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**The efficient use of the maternity workforce and the implications for safety &
quality in maternity care: An economic perspective**

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Aims and objectives

The over-riding aim of this project is to understand the relationships between maternity workforce size, skill mix and quality outcomes including patient safety and quality, effectiveness and unit level efficiency. Therefore this research aims to answer the following objectives:

1. Staffing Levels

What is the relationship between maternity staffing and key quality and safety outcomes? To what extent is there an optimal staffing level?

2. Staffing Mix

To what extent are staff roles substitutes or complements in maternity services? For example can doctors be substituted by midwives and/or physicians assistants and can registered midwives be substituted by support workers? To what extent therefore is there an optimal staffing mix?

3. Efficiency & Patient Safety

What is the relationship between maternity workforce staffing levels, quality and safety outcomes and healthcare output? What is the implication of efficiency savings for key quality and safety indicators?

Background

The performance of maternity services has been seen as a touchstone of whether we are delivering quality health services in general (Department of Health, 2009b). Current challenges for the maternity workforce include the delivery of a number of maternal health, NHS workforce and NHS policy objectives. In essence, the key challenges are the need to improve productivity and quality of maternal health care outcomes, including safety, and understand how the maternity workforce be organised to rise to these challenges.

Staffing levels have been linked to improved patient outcomes in a range of healthcare organizations. There is substantial international evidence showing that higher nurse to patient ratios are associated with enhanced patient outcomes (Kane et al., 2007) with emerging evidence of a similar relationship in the NHS (Rafferty et al., 2007, Shuldham et al., 2009, Griffiths 2010). There is also a literature on the optimal level of nurse staffing in the US (Harris et al., 2004, Sucov et al., 2009) and with some evidence of a medical staffing outcome relationship from both the US and the UK (Jarman et al., 1999, Pronovost et al., 2002). However this literature is limited in comparison, based mainly on research in acute services and academic hospitals. Recent research by team members has found associations between midwifery staffing levels and important outcomes including failure to rescue, extended hospital stay and readmissions (Gerova et al., 2010, Jones et al., 2010). In addition, better outcomes may be associated with a skill mix that is richer in medical staff) although

this is not always the case (Dawoud et al., ready for submission, Griffiths et al., 2010).

There is no uniform definition of skill mix, and we draw on previous definitions used in reviews of this topic. In a report by the World Health Organisation 'skill mix' is defined as "the mix of posts, grades or occupations in an organization..." (Buchan and Dal Poz, 2002, p575). In addition, task shifting, delegation and substitution are also terms used (Laurant et al., 2005). Findings are compounded by problems of definition of 'skill mix' and that most studies tend to be of poor methodological design, largely reflecting descriptive accounts of single sites using small sample sizes e.g. (Dubois and Singh, 2009). The majority of studies which focus on skill mix changes on patient outcomes are systematic reviews of the evidence base of substituting: i) doctors by extended nursing roles and to a much lesser extent other health professionals in primary and secondary care and ii) nurses and other health professionals by support workers/nursing assistants on patient safety and quality outcomes. However, in general, there is limited and inconclusive evidence that changing workforce skill mix or substitution of roles in maternity care and other acute or primary care settings is associated with improved health outcomes or a reduction in costs.

A scoping review of the relationship between maternity workforce staffing numbers, skill-mix, substitution and delegation, models of care, cost implications and safety found some evidence suggesting that consultant obstetrician and midwife staffing levels are linked to reductions in poor outcomes, and potential for support workers to be deployed more creatively in maternity services in terms of improving quality of care and freeing up midwife and medical time. However, the evidence for associated impacts upon safety and quality outcomes is largely absent (Sandall et al 2010).

Quality in maternity care has been defined as comprising a number of different aspects. We have drawn upon dimensions of quality of care as defined In Crossing the Quality Chasm (Institute of Medicine, 2001): consisting of safe, effective, patient-centred, timely, efficient, and equitable care. Three of these dimensions have been taken up in the Next Stage Review (safe, effective, patient-centred care) (Department of Health, 2008b) and the Government White Paper: Liberating the NHS (Department of Health 2010) and all have been suggested by Midwifery 2020 (2010). Safe Births: Everybody's Business (King's Fund, 2008) defines safety at its simplest, as 'the avoidance, prevention and amelioration of adverse outcomes or injuries stemming from the process of health care' (Vincent, 2006). Maternal and perinatal outcomes can either be clinical (eg, morbidity or mortality) or 'patient' derived (eg, quality of life or experience of care).

