Better for Less

DISCUSSION PAPER SERIES

DP No. 04/2016

Staffing and the determinants of caesarean sections in the English NHS

Graham Cookson

Surrey Business School, University of Surrey, GU2 7XH, UK

g.cookson@surrey.ac.uk

Ioannis Laliotis

School of Economics University of Surrey, GU2 7XH, UK

i.laliotis@surrey.ac.uk

School of Economics, Faculty of Arts and Social Sciences,
University of Surrey, Elizabeth Fry Building 04 AD 00,
Guildford, GU2 7XH, Surrey, UK. T: +44(0)01483686623,
E-mail: deliveringbetter@surrey.ac.uk,
Web: www.deliveringbetter.com.

Staffing and the determinants of caesarean sections in the English NHS

Graham Cookson*[a] and Ioannis Laliotis[a]

[a]University of Surrey

Abstract

In this paper we attempt a formal modelling of the incidence of caesarean deliveries in the English NHS for the period 2000-2013. Using richer data sources than previous relevant studies, we separately model the elective and emergency caesarean section probabilities on a full set of maternal, clinical, provider and maternity workforce characteristics after removing any time, region and provider fixed effects. Regarding the maternal and clinical characteristics our results are in line with previous cross-sectional evidence. However, we further show that the greater use of consultants, doctors and midwives tends to lower the probability for a caesarean section. Moreover, caesareans are more likely to occur in providers with higher caesarean rates in the past, indicating significant levels of persistence.

Keywords: Caesarean sections; English NHS; Workforce

JEL Classification: I10; I11

*Address for correspondence: Surrey Business School, University of Surrey, UK. E-mail: g.cookson@surrey.ac.uk.
The authors thank Dr Chris Bojke (Centre for Health Economics, University of York) for his comments and suggestions. The authors acknowledge financial support from The Leverhulme Trust (RL-2012-681). The views expressed here are those of the authors and do not necessarily reflect those of the funding organisation. The usual disclaimer applies.

1 Introduction

Caesarean delivery is one of the most common inpatient surgeries in the UK, and like other developed countries, caesarean section rates in English hospitals are on the rise (Declercq *et al.*, 2011). For instance, according to calculations based on Hospital Episode Statistics, the overall caesarean section rate increased from 21.8% in 2000 to over 25% in 2013, and was as low as 9% and 12% in 1980 and 1990, respectively (Bragg *et al.*, 2010; Francome and Savage, 1993; Lancet, 2000). The increased rates of caesarean section and the unjustified routine use on very healthy mothers in the developed world is a concern for policy makers, medical professionals and mothers. Adding to these concerns is evidence of considerable variation in rates of caesarean section within the various countries of the United Kingdom, with rates in the England being the highest. A National Sentinel Caesarean Section Audit in 2001 (England, Wales and Northern Ireland) was carried out in response. Further within England, rates of caesarean section ranged between providers from 9.53% to 30.01% in 2000 and 17.67% to 34.31% in 2013 based upon calculations from Hospital Episode Statistics. The figures also appear to show a north-south divide, with higher rates in the south of England especially within London, although this could be driven by case-mix e.g. mothers are, in general, older in London and the South-East.

To date, there is no consensus on the ideal rate of caesarean sections and the observed variations between countries, regions and providers may indicate clinical uncertainty and different practice styles (Baicker *et al.*, 2006; Francome and Savage, 1993; Paranjothy *et al.*, 2005). World Health Organization recommended rate for caesarean sections in 1985 was for 10-15% (WHO, 1985). This upper threshold was a theoretical estimate at the time but several recent global studies (Althabe *et al.*, 2006; Villar *et al.*, 2006) have since supported that estimate. These studies found no decline in maternal and neonatal mortality and morbidity if the caesarean section rate was more than 15% and even an increase in maternal and neonatal mortality and morbidity when higher than 15% (Villar *et al.*, 2006). In their 2009 Handbook, WHO acknowledged the existence of a growing body of research showing the negative impact of a high caesarean section rate; that both very high and very low rates were dangerous but that the optimum rate was unknown. It identified a lack of empirical evidence for an optimum percentage or range of percentages for caesarean sections (WHO, 2009).

Despite a lack of consensus, there is concern about whether high rates of caesarean section are justified because the procedure is not without risk (Shorten, 2007). Furthermore, it is extremely expensive. Over £3 billion of the £97 billion gross expenditure was spent on maternity services in 2010, of which over £1 billion was spent on deliveries. Caesarean delivery is reimbursed at approximately 3 times the rate of normal, vaginal deliveries. Besides the perverse financial incentive to perform more caesarean sections, planned procedures offer predictability and convenience - shorter procedure timing, advanced staff planning, weekday working hours for staff (scheduling births by time of day, day of week and non-holidays, which is also cheaper when outsourcing staff), quick turnover of delivery rooms and higher fees (Sakala and Corry, 2008).

Identifying the sources of variation in caesarean section rates is central to improving the consistency and quality of obstetric care in the NHS, as well as controlling cost pressures. Many studies from a number of countries have focused on the rising caesarean section rates as well as on the factors which affect the probability of a woman to have caesarean section delivery. However, most of them rely on the use of cross-sectional data (e.g. Barley *et al.*, 2004; Bragg *et al.*, 2010; Paranjothy *et al.*, 2005) or survey data collected from hospitals. In an older study for England, Alves and Sheikh (2005) used data for the period 1996-2000, however, a considerable number of factors were omitted from their analysis.

For more than two decades, the reasons for practising such a procedure have been under an wide debate, with numerous studies discussing the risks and benefits for both mothers and infants (Menacker and Hamilton, 2010). During caesarean deliveries, major abdominal surgeries take place and there are some serious risks associated with such procedures (Bragg *et al.*, 2010; Menacker and Hamilton, 2010; Shorten, 2007). Women may experience surgical complications, they are more likely to be rehospitalized and they face increased probabilities for complications in subsequent pregnancies (Bragg *et al.*, 2010; Deneux-Tharaux *et al.*, 2006; Landon *et al.*, 2004; Lavender *et al.*, 2012; Shearer, 1993; Yang *et al.*, 2007; Villar *et al.*, 2006). Moreover, serious neonatal complications requiring intensive care may also occur, although in a less frequent basis (DiMatteo *et al.*, 1996; Lavender *et al.*, 2012; Shorten, 2007). At the same time, hospital costs for caesarean section deliveries are significantly higher as compared to those of a normal (vaginal) delivery (Menacker and Hamilton, 2010; Shearer, 1993). On the other hand, some of the benefits linked with planned caesarean deliveries include greater safety for the mother and the baby due to technological advances in the procedure, avoidance of labour pain and convenience (Bragg *et al.*, 2010; Lavender *et al.*, 2012; Shearer, 1993).

Several factors have been suggested in order to explain the rising tide of caesarean deliveries. A quite popular one is the increased maternal requests in cases where medical or obstetrical indications are small or absent, mostly for lifestyle reasons (Alves and Sheikh, 2005).[1] In these cases, women seek to plan an elective caesarean delivery because the physical or psychological benefits outweigh the risk of an adverse outcome (Fenwick *et al.*, 2010; Lavender *et al.*, 2012). Other common explanations for these upward trends include the rising maternal age, improvements in medical and technological equipment which have made the procedure safer and the growing portion of women who had previous caesarean sections in the past (Bragg *et al.*, 2010;

[1] However, Kalström *et al.* (2011) reported that the rising caesarean section rates seem to be related to factors other than preferences, after analysing a Swedish regional cohort of women.

Lancet, 2000). Some authors also mention that malpractice claims risks faced by hospitals and physicians may also lead to defensive medicine since the threat of lawsuits wary clinicians about the childbirth risks (Dubay *et al.*, 1999; Localio *et al.*, 1993; Yang *et al.*, 2009).[2] The role of financial incentives has also been explored. For example, Gruber *et al.* (1999) show that the larger fee differentials between caesarean and normal childbirth increases the caesarean delivery rates.[3] Moreover, based on an induced-demand model, Gruber and Owings (1996) also show that declines in state-level fertility rates have led obstetricians and gynaecologists to substitute vaginal deliveries with more highly reimbursed alternatives. However, according to recent evidence using individual level data for the US, the physician induced demand for convenience is quite small and the decision takes place in the ward rather than being planned in advance (Lefèvre, 2014).

Another possible explanation for the rising caesarean section trends is the low levels of appropriately trained staff in maternity units. Increased levels of staffing, training and experience for particular types of maternity workers may contribute in lowering the caesarean section rates, especially the non-elective ones, and this is a possibility which has not received any formal investigation in the relevant literature (Alves and Sheikh, 2005; Lancet, 2000). The availability of a skilled workforce is of crucial importance since the skills required for a justified medical decision of whether a woman should have a caesarean delivery can be greater than the skills needed to perform the procedure alone (Roberts and Nippita, 2015). However, even if the role of the workforce is more rarely discussed, different opinions are expressed. Some argue that caesarean section rates are lower when midwives instead of doctors attend the procedure, since the latter prefer technology and they promote caesarean deliveries in order to keep maternity care under the control of obstetricians (e.g. Wagner, 2000). Others argue that the lack of obstetric skills and the inadequate presence of consultants, especially in smaller wards, is a major reason for the growing incidence of caesarean deliveries (Savage, 2007).

In this paper we attempt a more thorough investigation of the factors affecting the incidence of caesarean section deliveries. Using Hospital Episode Statistics data for the period 2000-2013 we model the incidence of each type of caesarean section after accounting for maternal, clinical and provider characteristics. Regarding the latter, we are able to perform an explicit investigation of the role of maternity staffing on the probability of a caesarean delivery given the matching of the maternal tail of the Hospital Episode Statistics database with the Medical and Non-Medical Workforce Censuses for the years 2004-2013. Our results regarding the effects of maternal and clinical characteristics are close to those reported in the relevant literature after properly accounting for time, region and hospital fixed effects. Regarding the role of the workforce we

[2] Dubay *et al.* (1999) also found that the defensive response of physicians varies with the mother's socio-economic status, with the effect being stronger for those women with the lowest socio-economic status.

