01	0.09	1.02	1.00	1.05
	White and Black Caribbean	-0.24	0.03	0.03	0.00	0.79	0.75	0.83
	White and Black African	0.03	0.03	0.03	0.38	1.03	0.96	1.10
	White and Asian	-0.16	0.04	0.04	0.00	0.86	0.80	0.92
	Any other Mixed background	-0.06	0.03	0.03	0.03	0.94	0.90	0.99
	Indian	-0.27	0.01	0.01	0.00	0.77	0.75	0.79
	Pakistani	-0.14	0.01	0.01	0.00	0.87	0.85	0.90
	Bangladeshi	-0.20	0.02	0.02	0.00	0.82	0.79	0.85
	Any other Asian background	-0.10	0.02	0.02	0.00	0.90	0.87	0.93
	Caribbean	-0.28	0.02	0.02	0.00	0.75	0.73	0.78
	African	-0.03	0.01	0.01	0.03	0.97	0.94	1.00
	Any other Black background	-0.16	0.02	0.02	0.00	0.85	0.82	0.89
	Chinese	0.24	0.03	0.03	0.00	1.27	1.21	1.34
	Not known	-0.03	0.02	0.02	0.18	0.97	0.94	1.01
	Not stated	-0.02	0.01	0.01	0.15	0.98	0.95	1.01
	Any other ethnic group	0.00				0.00		
Parity	**0**	-0.22	0.01	0.01	0.00	0.80	0.79	0.82
	1	0.25	0.01	0.01	0.00	1.29	1.27	1.31
	2	0.22	0.01	0.01	0.00	1.25	1.23	1.27
	3	0.12	0.01	0.01	0.00	1.13	1.11	1.15

	4>	0.00				0.00		
IMD	**Missing**	-0.42	0.03	0.03	0.00	0.65	0.61	0.70
	1	-0.25	0.01	0.01	0.00	0.78	0.77	0.79
	2	-0.17	0.01	0.01	0.00	0.84	0.83	0.86
	3	-0.11	0.01	0.01	0.00	0.89	0.88	0.90
	4	-0.06	0.01	0.01	0.00	0.94	0.93	0.95
	5	0.00				0.00		
Rural/Urban	**Missing**							
	Urban =>10K - sparse	-0.16	0.05	0.05	0.00	0.85	0.78	0.93
	Town and Fringe - sparse	-0.07	0.03	0.03	0.02	0.93	0.87	0.99
	Village - sparse	0.00	0.03	0.03	0.96	1.00	0.94	1.07
	Hamlet and Isolated dwelling - sparse	0.02	0.04	0.04	0.66	1.02	0.94	1.11
	Urban =>10K - less sparse	-0.03	0.01	0.01	0.01	0.97	0.94	0.99
	Town and Fringe - less sparse	-0.04	0.01	0.01	0.01	0.96	0.93	0.99
	Village - less sparse	0.01	0.02	0.02	0.41	1.01	0.98	1.04
	Rest of UK	-0.47	0.08	0.08	0.00	0.62	0.53	0.73
	Hamlet and Isolated Dwelling - less sparse	0.00				0.00		
SHA	**East Midlands**	0.40	0.08	0.08	0.00	1.49	1.28	1.74
	East of England	0.25	0.07	0.07	0.00	1.28	1.12	1.46
	London	0.26	0.06	0.06	0.00	1.29	1.15	1.46
	North East	0.28	0.08	0.08	0.00	1.33	1.13	1.56
	North West	0.29	0.06	0.06	0.00	1.34	1.18	1.52
	South East	0.29	0.06	0.06	0.00	1.34	1.18	1.52
	West Midlands	0.28	0.07	0.07	0.00	1.33	1.16	1.52
	Yorkshire & Humberside	0.21	0.07	0.07	0.00	1.24	1.08	1.42
	South West	0.00				0.00		
Maternities (thousands)		0.00	0.00	0.00	0.34	1.00	1.00	1.01
FTE per 100 maternities	**Midwives**	0.00	0.00	0.00	0.92	1.00	0.99	1.01
	Support Workers	-0.05	0.02	0.02	0.00	0.95	0.92	0.98
	Doctors	-0.03	0.02	0.02	0.19	0.97	0.94	1.01

	Consultants	0.09	0.05	0.05	0.07	1.10	0.99	1.21
Hospital Load Ratio		0.28	0.11	0.11	0.02	1.32	1.05	1.65
Year	**2004**	0.00				0.00		
	2005	0.05	0.01	0.01	0.00	1.05	1.04	1.07
	2006	0.06	0.01	0.01	0.00	1.06	1.04	1.07
	2007	0.10	0.01	0.01	0.00	1.10	1.09	1.12
	2008	0.13	0.01	0.01	0.00	1.14	1.12	1.16
	2009	0.13	0.01	0.01	0.00	1.14	1.13	1.16
	2010	0.17	0.01	0.01	0.00	1.19	1.17	1.21
	2011	0.21	0.01	0.01	0.00	1.24	1.22	1.26
	2012	0.25	0.01	0.01	0.00	1.28	1.26	1.30