While there is ample evidence on the benefits of improved patient safety very little is known about the impact of diverting resources to this cause on a healthcare provider's efficiency and output (Øvretveit, 2009). The limited evidence points toward complex relationships between workload, efficiency and quality (Judge et al., 2006, Kc and Terwiesch, 2009, Masnick and McDonnell, 2010). While reduced complications and higher staffing may lead to reduced length of stay (improved productivity) this finding is not universally supported. Cost effectiveness and effective use of fixed resources involving alteration in the composition of the workforce is clearly dependent upon wage differentials and so replication and extension of these findings in other health economies is clearly warranted. It also seems clear from the existing evidence that there is unlikely to be a general relationship between skill mix

and quality / productivity that is generalisable across care settings. Furthermore, all the above cited economic models are limited because the staffing variation observed in cross sectional observational studies is assumed to cause the differences that are observed and the effect of variation associated with nurse staffing is assumed to be accurately estimated even though for most studies there is little consideration of the staff deployed in relation to the particular group of patient outcomes examined. Finally deployment and organisation of staff within organisations is also a key variable which needs to be considered as a potential confounding variable as well as a potential alternative approach to increasing the effectiveness and productivity of the workforce. Human resource management factors at an organisational level have been associated with improved outcomes; while organisational culture and aspects of the work environment have also been associated with enhanced outcomes. While calls for mandated staffing ratios remain there is also renewed interest in using tools to match workload to staffing at a hospital/community level as a bottom up approach (Smith et al., 2009). This, in theory, could maximise efficiency by matching staffing to patient need most closely but generally lacks full validation (Scott, 2003). For example, midwife-led care which involves continuity and matching midwife input to the needs of women, is associated with several significant clinical benefits for mothers and babies, and increased satisfaction and had no identified adverse effects and reduced costs (Hatem and Sandall et al 2008).

Few if any studies have considered the potential trade-offs between staff groups to optimise quality and efficiency nor have they attempted to explore differential effects on different outcomes simultaneously. The range of staff groups considered in most existing research has been limited and of particular relevance, most studies in acute care have omitted consideration of medical staffing altogether. The use of observational data limits the ability to draw causal inferences and so the implications of observed associations remain unclear. Potential changes in the deployment and composition of the maternity workforce (including the emergence of enhanced assistant practitioner roles), raise significant questions regarding the most efficient use of scarce workforce resources and the extent to which clinical work can be safely and efficiently supported or delivered by other (currently unregistered) practitioners and/or support workers. Our proposal aims to build on this research by exploring maternity staffing and outcome relationships and to incorporate economic modelling and in order to consider issues the cost and operational efficiency implications.

Need

In the Department of Health England Draft Structural Reform Plan (July, 2010) there is an emphasis to shift resources to promote better healthcare outcomes. This includes national healthcare outcome measures, patient-reported outcomes and patient experience measures. The White Paper (DOH, 2010: 10) aims to make the NHS both self-improving and financially sustainable through introducing or bolstering incentives for quality improvement through the NHS Outcomes Framework giving patients/service users more input to decisions made about their care. This is to ensure that services provided are of sufficient quality, and that provision of essential services is maintained. It is hoped that cost reductions will accrue through the reduction in management costs which will start to be realised in the short term, and in the longer term through the economic use of resources. The White Paper acknowledges that the “very challenging financial position” in the Coalition Agreement, and that the single greatest priority for the next Parliament will be to reduce the deficit. It considers that it is “even more pressing” (DOH, 2010: 10) to implement reforms in order to increase productivity and efficiency in the NHS. These

constrained public resources may require efficiency savings of £15-20 billion therefore understanding the implications of output and efficiency on patient safety and other quality outcomes is crucial for managers and policy makers.

The midwifery workforce (including both registered and unregistered practitioners engaged in delivering or supporting midwifery care) represents a significant resource in enabling change but also a significant proportion of NHS staff expense. Qualified midwives and pay accounts for approximately 4.1% of the English NHS pay bill¹. If health care assistants and NHS paid students on secondment are also considered, the proportion rises to 5.1%. The cumulative NHS pay bill in turn represents approximately 30% of the total NHS budget and an even higher proportion of non-fixed costs. The Workforce Review Team has stated that workforce planning should flow explicitly from agreed service strategy and that the future workforce should be characterised by offering "the right people, with the right skills, in the right places, at the right time" (The Workforce Review Team, 2009). This will require fundamental changes in the way that staff are deployed and services are delivered to improve productivity and quality outcomes. There will be significant pressures to improve productivity by developing new ways of working, creating new assistant and advanced practice roles and increasing the flexibility and adaptability of the maternity workforce.