[3] This study has been recently replicated by Grant (2009) who also found a positive but much smaller impact of reimbursement fees on caesarean section rates.

present some very first evidence on the links between various types of maternity workers and the incidence of caesarean deliveries. We also show that higher caesarean delivery rates of a provider in the past are associated with higher probability of a caesarean section for women admitted in that provider.

The rest of the paper is organized as follows: Section 2 presents the data sources and some preliminary descriptive analysis. Section 3 outlines the adopted empirical strategy the results of which are discussed in Section 4. Section 5 concludes.

2 Data

For the purposes of the analysis we have linked several data sources, namely the Hospital Episodes Statistics database for the years 2000q2-2013q1 and the Medical and Non-Medical Workforce Censuses for the years 2004-2013 provided by the Health and Social Care Information Centre (HSCIC). Hospital Episode Statistics (HES hereafter) 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 registered 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. Exploiting the anonymous but unique patient identifiers in the HES records helps to append or derive relevant information from previous delivery and spells. 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. This was done mostly to avoid any confounding errors. For example, primary trusts provide a great deal of community based midwifery care (e.g. antenatal care and home deliveries), which will distort the representation somewhat.

Attached to a mother's delivery episode are records for up to nine 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 records were extracted from the HES database for the period 2000q2-2013q1 by the HSCIC along with non-delivery episodes for these mothers.[4]

Table 1 presents some basic descriptive statistics regarding the outcome, mother-level and trust-level

[4]These were stored in an SQL database on a secure, private network. Full details on 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 the NHS and HSCIC under the HES and Electronic Staff Record (ESR) data sharing agreements.

variables. These are calculated using the estimation sample after regressing the caesarean delivery indicator on a vector containing individual and hospital variables as well as year and region fixed effects. After removing any missing value from key characteristics, the remaining sample consists of 7,484,471 mothers who delivered a baby in one of 165 English NHS providers during the period 2000-2013.[5] The outcome variables which are of our main interest here, are three binary indicators regarding the incidence of a caesarean section (general case), an elective (planned) caesarean section and a non-elective (emergency) caesarean section. Figure 1 displays their evolution over the period under examination. The total caesarean section rate has increased from 21.8% in 2000 to 25.1% in the first quarter of 2013. The elective caesarean section rate has escalated more rapidly, especially after 2011. Figure 1 also reveals a significant degree of variation in the caesarean section rates each year, indicating large disparities across regions and providers.

[Figure 1 about here]

The individual-level variables can be grouped into two categories: maternal and clinical. The maternal category includes some basic demographic variables, such as the age category, the ethnic group and the socio-economic status of mothers. The latter is based on the socio-economic quintile of their residence area and it is measured using the 2007 Index of Multiple Deprivation (IMD hereafter) at the super output area (DCLG, 2011).[6] The clinical variables include the mother's parity (whether she is nulliparous or not), the baby's weight category (classified into four weight categories, i.e. "very low" for newborns weighting lower than 1500 grams, "low" for newborns between 1500 and 2499 grams, "normal" for those between 2500 and 4999 grams and "high" for those weighting more than 5000 grams), the incidence of a previous caesarean section, a binary variable indicating singleton births, the gestational age (in weeks) and a binary variable classifying women as "high risk" or not. In this paper we adopted the innovative method developed in Sandall *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 National Institute for Health and Care Excellence (NICE hereafter) intrapartum care guideline (NICE, 2007) 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

[5] The descriptive statistics calculated using the total available sample for each variable were practically identical to those of Table 1 and they are available from the authors upon request. Therefore our results are not systematically affected from missing observations.

[6] The index is constructed from 38 indicators across seven weighted domains measuring an area's income, deprivation, employment deprivation, health deprivation and disability, education, skills and training, barriers to housing and service, crime and the local environment. The index is produced periodically for the Department of Communities and Local Government by researchers at the University of Oxford. The raw scores are meaningless, and it is the relative deprivation that is relevant. Here we categorize the raw scores into deprivation quintiles.

pregnancy.[7]

[Table 1 about here]

The HES data were extracted to a secure, private R-Studio server for statistical analysis where they then were matched to the maternity workforce dataset. The HSCIC provided staffing data for English trusts under a Data Sharing Agreement. The staffing data were annual Full Time Equivalent (FTE) members by grade and hospital. Data provided for 2004 to 2013 were taken from the Non-Medical Workforce Census as at 30 September in each specified year. NHS Hospital and Community Health Service (HCHS) data for medical staff in Obstetrics and Gynaecology by organisation and grade were taken from the Medical Workforce Census as at 30 September in each specified year for the period 2004-2013. From the staffing data, the main focus is in the following four categories: doctors, consultants, registered midwives and support workers. The largest maternity staff group is registered midwives with a mean annual FTE of 131.2 and a standard deviation of 60.8. They are followed by doctors (mean=23.3, standard deviation=12.4), consultants (mean=10.7, standard deviation=5.6) and support workers (mean=5.6, standard deviation=9.9). However, for reasons of comparability between larger and smaller organisations we calculated the annual FTE per 100 deliveries for each staff group. The annual total number of deliveries per trust was derived using the total count of delivery records contained in the HES data by trust and year.[8] As before, registered midwives are clearly the largest staff group. Their mean FTE per 100 maternities regarding the period 2004-2013 is 4.3 with a standard deviation equal to 3.8. Next are doctors (mean=1.9, standard deviation=46.01), consultants (mean=0.85, standard deviation=18.2) and support workers (mean=0.18, standard deviation=0.41). Figure 2 presents the evolution of the annual FTE per 100 maternities for each staff group over the period under examination. The annual FTE per 100 deliveries for consultants and support workers have increased substantially during the last decade. The FTE per 100 maternities for doctors has also increased since the beginning of the period under study althought there is a decline after 2009. Regarding registered midwives, their average annual FTE per 100 deliveries has decreased since 2004, however there is an upward trend after 2008.

[Figure 2 about here]

However, the staffing data described above are annual census data and so they provide only one observation per trust each year, hence they have limited variation over time and across regions. Their low degree of variation may hinder the estimated results, as it was evident in other studies (Cookson *et al.*, 2014; Sandall *et al.*, 2014). Moreover a trust's annual total or occupation-specific FTE can be correlated

[7]See pages 23-24 in Sandall *et al.* (2014) for further details.

[8]Alternatively, we could use the total number of deliveries per trust each year, as reported in the ONS Birth Registration Records. Yet the correlation coefficient between these two measures was found to be remarkably high ($\simeq 0.97$) while the results of our analysis remained practically the same after using either of the two.

with the casemix so this could impose some bias to the results. For a better proxy of the temporal and the intra-trust variation we matched the HES and the Workforce Censuses data to generate a Hospital Load Ratio (HLR) variable.[9] First, we used the delivery dates to calculate the number of maternities on the same day at the same provider (i.e. the hospital load). Despite the fact that this is a crude measure of the service demand, because it ignores the length of deliveries or other women who did not deliver the same day they were admitted to the maternity service, it does have a much larger degree of variation. The HLR variables were created by dividing the hospital load by the occupation-specific annual FTE of each trust. Therefore we have a patient-level measure of the intensity of each trust with respect to each maternity worker group. As pointed out in Cookson *et al.* (2014) all staff are not working at the same time in the delivery ward. But a reasonable assumption is that the shifts and splits between wards follow similar patterns. Therefore, if a trust has 60 midwives on its payroll and on a particular date there are 15 deliveries then the HLR for registered midwives would be 0.25. If the next day there are only 6 deliveries this variable would fall to 0.10. Therefore, for any given maternity worker group, an increasing HLR can be considered as an undesirable event. As illustrated in Table 2, support workers have the highest mean HLR which is equal to 4.31 with a standard deviation of 6.35. They are followed by consultants (mean=1.29, standard deviation=0.57), doctors (mean=0.61, standard deviation=0.47) and registered midwives (mean=0.11, standard deviation=0.13). This variable is difficult to be displayed in a graph due to the large number of observations. However, Figure 3 attempts to illustrate the variation in staff-patient ratios. It plots data from 5 providers in 2013. All the providers in the dataset were ordered by their 2013 average Hospital Load Ratio and those at each quartile were plotted on a daily basis for the whole year. Superimposed on the plot are the total sample's minimum, maximum and mean values as dotted horizontal lines (Cookson *et al.*, 2014).

[Figure 3 about here]

In addition, a binary variable for whether the hospital was a University Teaching Hospital was generated from data provided by Association of University Hospital Trusts (2014). Similarly, based on the NHS Foundation Trust Directory, a binary indicator regarding the foundation status of each trust was also added in the dataset. The relationship between the teaching status of the hospital and the caesarean probability has been documented in older studies (e.g. Oleske *et al.*, 1991). Therefore, including status indicators can control for the organizational, technological and workforce characteristics of these providers which in turn may be associated with the likelihood of caesarean deliveries.

[Table 2 about here]

[9] Regarding the staffing implications on hospital outcomes, this variable was first used in Cookson *et al.* (2014). The authors are thankful to Dr Chris Bojke at Centre for Health Economics (University of York) for suggesting this potential solution to overcome the lack of variation in conventional maternity staffing variables.

Overall, these are the same variables as used in Sandall *et al.* (2014) with the exception of service configuration, i.e., a categorical variable that captured the service configuration (e.g. Midwifery Led Unit) that was provided by BirthChoiceUK. However that was a cross sectional study using only 2010 data. In this paper, a much larger period is covered, i.e. from 2000 to 2013 when only HES data are used and from 2004 to 2013 when the maternity tail of the HES data is matched to the maternity workforce censuses. Moreover, the service configuration variable was not found to be statistically significantly related to outcomes in Sandall *et al.* (2014), and to the extent to which configuration, or any other trust-level characteristic, is largely expected to be time invariant, any potential confounding problems should be eliminated from the use of provider fixed effects.

Finally, a variable indicating the percentage of caesarean deliveries in each provider during the previous year is constructed. In this way we try to tackle any biases caused from omitted variables, especially at the trust level, since we either do not know or observe all the explanatory variables and some of them can be correlated with those already included. Moreover, the lagged caesarean section rate of the provider can serve as a proxy for the "caesarean culture" or the "practice style" of that provider which can also be an important determinant of the caesarean probability.

3 Empirical strategy

The main objective of this paper is to model the probability of a caesarean section delivery in the English NHS during the period 2000-2013 using very rich sources of data and investigating the implications of provider staffing levels. Elective and non-elective caesarean deliveries will be separately examined, since the influence from maternal, clinical and hospital characteristics may not have the same sign or magnitude in each case. Our empirical strategy will rely on estimating linear probability models of the following form:

$$\text{c-section}_{it} = \mathbf{M_{it}}\boldsymbol{\beta} + \mathbf{C_{it}}\boldsymbol{\gamma} + \mathbf{H_{j(i,t)t}}\boldsymbol{\delta} + \psi_{j,(i,t)} + \mu_t + \lambda_r + \epsilon_{it} \qquad (1)$$

where c-section_{it} is a binary indicator taking the value 1 if the i-th woman in the t-th year is going through a caesarean section delivery and ϵ_{it} is the disturbance term.[10] The function $j(i,t)$ maps woman i in provider j at time t.[11] $\mathbf{M_{it}}$ is a vector containing maternal characteristics such as age (age categories with women between 15 and 19 years old being the reference group), ethnic categories (the base ethnic group consist

[10] The use of OLS techniques to estimate the marginal effects of limited dependent variable models is very popular in applied microeconometrics and health economics, e.g. Cooper *et al.* (2011) used OLS to estimate limited dependent variable models while using HES data. Despite that nonlinear models may fit better than linear ones when the dependent variable is limited, it makes little difference when estimating marginal effects (Angrist, 2001; Angrist and Pischke, 2008).

[11] Given the design of the HES data, each delivery is recorded independently and we are not able to follow mothers over time. Therefore our model does not incorporate any time invariant components at the individual level.

of women having white background, i.e. British, Irish and any other white background), socio-economic status (women from the most deprived areas are the reference group) and an urban status indicator. $\mathbf{C_{it}}$ is a vector containing clinical characteristics, i.e. a binary variable indicating whether a woman is nulliparous or not, birth weight categories ("very low" is the reference weight group), a dummy variable regarding the incidence of a previous caesarean section and a binary variable classifying women into "high risk" ones or not. The time (μ_t) and region (λ_r) components are assumed to be fixed and they are estimated using time and Strategic Health Authority dummies, respectively.

Hospital-level covariates are included in vector $\mathbf{H_{j(i,t)t}}$. Apart from dummy variables indicating the teaching or the foundation status of each hospital, it contains a complete set of trust binary indicators. Therefore, apart from controlling for individual-level heterogeneity using the aforementioned demographic and clinical characteristics, we are able to control for time-invariant provider-level heterogeneity using a full set of hospital dummies. Their insertion to the explanatory vector draws any fixed effects out of the disturbance term, hence the determinants of caesarean sections are estimated through within-hospital deviations from aggregate trends. Moreover, they could contribute in capturing a part of the variation which cannot be attributed to patient characteristics or other observable hospital characteristics. This is often being labelled as "local practice style" (e.g. Baicker *et al.*, 2006) while other studies argue for a "provider-led" trend, especially for elective caesareans (e.g. Barley *et al.*, 2004). The term $\psi_{j,(i,t)}$ is assumed to be fixed over time for providers. Controlling for provider fixed effects, relaxes the implicitly imposed assumption of no correlation between observables and provider heterogeneity and improves the consistency of the estimated parameters.

Apart from the conventional hospital-level controls often reported in similar studies, a novel feature of this paper is that it explicitly investigates the influence of maternity staffing levels on the incidence of caesarean deliveries. This is made possible due to the matching of the maternity workforce censuses to the maternity tail of the HES database. We attempt to control for this time-variant provider-level source of heterogeneity through three alternative ways. The first one is to include into the $\mathbf{H_{j(i,t)t}}$ vector the FTE per 100 maternities for the four maternity worker groups i.e. (consultants, doctors, registered midwives and support workers) by trust and year. The second is to use the ratio of the annual group-specific FTE to the total annual FTE of the maternity unit; however, this still provides with only one observation by trust per year. The third alternative is to use the maternity worker group-specific HLR variables, in order to take advantage of their greater degree of temporal and intra-trust variation. Finally, the probability of the i-th woman to have a caesarean section delivery in the j-th trust in period t is also regressed on the caesarean section rate of that trust in period $t-1$. Preliminary analysis of the data has shown that there is a persistently substantial degree of variation in caesarean section rates among English hospitals with many of them lying well above or below the national average each year. Among other things such as the different needs or the characteristics of the local treated population, this lagged variable could offer a more flexible way to proxy the caesarean section culture of each trust which is considered to explain a part of the residual variation reported in studies using cross-sectional data. If the rising caesarean section trend is provider-led up to some point, the lagged trust-level rates would be important determinants of the probability of caesarean deliveries. Moreover, the inclusion of these lagged rates could contribute in removing any biases caused by omitted variable problems, especially at the provider level.

Given the dichotomous nature of all the outcomes of interest, the Linear Probability Model (LPM) is used in order to model caesarean section deliveries, in general as well as for electives and non-electives separately. Because the error term in the LPM is by definition heteroskedastic, we estimate standard errors which are robust to heteroskedasticity. Moreover, we apply a clustering by trust correction in order to allow for common error components for mothers who delivered in the same trust (Moulton, 1986;1990).

4 Results

Table 3 displays the results obtained while modelling the probability of a woman to have a caesarean section delivery (either elective or not) in an English NHS hospital during the period 2000-2013. We follow a step-wise approach by gradually augmenting the explanatory vector with additional controls. In column [1], the probability of a caesarean section delivery is regressed only upon a conventional set of maternal, clinical and hospital characteristics typically used in previous cross-sectional studies (e.g. Barley *et al.*, 2004; Bragg *et al.*, 2010).[12] The estimated coefficients have the expected sign and magnitude while most of them are also highly significant. The probability of a caesarean section delivery increases monotonically with age, e.g. women older than 40 years have 21% higher probability for a caesarean as compared to women between 15 and 19 years of age. Women of Afro-Caribbean ethnic background have nearly 5% higher probability to have a caesarean delivery as compared to those of British, Irish or other white background. Women of Asian ethnic background have a marginally smaller probability for a caesarean section. The probability of a caesarean section is increased for women from more affluent areas, as compared to women living in more deprived areas as classified by the Index of Multiple Deprivation. Women living in urban areas also appear to be more likely to deliver their baby with a caesarean section. Overall, these results are in accordance with

[12]Some individual-level variables had to be omitted because they were poorly recorded. The gestational age is such an example. Although its relationship with caesarean deliveries has been under examination (e.g. Alves and Sheikh, 2005; Bettegowda *et al.*, 2008; Paranjothy and Thomas, 2005) its inclusion would lead to a significant loss of sample. This has been mentioned as a problem in other studies as well, e.g. in Bragg *et al.* (2010). However, even when it was included the results of the rest of the explanatory variables were similar to those reported here. Regarding the effect of gestational age on the caesarean probability, it seems to be negative in the case of planned and positive in the case of emergency procedures. Full results are available from the authors upon request.

what is so far known by previous studies (e.g. Bragg *et al.*, 2010; Alves and Sheikh, 2005).

The probability of a caesarean is also higher (by 14% to 16%) for nulliparous women, while this probability tends to get smaller the higher the weight of the baby. The incidence of a previous caesarean section seems to exert the strongest influence (Bragg *et al.*, 2010; Paranjothy and Thomas, 2005); the probability of those women to have a caesarean section is by nearly 45% higher as compared to those who had never have a caesarean section delivery before. In singleton births, the probability of a caesarean section is by 20%-23% smaller, while women who have been classified as "high risk" ones are also more likely to deliver with a caesarean section. The estimated effects of the university and the foundation hospital statuses seem to depend on the model specification. In the full model specification, both the teaching and the foundation statuses seem to lower the caesarean probability. Regarding the teaching status, similar evidence has been given elsewhere, e.g. in Oleske *et al.* (1991).

In column [2] we take advantage of the multi-year structure of our dataset and we control for year and region (Strategic Health Authority) fixed effects. Their inclusion seems to affect mostly the ethnic background dummies, the urban and the deprivation indicators, with the probability of having a caesarean section delivery following a bell-shaped path across the IMD index quintiles. Although more detailed results are not reported here, most of this change is stems from the inclusion of the SHA indicators. These account for the differences between regions regarding the concentration of women from various ethnic groups (e.g. they are mostly concentrated in London), the degree of urbanization (it is significantly lower in the South West and the East of England) and the distribution of women according to their socio-economic status (in the South East and the East of England more than the 50% is located in the most affluent areas).

Regarding the year and the SHA fixed effects *per se*, the reported p-values of the F-tests for their joint significance seem to justify their inclusion to the models.

[Table 3 about here]

Assuming that the provider-level heterogeneity (the term $\psi_{j(i,t)}$ in equation (1)) is not correlated with the observed explanatory variables is a rather strict assumption. For example, management quality and other unobserved organizational factors which are fairly constant over time may be correlated with both the outcome and the explanatory variables. Therefore using random effects methods may produce inconsistent estimates and will not identify the true effect of time-invariant hospital characteristics. Controlling for unobserved time-invariant heterogeneity at the provider level in column [3] of Table 3, does not alter the results significantly. Yet, the provider binary indicators are jointly significant at the 1% level. All the estimated coefficients retain their sign and magnitude as in the previous model specifications. The only notable change is on the university and the foundation trust indicators which do not vary over time and now become negative and statistically significant at the 1% level. Hence, a woman delivering in a teaching hospital or a NHS Foundation Trust are less likely to have a caesarean section after adequately controlling for individual and provider-level heterogeneity.