The Department of Health's National Service Framework for Children, Young People and Maternity Services (Department of Health, 2004), with a ten-year timeframe for implementation, and Maternity Matters (Department of Health Partnerships for Children Families and Maternity., 2007), are consistent in the commitment to deliver a choice of safe, accessible, high quality maternity care which is women focused and family centred. Underpinning principles include the view that pregnancy and birth are normal life events, maximising the opportunity for all women, regardless of risk profile, to have as physiological and positive a birth experience as possible. In 2008 the report of the independent inquiry commissioned by the King's Fund, *Safe Births: Everybody's Business* (King's Fund, 2008) and the Healthcare Commission's review of maternity services, *Towards Better Births* (Commission for Healthcare Audit and Inspection, 2008), identified similar areas in need of improvement, including staffing, training and communication. Together with a number of other reports, guidance documents and reviews over the past few years, they identified the challenges for maternity services and set out recommendations.

Staffing has been identified in numerous reports as being a critical component of safe, effective, patient-centred care. Staffing levels contributed to 3.5% of all reported safety incidents (National Patient Safety Agency, 2009) with workforce factors likely to contribute to a far higher total proportion. A growing literature has established that the extent and cost of poor patient safety is significant in the UK and elsewhere. Andrews et. al. (1997) found that 45% of patients in the UK experienced some medical mismanagement, with 17% requiring a longer hospital stay or resulting in more serious problems. The estimated cost of additional hospital stays resulting from clinical errors is between £1 billion (Vincent et al., 2001) and £2 billion (Department of Health, 2005) while an additional £1 billion per annum is the estimated cost of hospital acquired infections (House of Commons Public Accounts Committee, 2009).

¹ Source: Information Centre for Health and Social Care NHS Staff Earnings Estimates, October to December 2010 Includes all AFC bands and medical staff but excludes senior managers non on AFC grades.

Maternity litigation represent 12% of the settlements and 15% of the claims presented to the Medical Defence Union (MDU, 2010), and the highest cost of NHSLA claims. The National Audit Office expected litigation costs to exceed £2 billion per annum from 2005 (National Audit Office, 2005). In an extensive review of the patient safety literature, Øvretveit, (2009) states that there is a dearth of research on the economic costs and benefits of patient safety interventions. While studies have demonstrated that higher staff to patient ratios increases patient safety across a range of indicators (Jarman et al., 1999, Kane et al., 2007, Rafferty et al., 2007), no work has focused on the economic implications of maternity staffing and outcomes. Birthrate Plus (BR+) (Ball et al 2003) is widely used in the UK to calculate the number of midwives required. Despite the widespread use and recommended use of BR+, it is not known whether ratios or staffing establishment numbers reflect 'the ideal' or 'what is current' and how these are related to providing a high quality and safe maternity service. Similarly, there is some evidence suggesting that consultant obstetrician and midwife staffing levels are linked to reductions in poor outcomes, and highlight the need to provide 24 hour obstetric cover in labour wards, there is very little direct evidence on the relationship between consultant obstetric presence on the labour ward and quality outcomes.

Similarly, strategic approaches to Maternity Support Worker development are underway at a national level in Scotland, Wales and Northern Ireland and at a more local level in England (NHS Employers and Care Services Improvement Partnership, 2006) although within a national initiative. Support workers are perceived to play a key role in the future maternity workforce and although the role has been established for some time, but there has been little overview of who makes up the support workforce, what they do, and what competencies they possess. However no research has been done in relation to operational efficiency of maternity provision in relation to workforce skills mix. Areas identified requiring further research included exploring the impact of the support worker role on outcomes for mothers and babies, the cost-effectiveness of the support worker role at different levels of training and scope of practice, and exploration of the views and experience of women receiving care from support workers (Sandall et al., 2007).

In summary, as the NHS moves into a time of constrained public resources which may require efficiency savings, very little is known on the optimal combination of labour inputs to achieve efficient production of safe and high quality maternity care and this research is essential.

Overview of design and methods

This study will compile secondary data from a range of public sources before applying econometric techniques to answer important policy questions related to staffing levels and mix and their impact upon productivity and safety. The over-riding aim of this project is to understand the relationships between maternity workforce size, skill mix and quality outcomes including patient safety and quality, effectiveness and unit level efficiency.