Next, in column [4], we investigate whether maternity staffing levels are associated with the caesarean probability.[13] According to many studies and reports (e.g. Alves and Sheikh, 2005; Lancet, 2000; Savage, 2007; Wagner, 2000), the use of more staff or more skilled and experienced staff may contribute in lowering the caesarean section rates and promote normal births instead. However, most of these suggestions stem primarily from anecdotal evidence. This is the first formal attempt to explore the implications of maternity staffing levels on the probability of a caesarean section using the richest data available. Although the reported coefficients are not statistically significant, it seems that the greater use of consultants is negatively linked to the incidence of caesarean section deliveries. Doctors and support workers enter with a positive sign, while the estimated coefficient of registered midwives is negative although quite close to zero.

Finally, column [6] reports the estimated results from a model specification which also includes a control for the trust-level rate of caesarean section deliveries during the previous year. This lagged variable can be a strong determinant of the probability of caesarean sections since it can tackle some potential problems, especially due to the presence of omitted variables at the trust level. Moreover, it may serve as a proxy to the caesarean culture or the local practice which is believed to be associated with the rising caesarean section rates. Although the estimated impacts of the rest of the maternal and clinical variables remain practically the same, it seems that higher trust caesarean section rates in the past are associated with a higher probability of a woman to have a caesarean section delivery.[14] The inclusion of the lagged provider-level caesarean section rate deflates the estimated coefficient of FTE consultants per 100 maternities (from -.120 to -.094) and leaves the impacts of the other staffing variables practically unaffected.

Next we repeat the same sets of estimations for elective and non-elective caesarean sections separately. The reason is that the demographic, clinical and hospital characteristics may affect in a different way the probability of each type of caesarean delivery and considering them separately would provide with more insight regarding their determinants. Table 4 reports the results obtained after modelling the incidence of elective caesareans and Table 5 those of the emergency cases. Regarding the impact of the age categories, the results are quite similar to those of the general case (Table 3), i.e. the probability steadily increases with age. The first evidence of a differentiation comes from the ethnic background dummies. Women of white background are more likely to have an elective caesarean, and women of other ethnic backgrounds

[13] This leads to a sizeable reduction of the estimation sample since we do not have maternity staffing information for every trust, however this does not seem to affect the results.

[14] We have also experimented with half-year, quarter and month lags of the trust-specific caesarean section rates which have also led us to the same conclusions. The results are available upon request from the authors.

are more likely to undergo a non-elective caesarean section procedure. These results hold no matter the empirical specification of the model. Moreover, in accordance to previous empirical evidence, it seems that the probability of an elective caesarean procedure is higher for residents of more affluent areas (e.g. Alves and Sheikh, 2005; Barley *et al.*, 2004). However, no significant differentiation occurs based on the level of deprivation for the non-elective cases. Women from urban areas are more likely to have an emergency caesarean procedure while the probability of an elective caesarean delivery is marginally lower for women living in urban areas.

[Table 4 about here]

Nulliparous women are more likely to have a caesarean and the effect is much stronger for the emergency cases. Birth weight affects the probability for planned and emergency caesareans in a different way. More specifically, the probability of an elective procedure increases with birth weight while the probability of an emergency caesarean delivery is lower the larger the birth weight is. The incidence of a previous caesarean section affects the probability in a positive way, however, the effect is much stronger for the elective cases (the probability is nearly 38% larger for elective and approximately 10% for emergency procedures). In singleton births the probability is lower in both cases, but it is approximately two times higher for elective caesareans. As expected, high risk women are always facing an increased probability either the procedure is planned or not. Women delivering in foundation trusts have a lower probability for either a planned or a non-elective caesarean, however, in university hospitals the probability of an elective caesarean procedure seems to be higher.

[Table 5 about here]

Regarding the maternity staffing variables, the results are in line with the general case. Although we did not get any significant estimates, consultants always enter with a negative sign, indicating that their greater use could be associated with lower caesarean section rates. Doctors appear to have a negative sign in the case of elective and a positive sign in the case of non-elective caesarean deliveries. Support workers always enter with a positive sign while registered midwives have a positive sign in the case of elective caesareans and a negative sign in the case of emergency caesareans (but they are closed to zero in both cases). Finally, the lagged provider-level caesarean section rate is a positive and quite strong determinant of caesarean section probability in both kinds of the procedure.

However, as outlined in a previous section, using the FTE per 100 maternities for each maternity worker group provides only with a single trust-year observation for each staffing variable. In Table 6 we experiment with some alternative ways to take the role of medical and clinical staff into consideration. The first one

(Panel A) is to use the percentage FTE of each maternity worker type with respect to the total annual FTE of all medical and clinical staff of a given provider. However, this still generates only one observation for each provider per year. Therefore, the statistical significance of the results will still be affected from the low degree of variation. Indeed, as seen in Panel A of Table 6, the estimated coefficients have the expected sign and are more presentable than those reported in previous tables, however, they are not significant in this case either. More doctors are always associated with increased caesarean probabilities and consultants with lower ones. More midwives and support workers increase the likelihood of a planned caesarean deliveries and reduce that of emergency caesareans.

As an alternative, we experiment with the Hospital Load Ratio variables for each worker type in order to benefit from the greater degree of variation. The results are presented in last two panels of Table 6. Each type of caesarean section delivery is regressed upon the full model specification. The estimated coefficients of the rest of the variables are not reported since the results are quite similar those presented so far. Regarding the general case of caesarean section deliveries (column [1] of Table 6), it seems that a higher HLR for consultants increases the probability of a caesarean delivery. The rest HLR variables do not seem to be statistically significant but they all have positive signs (except for the support workers). The results are stronger in the case of planned caesarean deliveries (column [2]). The HLR variables for consultants, doctors and nurses are highly statistically significant and once again enter with a positive sign. Therefore, elective caesarean deliveries seem to be more likely in trusts with increased HLR for these types of maternity workers. However, this picture is reversed in the case of non-elective caesareans. Higher levels of HLR for doctors, consultants and nurses are negatively linked with the probability of an emergency procedure.

From Panel B of Table 6 it seems that support workers are not systematically associated with any of the outcomes of interest. Moreover, given the construction of the HLR variables, numerous missing cases were generated since the annual FTE for support workers was zero for several providers. This led to a considerable reduction in the estimation sample as compared to those reported in previous tables. Therefore, in order check if the results regarding the HLR variables were affected from this sample attrition, we repeat the same set of estimation but excluding the HLR for support workers. The results are displayed in Panel C of Table 6. In general, the results are qualitatively and quantitatively similar. Higher ratios for consultants, doctors and registered midwives are positively associated with the incidence of an elective and negatively with that of a non-elective caesarean delivery. However, further formal research with more accurate data (i.e. collected at the ward level) should be carried out in order to explore more closely the implications of medical and clinical staff on the incidence of caesarean sections.

5 Conclusions

In this paper we presented some further evidence regarding the factors affecting the incident of a caesarean section delivery in the English NHS for the period 2000-2013. In order to overcome some serious drawbacks and limitations often reported in the relevant literature, we collated several detailed data sources, namely the Hospital Episodes Statistics database for the years 2000-2013, the Medical Workforce Census and the Non-Medical Workforce Census for the years 2004-2013. Merging these databases allowed us to perform a more thorough examination of the incidents affecting the probability of a caesarean section delivery for mothers admitted in English NHS providers. Contrary to studies using survey or cross-sectional data, employing a dataset that spans over a large number of years is advantageous since it allowed to control for unobserved time invariant heterogeneity at the provider level and proxy the caesarean section culture of each trust which is considered to be an important determinant of caesarean deliveries. A novel feature of this study is that it is the first one to assess the implications of medical and non-medical staff which, despite being widely discussed, they had not received any formal investigation.

In general, most of the estimated results are in line with the evidence so far. Caesarean section deliveries are more likely for older women, women from more affluent areas, those who had had a caesarean section in the past, nulliparous and women classified as high risk ones. Women of non-white background have lower probability of a planned caesarean delivery and a higher probability of an emergency caesarean. The caesarean probability is also lower for women admitted in NHS Foundation Trusts but it is higher for women having elective procedures in teaching hospitals. The probability of a woman to have a caesarean delivery also increases with the trust caesarean section rate of the previous year, with this effect being more pronounced in the emergency cases.

We have also presented some very first evidence regarding the role of the maternity workforce in the incidence of caesarean sections. At first, our results seem to support the view that the greater use of skilled and experienced doctors (consultants) are associated with lower caesarean section probabilities. The greater use of registered midwives is also seemed to be negatively linked with caesarean deliveries, especially the emergency ones. The results obtained using the Hospital Load Ratio variables which have a greater degree of variation as compared to the annual Full Time Equivalent figures for each trust, indicate that higher levels of hospital load per staff group increase the probability of caesarean delivery. However, higher levels of hospital load per group are positively associated with the incidence of a caesarean delivery in the case of the elective procedures and negatively linked in the case of emergency caesareans. However, despite this first empirical evidence, more accurate data are needed, e.g. collected at the ward level, in order to assess the implications of medical and clinical staff on the incidence of caesarean section deliveries.

References

[1] Althabe, F., Sosa, C., Belizán, J.M., Gibbons, L., Jacquerioz, F. and Bergel, E. (2006), "Cesarean Section Rates and Maternal and Neonatal Mortality in Low-, Medium-, and High-Income Countries: An Ecological Study", *Birth*, 33(4): pp. 270–277.

[2] Alves, B. and Sheikh, A. (2005), "Investigating the Relationship Between Affluence and Elective Caesarean Sections", *British Journal of Obstetrics and Gynaecology*, 112: pp. 994-996.

[3] Angrist, J.D. (2001), "Estimation of Limited Dependent Variable Models with Dummy Endogenous Regressors: Simple Strategies for Empirical Practice", *Journal of Business & Economic Statistics*, 19(2): pp. 2–16.

[4] Angrist, J.D. and Pischke, J.S. (2008), *Mostly Harmless Econometrics: An Empiricist's Companion*, Princeton University Press, Princeton, NJ.

[5] Baicker, K., Buckles, K.S. and Chandra, A. (2006), "Geographic Variation in the Appropriate Use of Cesarean Delivery", *Health Affairs*, 25(5): pp. w355–w367.

[6] Barley, K., Aylin, P., Bottle, A. and Jarman, B. (2004), "Social Class and Elective Caesareans in the English NHS", *British Medical Journal*, 329(7458): 148.

[7] Bettegowda, V.R., Dias, T., Davidoff, M.J., Damus, K., Callaghan, W.M. and Petrini, J.R. (2008), "The Relationship Between Cesarean Delivery and Gestational Age Among US Singleton Births", *Clinics in Perinatology*, 35(2): pp. 309–323.

[8] Bragg, F., Cromwell, D.A., Edozien, L., Gurol-Urganci, I., Mahmood, T.A., Templeton, A. and van der Meulen, J.H. (2010), "Variation in Rates of Caesarean Section Among English NHS Trusts After Accounting for Maternal and Clinical Risk: Cross Sectional Study", *British Medical Journal*, 341: c5065.

[9] Cookson, G., Jones, S., van Vlymen, J. and Laliotis, I. (2014), "The Cost-Effectiveness of Midwifery Staffing and Skill Mix on Maternity Outcomes", A Report for the National Institute for Health and Care Excellence.

[10] Cooper, Z., Gibbons, S., Jones, S. and McGuire, A. (2011), "Does Hospital Competition Save Lives? Evidence from the English NHS Patient Choice Reforms", *Economic Journal*, 121(554): pp. F228–F260.

[11] DCLG (2011), "The English Indices of Deprivation 2010", Neighbourhood Statistics Release, URL: `https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/6871/1871208.pdf`, accessed on 10 December 2014.

[12] Declercq, E., Young, R., Cabral, H. and Ecker, J. (2011), "Is a Rising Caesarean Delivery Rate Inevitable? Trends in Industrialized Countries, 1987 to 2007", *Birth*, 38(2): pp. 99–104.

[13] Deneux-Tharaux, C., Carmona, E., Bouvier-Colle, M.H. and Bréart, G. (2006), "Postpartum Maternal Mortality and Cesarean Delivery", *Obstetrics & Gynecology*, 108(3, Part 1): pp. 541–548.

[14] DiMatteo, M.R., Morton, S.C., Lepper, H.S., Damush, T.M., Carney, M.F., Pearson, M. and Kahn, K.L. (1996), "Cesarean Childbirth and Psychosocial Outcomes: A Meta-Analysis", *Health Psychology*, 15(4): pp. 303–314.

[15] Dubay, L., Kaestner, R. and Waidmann, T. (1999), "The Impact of Malpractice Fears on Cesarean Section Rates", *Journal of Health Economics*, 18(4): pp. 491–522.

[16] Fenwick, J., Staff, L., Gamble, J., Creedy, D.K. and Bayes, S. (2010), "Why do Women Request Caesarean Section in a Normal, Healthy First Pregnancy?", *Midwifery*, Volume 26, Issue 4, August 2010, Pages 394-400

[17] Francome, C. and Savage, W. (1993), "Caesarean Section in Britain and the United States 12% or 24%: Is Either the Right Rate?", *Social Science & Medicine*, 37(10): pp. 1199–1218.

[18] Grant, D. (2009), "Physician Financial Incentives and Cesarean Delivery: New Conclusions From the Healthcare Cost and Utilization Project", 'emphJournal of Health Economics, 2(1): pp. 244–250.

[19] Gruber, J., Kim, J. and Mayzlin, D. (1999), "Physician Fees and Procedure Intensity: The Case of Cesarean Delivery", *Journal of Health Economics*, 18(4): pp. 473–490.

[20] Gruber, J. and Owings, M. (1996), "Physician Financial Incentives and Cesarean Section Delivery", *RAND Journal of Economics*, 27(1): pp. 99–123.

[21] Kalström, A., Nystedt, A., Johansson, M. and Hildingsson, I. (2011), "Behind the Myth: Few Women Prefer Caesarean Section in the Absence of Medical or Obstetrical Factors", *Midwifery*, 27(5): pp. 620–627.

[22] Lancet [editorial] (2000), "Caesarean Section on the Rise", *Lancet*, 356(9243): pp. 1697.

[23] Landon, M.B., Hauth, J.C., Leveno, K.J., Spong, C.Y., Leindecker, S., *et al.* (2004), "Maternal and Perinatal Outcomes Associated with a Trial of Labor After Prior Cesarean Delivery", *New England Journal of Medicine*, 351: pp. 2581–2589.

[24] Lavender, T., Hofmeyr, G.J., Neilson, J.P., Kingdon, C., Gyte, G.M.L. (2012), "Caesarean Section for Non-Medical Reasons at Term", *Cochrane Database of Systematic Reviews*, Issue 3. Art. No.: CD004660.

[25] Lefèvre, M. (2014), "Physician Induced Demand for C-Sections: Does the Convenience Incentive Matter?", Working Paper 14/08, Health Econometrics and Data Group (HEDG), University of York.

[26] Localio, A.R, Lawthers, A.G., Bengtson, J.M., Hebert, L.E., Weaver, S.L., Brennan, T.A. and Landis, J.R. (1999), "Relationship Between Malpractice Claims and Cesarean Delivery", *Journal of the American Medical Association*, 269(3): pp. 366–373.

[27] Menacker, F. and Hamilton, B.E. (2010), "Recent Trends in Cesarean Delivery in the United States", *National Center for Health Statistics Data Brief*, 35: pp. 1–8.

[28] Moulton, B.R. (1986), "Random Group Effects and the Precision of Regression Estimates", *Journal of Econometrics*, 32(3): pp. 385–397.

[29] Moulton, B.R. (1990), "An Illustration of a Pitfall in Estimating the Effects of Aggregate Variables in Micro Units", *Review of Economics and Statistics*, 72(2): pp. 334–338.

[30] National Institute for Health and Care Excellence (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 on 10 September 2014.

[31] Oleske, D.M., Glandon, G.L., Giacomelli, G.J. and Hohmann, S.F. (1991), "The Cesarean Birth Rate: Influence of Hospital Teaching Status", *Health Services Research*, 26(3): pp. 325–337.

[32] Paranjothy, S., Frost, C. and Thomas, J. (2005), "How Much Variation in CS Rates Can Be Explained by Case Mix Differences?", *British Journal of Obstetrics and Gynaecology*, 112(5): pp. 658–666.

[33] Roberts, C.L. and Nippita, T.A. (2015), "International Caesarean Section Rates: The Rising Tide", *Lancet Global Health*, 3(5): pp. e241–e242.

[34] Sakala, C. and Corry, M.P. (2008), "Evidence-Based Maternity Care: What It Is and What It Can Achieve", New York: Milbank Memorial Fund 2008, URL: `http://www.childbirthconnection.com/pdfs/evidence-based-maternity-care.pdf`, accessed on 5 June 2015.

[35] 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 and Quality in Maternity Care: A Population-Based, Cross-Sectional Study", *Health Services and Delivery Research*, 2(38).

[36] Savage, W. (2007), "The Rising Caesarean Section Rate: A Loss of Obstetric Skill?", *Journal of Obstetrics and Gynaecology*, 27(4): pp. 339–346.

[37] Shearer, E.L. (1993), "Cesarean Section: Medical Benefits and Costs", *Social Science & Medicine*, 37(10): pp. 1223–1231.

[38] Shorten, A. (2007), "Maternal and Neonatal Effects of Caesarean Section", *British Medical Journal*, 335: pp. 1003–1004.

[39] Villar, J., Valladares, E., Wojdyla, D., Zalaveta, N., Carroli, G., Velazco, A., *et al.* (2006), "Caesarean Delivery Rates and Pregnancy Outcomes: The 2005 WHO Global Survey on Maternal and Perinatal Health in Latin America", *Lancet*, 367: pp. 1819–1829.

[40] Wagner, M. (2000), "Choosing Caesarean Section", *Lancet*, 365(9242): pp. 1677–1680.

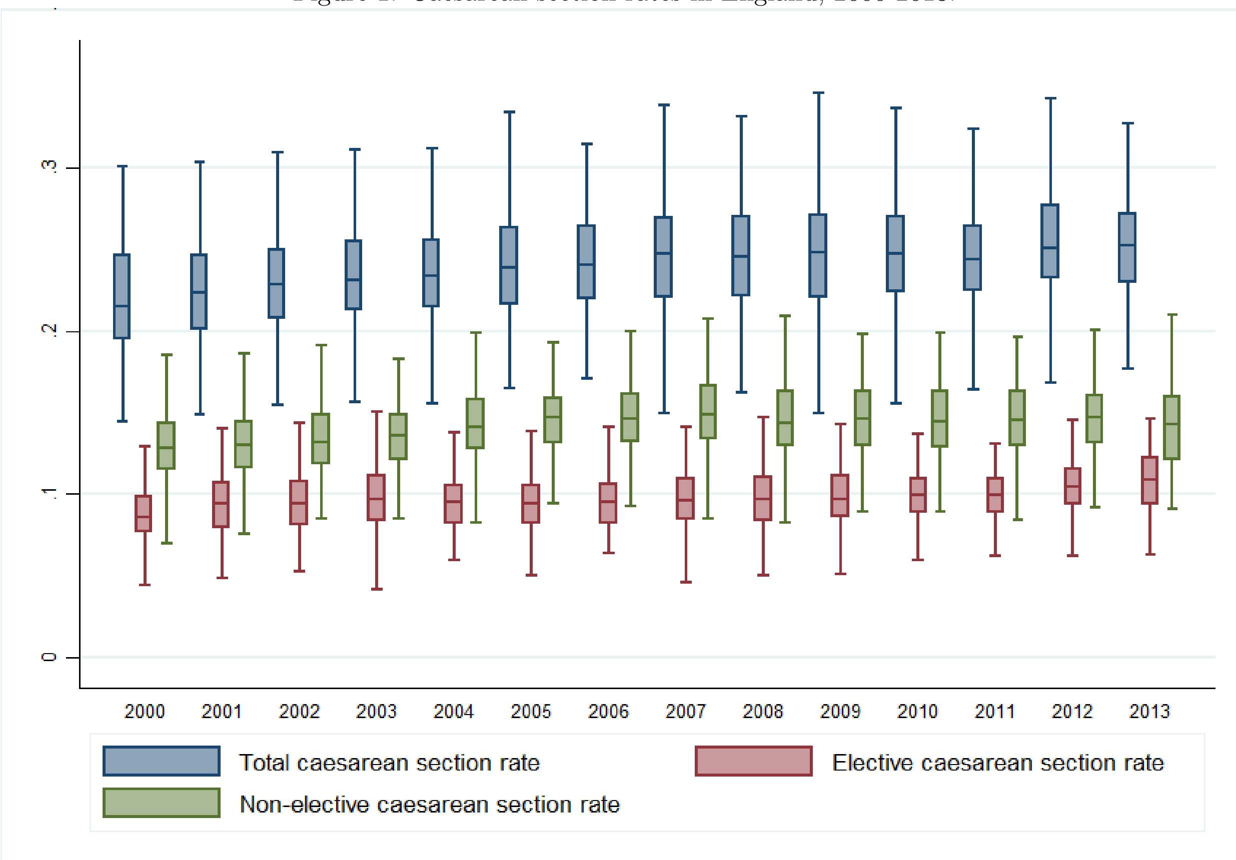
[41] World Health Organization (1985), "Appropriate Technology for Birth", *Lancet* 2, 8452: pp. 436–437.