In Phase 1, we envisage a cross-sectional analysis using multilevel logistic regression to investigate the relationship between a number of quality and safety outcomes and the workforce configuration as well as adjusting for confounding characteristics previously discussed. We have complete data on aim to extend the analysis to a longitudinal (panel) analysis using data through to December 2010 in Phase 2 where we have complete and synchronous outcome, experience and

workforce data and we will explore the impact of change in workforce configuration on outcomes. However, this will depend on the ability to synchronise the time period that each dataset covers.

Phase 1: Data Access and Collection & Statistical Controls

This project will examine the efficient use of the maternity workforce and the implications for safety and quality in maternity care. Data items will be used to explore dimensions of quality of care consist of safe, effective, women-centred, timely, efficient, and equitable care (Institute of Medicine, 2001).

We plan to include every Trust in England. Many Trusts contain more than one obstetric unit and/or freestanding midwife units. We will be able to draw upon Birthplace in England (also funded by NCCSDO) mapping data to conduct a validity check. The unit of analysis will be at Trust level, as many Trusts contain more than one obstetric unit and/or freestanding midwife units, and also provide home birth services. This unit of analysis is logical as women move through services organised at Trust level, ie from receiving antenatal care by a trust employed midwife in her local GP facility or sure start centre or home, to having a birth out of hospital which then requires transfer to an obstetric unit. This unit of analysis is also justified as women move through services organised at Trust level, ie from receiving antenatal care by a trust employed midwife in her local GP facility or sure start centre or home, to having a birth out of hospital which then requires transfer to an obstetric unit.

We will adjust statistically to try to take account of the differences between the types of centres using the level of neonatal care (level 1, 2 or 3), and the number of births provided at Trust level using groupings outlined in the review *Safer Childbirth*² (<2,500; 2,500–4,000; 4,000–5,000; 5,000–6,000 and > 6,000 deliveries). In addition we will adjust for the different types of women giving birth in each unit, and the case-mix and severity using the Index of multiple deprivation, age and ethnicity of the population at Trust level. Current co-morbidity indices used in general health care such as the Charlson or Elixhauser co-morbidity index are not appropriate for childbearing women, and we will explore and test alternatives. The resulting index would prove valuable in future work as the load of co-morbidity increases in this population.

We intend to use the following datasets, from January 2007 to 2010

- Hospital Episode Statistics (HES) admitted patient (including the “maternity and baby tail”) and accident & emergency data for January 2007 to December 2010.
- NHS Maternity Statistics, England: 2006-07, 2007-08, 2009-10 from the NHS IC.
- Home birth statistics derived from information collected at birth registration provided to BirthChoiceUK by the Office for National Statistics.

² Royal College of Obstetricians and Gynaecologists, Royal College of Midwives, Royal College of Anaesthetists, Royal College of Paediatrics and Child Health (2007). *Safer Childbirth: Minimum standards for the organisation and delivery of care in labour*. London: RCOG Press.

- NHS Workforce Statistics, England: 2007-2010 from the NHS IC which includes staff in post including bank staff. This will be supplemented, where appropriate, by data from NHS iView.
- Wage data will be taken from the NHS Workforce Executive System (WES) and the New Earnings Survey.
- CQC Maternity Survey of Maternity Provider Trusts 2007 and survey of women's' experiences, 2007 and 2010 from the UK Data Archive.

This will be used to determine if a change in staffing level produces a change in a range of outcome measures by using longitudinal data and explore the association between staffing and outcomes as staffing levels change over time. It will also be used to model the effect of various workforce inputs on both quality (measured by safety outcomes) and productivity. The study will generate new management information including: Measurement of the impact of altering skills mix on efficiency; degree of substitutability of labour inputs and optimal mix of labour inputs.

Phase 2: Economic Analysis

The study will adopt a framework where both outcomes and cost are taken into account when measuring efficiency. Efficiency measurement will therefore include any exchange between resources and outcomes (Zuckerman et al., 1994). Inefficiency at the hospital/community level is defined as the difference between actual cost and the minimum admissible total cost of producing a set of output for a given level of patient safety.