[42] World Health Organization, UNFPA, UNICEF and AMDD, "Monitoring Emergency Obstetric Care: a Handbook", Geneva: WHO; 2009.

[43] Yang, Q., Wen S.W., Oppenheimer L., Chen X.K., Black D., Gao J. and Walker, M.C. (2007), "Association of Caesarean Delivery for First Birth with Placenta Praevia and Placental Abruption in Second Pregnancy", *British Journal of Obstetrics and Gynaecology*, 114(5): pp. 609–613.

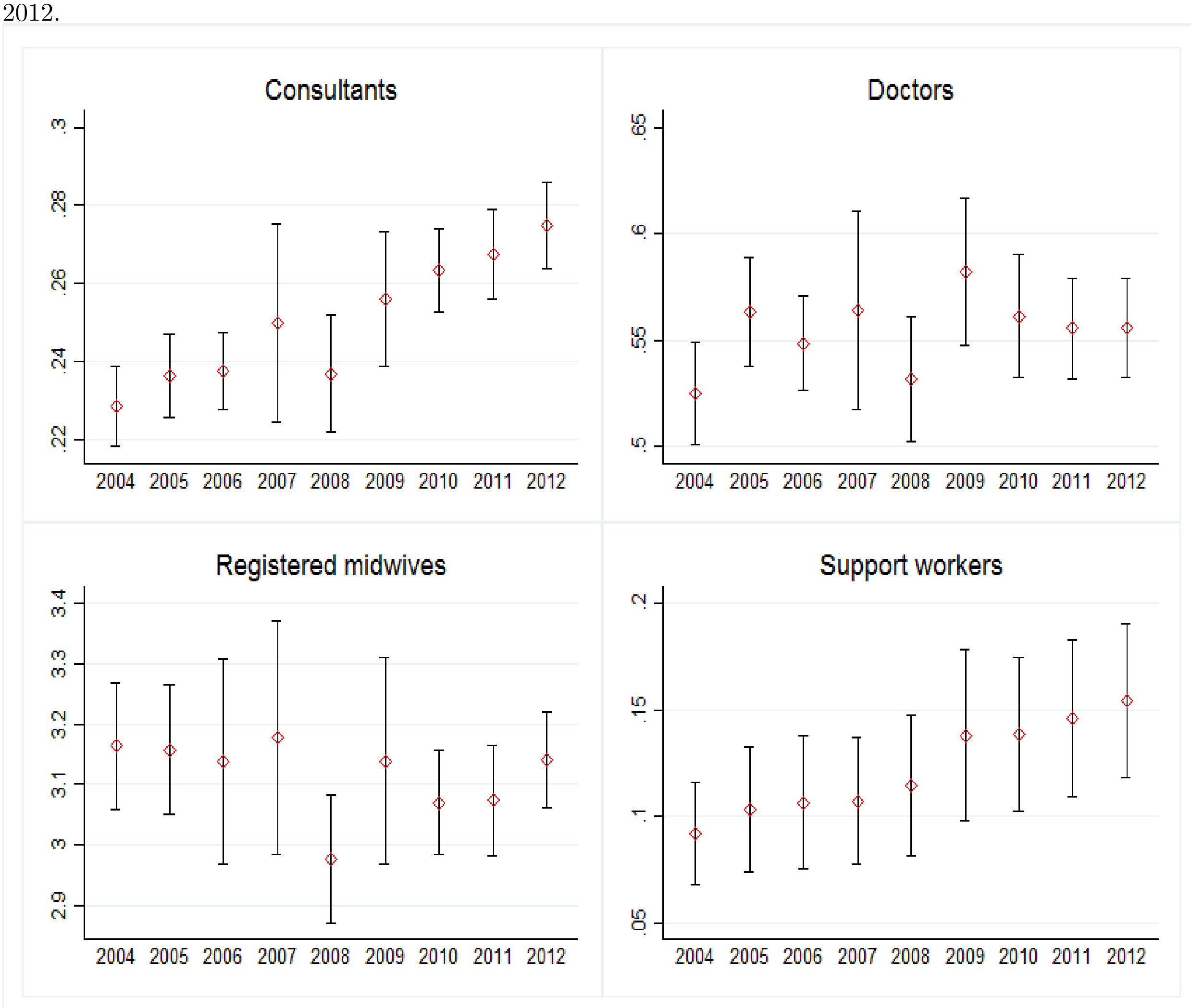
[44] Yang, Y.T., Mello, M.M., Subramanian, S.V. and Studdert, D.M. (2009), "Relationship Between Malpractice Litigation Pressure and Rates of Cesarean Section and Vaginal Birth After Cesarean Section" *Medical Care*, 47(2): pp. 234-242.

Figure 1: Caesarean section rates in England, 2000-2013.



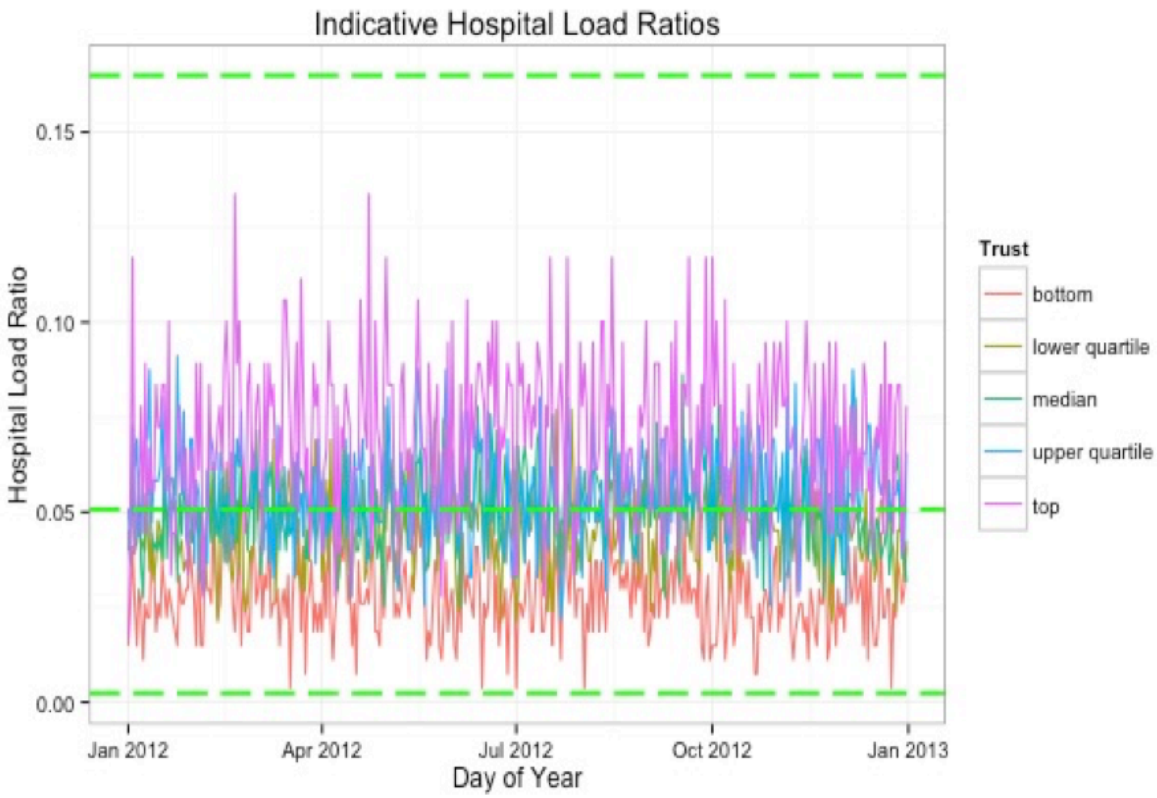
Source: Hospital Episode Statistics (HES), Health & Social Care Information Centre (HSCIC).
Notes: The horizontal lines within each box represents the median rate for each year. Each box represents the interquantile range for each year. The vertical lines represent the 95% confidence interval.

Figure 2: Annual average FTE per 100 maternities for each worker group in English NHS providers, 2004-2012.



Source: Medical and Non-Medical Workforce Censuses as at 30 September in each year (for 2014 they are as at the 30th of May). NHS Hospital and Community Health Service (HCHS) medical staff in Obstetrics and Gynaecology.
Notes: The hollow diamond symbols represent the average annual FTE for each maternity worker type across all English NHS providers. The vertical lines represent the 95% confidence interval for each year.

Figure 3: Hospital Load Ratio variation in 2013.



Source: Hospital Episode Statistics (HES), Health & Social Care Information Centre (HSCIC).
Medical and Non-Medical Workforce Censuses as at 30 September in each year (for 2014 they are as at the 30th of May). NHS Hospital and Community Health Service (HCHS) medical staff in Obstetrics and Gynaecology.

Table 1: Basic descriptive statistics for maternal, clinical and hospital-level variables.

Variable name	Mean	Std. dev.
Dependent variables		
Caesarean section	.240	.427
Elective caesarean section	.096	.295
Non-elective caesarean section	.144	.351
Independent variables		
Age: <20 years	.063	.243
Age: 20-24 years	.188	.391
Age: 25-29 years	.267	.442
Age: 30-34 years	.288	.453
Age: 35-39 years	.158	.365
Age: ≥40 years	.035	.184
Ethnic background: White	.719	.450
Ethnic background: Mixed	.013	.114
Ethnic background: Asian	.103	.304
Ethnic background: Afro-Caribbean	.050	.219
Ethnic background: Other	.025	.157
Ethnic background: Unknown	.090	.286
IMD quintile: I (most deprived)	.280	.449
IMD quintile: II	.218	.413
IMD quintile: III	.181	.385
IMD quintile: IV	.163	.369
IMD quintile: V (most affluent)	.159	.365
Urban area	.858	.349
Nulliparous	.485	.499
Birth weight: Very low (<1500 grams)	.009	.097
Birth weight: Low (1500-2499 grams)	.046	.210
Birth weight: Normal (2500-4999 grams)	.742	.438
Birth weight: High (≥5000 grams)	.203	.402
Previous caesarean section	.080	.271
Singleton birth	.983	.128
High risk woman	.447	.497
Hospital load	14.434	6.923
University hospital	.206	.405
NHS Foundation Trust	.530	.499
Caesarean section rate	.243	.084
Elective caesarean section rate	.098	.052
Non-elective caesarean section rate	.145	.074
Observations	7,484,471	
Providers	165	

Source: Maternity tail of Hospital Episode Statistics (HES) data, April 2000 to March 2013. Health & Social Care Information Centre (HSCIC).
Notes: Totals may not sum exactly due to rounding. Descriptive statistics were calculated using a sample with non-missing values obtained after regressing the caesarean section indicator on some basic maternal, clinical, provider variables as well as on year and SHA fixed effects.

Table 2: Descriptive statistics for maternity staffing variables.

Variable name	Mean	Std. dev.
FTE		
Consultants[a]	10.709	5.599
Doctors[a]	23.285	12.412
Registered midwives[b]	131.208	60.768
Support workers[b]	5.645	9.936
FTE per 100 maternities		
Consultants[a,c]	.846	18.166
Doctors[a,c]	1.963	46.069
Registered midwives[b,c]	4.255	3.764
Support workers[b,c]	.180	.412
Hospital Load Ratio		
Consultants[a,c]	1.291	.565
Doctors[a,c]	.610	.473
Registered midwives[b,c]	.105	.133
Support workers[b,c]	4.312	6.353

Source: [a] Medical Workforce Census as at 30 September in each year (2004-2013). NHS Hospital and Community Health Service (HCHS) medical staff in Obstetrics and Gynaecology.

[b] Non-Medical Workforce Census as at 30 September in each year (2004-2013).

[c] Maternity tail of Hospital Episode Statistics (HES) data, April 2000 to March 2013. Health & Social Care Information Centre (HSCIC).

Table 3: Determinants of caesarean section deliveries in the English NHS: 2000-2013.

Explanatory variable	[1]	[2]	[3]	[4]	[5]
Age group:					
20-24 years	.0433(.0010)	.0441(.0010)	.0446(.0010)	.0466(.0011)	.0467(.0011)
25-29 years	.0818(.0014)	.0821(.0013)	.0825(.0013)	.0825(.0014)	.0825(.0014)
30-34 years	.1202(.0018)	.1190(.0016)	.1195(.0015)	.1199(.0016)	.1199(.0016)
35-39 years	.1585(.0023)	.1571(.0019)	.1577(.0018)	.1591(.0018)	.1592(.0018)
$\geq$40 years	.2119(.0031)	.2113(.0026)	.2117(.0024)	.2149(.0024)	.2150(.0024)
Ethnic background:					
Mixed	.0117(.0025)	.0089(.0024)	.0098(.0021)	.0126(.0021)	.0127(.0021)
Asian	-.0062(.0032)	-.0085(.0027)	-.0082(.0027)	-.0053(.0029)	-.0054(.0029)
Afro-Caribbean	.0485(.0043)	.0389(.0034)	.0394(.0027)	.0423(.0028)	.0422(.0028)
Other	.0157(.0030)	.0081(.0022)	.0070(.0019)	.0107(.0018)	.0105(.0018)
Unknown	-.0016(.0023)	-.0088(.0022)	-.0087(.0016)	-.0086(.0016)	-.0087(.0016)
IMD deprivation index:					
Quintile II	.0066(.0020)	.0044(.0017)	.0071(.0008)	.0063(.0008)	.0063(.0008)
Quintile III	.0081(.0024)	.0057(.0020)	.0083(.0009)	.0071(.0009)	.0071(.0009)
Quintile IV	.0090(.0026)	.0059(.0021)	.0082(.0012)	.0068(.0013)	.0069(.0013)
Quintile V (most affluent)	.0087(.0032)	.0042(.0024)	.0076(.0011)	.0058(.0012)	.0058(.0012)
Urban area	.0070(.0021)	.0032(.0019)	.0018(.0008)	.0023(.0008)	.0023(.0008)
Nulliparous	.1409(.0025)	.1427(.0023)	.1468(.0024)	.1638(.0024)	.1638(.0024)
Birth weight category:					
Low (1500-2499 grams)	-.0802(.0047)	-.0780(.0048)	-.0777(.0049)	-.0754(.0047)	-.0755(.0047)
Normal (2500-4999 grams)	-.1395(.0057)	-.1340(.0055)	-.1317(.0053)	-.1364(.0055)	-.1365(.0055)
High ($\geq$5000 grams)	-.1458(.0059)	-.1462(.0058)	-.1423(.0056)	-.1391(.0059)	-.1396(.0060)
Previous c-section	.4511(.0043)	.4569(.0042)	.4558(.0043)	.4776(.0043)	.4775(.0043)
Singleton birth	-.2067(.0146)	-.2220(.0096)	-.2205(.0098)	-.2392(.0123)	-.2388(.0126)
High risk woman	.1866(.0028)	.1879(.0029)	.1911(.0029)	.1694(.0025)	.1695(.0025)
University hospital	-.0006(.0053)	.0017(.0051)	-.0121(.0010)	-.0152(.0017)	-.0292(.0041)
NHS Foundation Trust	-.0026(.0042)	.0005(.0042)	-.0496(.0010)	-.0545(.0011)	-.0514(.0015)
FTE per 100 maternities:					
Doctors	-	-	-	.0052(.0053)	.0050(.0054)
Consultants	-	-	-	-.0120(.0096)	-.0094(.0094)
Registered midwives	-	-	-	-.0005(.0019)	-.0008(.0019)
Support workers	-	-	-	.0047(.0047)	.0050(.0044)
Trust c-section rate$_{t-1}$	-	-	-	-	.2350(.0677)
Year fixed effects [F-test]	No	Yes [0.00]	Yes [0.00]	Yes [0.00]	Yes [0.00]
SHA fixed effects [F-test]	No	Yes [0.00]	Yes [0.00]	Yes [0.00]	Yes [0.00]
Provider fixed effects [F-test]	No	No	Yes [0.00]	Yes [0.00]	Yes [0.00]
Observations	7,673,786	7,484,471	7,484,471	5,671,541	5,654,794
Providers	215	165	165	158	157
R-squared	.1892	.1927	.1956	.2128	.2129

Source: [a] Medical Workforce Census as at 30 September in each year (2004-2013). NHS Hospital and Community Health Service (HCHS) medical staff in Obstetrics and Gynaecology.

[b] Non-Medical Workforce Census as at 30 September in each year (2004-2013).

[c] Maternity tail of Hospital Episode Statistics (HES) data, April 2000 to March 2013. Health & Social Care Information Centre (HSCIC).

Notes: Ordinary Least Squares estimates. Standard errors in parentheses have been corrected for heteroskedasticity and clustering by provider. p-values from F-tests of joint significance in brackets.

Table 4: Determinants of elective caesarean section deliveries in the English NHS: 2000-2013.

Explanatory variable	[1]	[2]	[3]	[4]	[5]
Age group:					
20-24 years	.0090(.0005)	.0095(.0005)	.0095(.0005)	.0073(.0005)	.0073(.0005)
25-29 years	.0246(.0007)	.0246(.0007)	.0244(.0007)	.0204(.0007)	.0204(.0007)
30-34 years	.0458(.0009)	.0447(.0009)	.0440(.0009)	.0390(.0009)	.0340(.0009)
35-39 years	.0708(.0013)	.0699(.0012)	.0690(.0011)	.0641(.0011)	.0641(.0011)
≥40 years	.1068(.0025)	.1073(.0022)	.1061(.0020)	.1032(.0020)	.1032(.0020)
Ethnic background:					
Mixed	-.0092(.0014)	-.0071(.0014)	-.0063(.0012)	-.0050(.0014)	-.0049(.0014)
Asian	-.0221(.0015)	-.0214(.0015)	-.0188(.0013)	-.0172(.0015)	-.0172(.0015)
Afro-Caribbean	-.0139(.0019)	-.0160(.0019)	-.0155(.0015)	-.0149(.0017)	-.0147(.0017)
Other	.0008(.0018)	-.0010(.0012)	-.0027(.0012)	-.0003(.0012)	-.0004(.0012)
Unknown	.0031(.0014)	-.0054(.0011)	-.0067(.0009)	-.0068(.0010)	-.0068(.0010)
IMD deprivation index:					
Quintile II	.0038(.0008)	.0043(.0007)	.0050(.0006)	.0051(.0006)	.0050(.0006)
Quintile III	.0066(.0010)	.0073(.0011)	.0079(.0007)	.0079(.0008)	.0079(.0008)
Quintile IV	.0089(.0012)	.0094(.0013)	.0101(.0010)	.0103(.0011)	.0103(.0011)
Quintile V (most affluent)	.0103(.0015)	.0110(.0015)	.0126(.0010)	.0124(.0011)	.0123(.0011)
Urban area	-.0004(.0012)	-.0014(.0009)	-.0014(.0006)	-.0014(.0006)	-.0013(.0006)
Nulliparous	.0207(.0016)	.0196(.0014)	.0198(.0014)	.0251(.0013)	.0251(.0013)
Birth weight category:					
Low (1500-2499 grams)	.0482(.0036)	.0499(.0036)	.0502(.0036)	.0516(.0035)	.0516(.0035)
Normal (2500-4999 grams)	.0897(.0047)	.0944(.0046)	.0954(.0046)	.0931(.0046)	.0932(.0046)
High (≥5000 grams)	.0919(.0048)	.0907(.0048)	.0913(.0048)	.0892(.0047)	.0890(.0047)
Previous c-section	.3594(.0043)	.3659(.0043)	.3646(.0043)	.3792(.0044)	.3792(.0043)
Singleton birth	-.1314(.0093)	-.1411(.0068)	-.1404(.0066)	-.1610(.0083)	-.1609(.0084)
High risk woman	.1151(.0024)	.1160(.0025)	.1178(.0025)	.1013(.0021)	.1013(.0021)
University hospital	.0010(.0028)	.0030(.0027)	.0239(.0006)	.0242(.0009)	.0161(.0032)
NHS Foundation Trust	-.0016(.0022)	-.0004(.0023)	-.0111(.0005)	-.0091(.0006)	-.0096(.0007)
FTE per 100 maternities:					
Doctors	-	-	-	-.0009(.0027)	-.0009(.0026)
Consultants	-	-	-	-.0042(.0053)	-.0036(.0050)
Registered midwives	-	-	-	.0003(.0011)	.0001(.0010)
Support workers	-	-	-	.0044(.0024)	.0039(.0021)
Trust c-section rate$_{t-1}$	-	-	-	-	.1997(.0713)
Year fixed effects [F-test]	No	Yes [0.00]	Yes [0.00]	Yes [0.00]	Yes [0.00]
SHA fixed effects [F-test]	No	Yes [0.13]	Yes [0.00]	Yes [0.00]	Yes [0.00]
Provider fixed effects [F-test]	No	No	Yes [0.00]	Yes [0.00]	Yes [0.00]
Observations	7,671,934	7,482,861	7,482,861	5,670,769	5,654,063
Providers	215	165	165	158	157
R-squared	.1984	.2037	.2054	.2295	.2296

Source: [a] Medical Workforce Census as at 30 September in each year (2004-2013). NHS Hospital and Community Health Service (HCHS) medical staff in Obstetrics and Gynaecology.

[b] Non-Medical Workforce Census as at 30 September in each year (2004-2013).

[c] Maternity tail of Hospital Episode Statistics (HES) data, April 2000 to March 2013. Health & Social Care Information Centre (HSCIC).

Notes: Ordinary Least Squares estimates. Standard errors in parentheses have been corrected for heteroskedasticity and clustering by provider. p-values from F-tests of joint significance in brackets.

Table 5: Determinants of emergency caesarean section deliveries in the English NHS: 2000-2013.

Explanatory variable	[1]	[2]	[3]	[4]	[5]
Age group:					
20-24 years	.0343(.0009)	.0345(.0009)	.0351(.0009)	.0393(.0009)	.0393(.0009)
25-29 years	.0572(.0013)	.0575(.0012)	.0582(.0011)	.0621(.0011)	.0621(.0011)
30-34 years	.0744(.0016)	.0744(.0014)	.0755(.0013)	.0809(.0012)	.0809(.0012)
35-39 years	.0878(.0019)	.0872(.0017)	.0887(.0016)	.0951(.0014)	.0951(.0014)
$\geq$40 years	.1053(.0021)	.1041(.0020)	.1056(.0019)	.1118(.0018)	.1188(.0018)
Ethnic background:					
Mixed	.0209(.0020)	.0160(.0019)	.0161(.0018)	.0176(.0019)	.0176(.0019)
Asian	.0160(.0022)	.0129(.0017)	.0106(.0016)	.0119(.0016)	.0118(.0016)
Afro-Caribbean	.0624(.0033)	.0549(.0022)	.0550(.0017)	.0571(.0016)	.0570(.0016)
Other	.0149(.0022)	.0091(.0016)	.0097(.0012)	.0110(.0011)	.0109(.0011)
Unknown	-.0046(.0018)	-.0034(.0016)	-.0020(.0012)	-.0018(.0012)	-.0019(.0012)
IMD deprivation index:					
Quintile II	.0027(.0017)	.0001(.0014)	.0022(.0005)	.0013(.0006)	.0013(.0006)
Quintile III	.0015(.0021)	-.0016(.0017)	.0004(.0007)	-.0008(.0007)	-.0008(.0007)
Quintile IV	.0001(.0023)	-.0034(.0018)	-.0018(.0008)	-.0035(.0009)	-.0040(.0009)
Quintile V (most affluent)	-.0017(.0027)	-.0069(.0020)	-.0051(.0008)	-.0066(.0008)	-.0065(.0008)
Urban area	.0074(.0015)	.0046(.0014)	.0032(.0005)	.0036(.0006)	.0036(.0006)
Nulliparous	.1202(.0018)	.1231(.0017)	.1269(.0016)	.1387(.0017)	.1387(.0017)
Birth weight category:					
Low (1500-2499 grams)	-.1284(.0054)	-.1280(.0055)	-.1280(.0054)	-.1271(.0049)	-.1272(.0049)
Normal (2500-4999 grams)	-.2293(.0066)	-.2285(.0066)	-.2272(.0064)	-.2296(.0062)	-.2298(.0063)
High ($\geq$5000 grams)	-.2376(.0068)	-.2367(.0069)	-.2334(.0066)	-.2283(.0063)	-.2285(.0063)
Previous c-section	.0919(.0022)	.0912(.0020)	.0913(.0021)	.0985(.0021)	.0984(.0021)
Singleton birth	-.0760(.0062)	-.0816(.0043)	-.0808(.0046)	-.0787(.0053)	-.0783(.0055)
High risk woman	.0715(.0018)	.0719(.0018)	.0733(.0018)	.0682(.0017)	.0682(.0017)
University hospital	-.0015(.0038)	-.0014(.0037)	-.0365(.0008)	-.0398(.0013)	-.0442(.0017)
NHS Foundation Trust	-.0010(.0031)	-.0009(.0031)	-.0384(.0007)	-.0452(.0008)	-.0410(.0013)
FTE per 100 maternities:					
Doctors	-	-	-	.0061(.0041)	.0058(.0041)
Consultants	-	-	-	-.0079(.0083)	-.0057(.0079)
Registered midwives	-	-	-	-.0008(.0013)	-.0009(.0012)
Support workers	-	-	-	.0002(.0040)	.0013(.0038)
Trust c-section rate$_{t-1}$	-	-	-	-	.2722(.0674)
Year fixed effects [F-test]	No	Yes [0.01]	Yes [0.00]	Yes [0.54]	Yes [0.36]
SHA fixed effects [F-test]	No	Yes [0.00]	Yes [0.00]	Yes [0.00]	Yes [0.00]
Provider fixed effects [F-test]	No	No	Yes [0.00]	Yes [0.00]	Yes [0.00]
Observations	7,671,934	7,482,861	7,482,861	5,670,769	5,654,063
Providers	215	165	165	158	157
R-squared	.0540	.0554	.0577	.0617	.0618

Source: [a] Medical Workforce Census as at 30 September in each year (2004-2013). NHS Hospital and Community Health Service (HCHS) medical staff in Obstetrics and Gynaecology.

[b] Non-Medical Workforce Census as at 30 September in each year (2004-2013).

[c] Maternity tail of Hospital Episode Statistics (HES) data, April 2000 to March 2013. Health & Social Care Information Centre (HSCIC).

Notes: Ordinary Least Squares estimates. Standard errors in parentheses have been corrected for heteroskedasticity and clustering by provider. p-values from F-tests of joint significance in brackets.

Table 6: Alternative ways to control for the impact of maternity staffing on the probability of caesarean deliveries: Percentages of annual FTE and Hospital Load Ratio variables.

Worker group	C-sections [1]	Elective C-sections [2]	Non-elective C-sections [3]
Panel A: Using percentages of annual FTE			
Doctors	.0274(.0449)	.0011(.0206)	.0273(.0347)
Consultants	-.1167(.0882)	-.0579(.0498)	-.0584(.0673)
Registered midwives	-.0198(.0166)	.0033(.0064)	-.0197(.0133)
Support workers	.0119(.0528)	.0537(.0340)	-.0397(.0406)
Observations	5,654,794	5,654,063	5,654,063
Providers	157	157	157
R-squared	.2129	.2296	.0618
Panel B: Full set of HLR staffing variables			
Doctors	.0005(.0009)	.0020(.0009)	-.0014(.0006)
Consultants	.0049(.0020)	.0168(.0016)	-.0120(.0013)
Registered midwives	.0021(.0016)	.0035(.0013)	-.0016(.0007)
Support workers	-.0002(.0002)	-.0001(.0001)	-.0001(.0002)
Observations	3,456,810	3,456,318	3,456,318
Providers	127	127	127
R-squared	.2149	.2324	.0620
Panel C: Excluding HLR for support workers			
Doctors	.0004(.0009)	.0034(.0018)	-.0034(.0016)
Consultants	.0041(.0010)	.0124(.0021)	-.0083(.0020)
Registered midwives	.0012(.0016)	.0052(.0033)	-.0043(.0022)
Support workers	-	-	-
Observations	5,654,703	5,653,972	5,653,972
Providers	157	157	157
R-squared	.2129	.2300	.0620
Individual characteristics	Yes	Yes	Yes
Provider characteristics	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
SHA fixed effects	Yes	Yes	Yes
Provider fixed effects	Yes	Yes	Yes

Source: Maternity tail of Hospital Episode Statistics (HES) data (2000-2013), Health & Social Care Information Centre (HSCIC). Medical & Non-Medical Workforce Censuses as at 30 September in each year (2004-2013), NHS Hospital and Community Health Service (HCHS).

Notes: Ordinary Least Squares estimates. All models control for the full set of individual and provider characteristics reported in previous Tables. Standard errors in parentheses have been corrected for heteroskedasticity and clustering by provider.