Phase 3: Dissemination

Early results will be disseminated through internal King's seminars and the larger research and policy community of the UK. We will also provide seminars for policy makers in settings and at times appropriate for the users of the research findings and offer seminars in the programmes of the All Parliamentary Group on Maternity Care, and the Royal Society of Medicine Forum for Maternity and Newborn. In addition, we will explore the possibility of the topic being of interest as an ESRC Seminar Series on the broader issue of the healthcare workforce, methodological learning in the use of secondary datasets and novel use of web based data presentation. Feedback and comments obtained will help assess the robustness of the findings and their importance/relevance in the context of the NHS and will inform further economic modelling.

We propose to disseminate the results of our research by using a web based tool using the Flash development environment and through face to face seminars. This will enable trusts and managers to explore and compare findings and to model the potential consequences of planned workforce changes. The website tools will enable decision makers and managers to (i) understand the findings of this study in a non-technical manner, and (ii) to apply the findings themselves. This approach has been adopted as it has been shown to provide an easy-to-use way to show the interrelationships between complex data.

Time line

This project is planned to last 18 months. Phase 1 will take 6 months and includes ethical approval, data access, extraction, cleaning, and variable creation. Multi-level modelling will take place in Phase 1 until month 9 overlapping with Phase 2. Phase 2 which focuses on the economic modelling will take 9 months and Phase 3 approximately 6 months but will be overlapping with the economic analysis in Phase 2. Work will be published as results are available. The research outputs would have both academic and practical significance. In particular, for healthcare managers, clinicians, midwives and policymakers, key research outputs include:

1. Workforce based efficiency metrics for NHS maternity providers in relation to patient safety and quality (England)
2. Contextual and team profiling of the operational workforce within the NHS and an indication of the optimum composition of the workforce relative to patient outputs and financial cost
3. Information on the optimal staff mix for efficient production of maternity care, and in particular information on the optimal use of the maternity workforce
4. Multivariate statistical modelling, which will explore relationships or associations between workforce configurations, output, safety and economic cost, including measures of the sensitivities (elasticities) of these factors to changes in the workforce
5. Web-based tools for decision makers to model the impact of changes in their own workforce and skill mix on these variables

If this project is successful we see scope to model more complex systems in the future.

Data Sources

The data will be assembled from a number of administrative datasets. Patient safety and quality data will be assembled from a number of sources including Health Episode Statistics (HES), Dr Foster Quality Accounts, and CQC provider and women's survey. The OECD guide "Selecting Indicators for Patient Safety at the Health Systems Level in OECD countries" will be used to guide the construction of a patient safety and quality measure from a range of indicators suggested by the literature, which will include standardised mortality ratios and failure to rescue indicators. Data on hospital outputs will be calculated from finished consultant episodes from the HES data. Input data will be taken from the NHS Information Centre's Workforce data and from the Laing and Buisson dataset on NHS Trusts' financial accounts. Wage data will be taken from the NHS Workforce data and the New Earnings Survey. The reliability of the datasets and the variables to be extracted are discussed in more depth below.

Health Episode Statistics

Health Episode Statistics (HES) data will derive a range of outcome measures via hospital site 1) Readmission rate for mothers, (2) Readmission rate for babies, (3) Total expenditure on mother (and baby) in an acute hospital care³ in the year following delivery (i.e. A&E, OP and IP expenditure), (4) Normal birth rate (Birth Choice UK deflation or other deflation), (5) Women with long post-delivery length of

³ Apart from a small number of PCT's, maternity care is provided by acute trusts either within the hospital or community settings.

stay (after standardisation for delivery type etc), (6) AHRQ Indicators (ref) - Birth trauma/ injury to neonate (PSI 17), Obstetric trauma/vaginal delivery with instrument (PSI 18), Obstetric trauma/ vaginal delivery without instrument (PSI 19), Obstetric trauma/caesarean delivery (PSI 20) and (7) Mortality rates. The Trust statement on Compliance with Core Standards can provide standardised data for a range of patient level measures including 1) Maternal age, (2) Number of previous pregnancies (estimated from HES), (3) Delivery type, (4) Anaesthetic type, (5) Maternal deprivation (accessed via IMD etc), (6) Ethnicity, (7) Emergency Admissions in 12 months prior to delivery, (8) Admission referral pathway (i.e. self-refer, referral via GP, midwife, emergency ambulance etc), (9) Days since birth to readmission, (10) Day of discharge from midwifery care, (11) No. of midwifery contacts postnatal, (12) Place of birth and (13) Model of care

HES Data Quality

Since 2007/8, the NHS Information Centre has produced annual reports on the data quality of HES in terms of completeness and validity. These reports highlight major projects with specific fields and trusts with a significant amount of missing or invalid records. These reports show a steady increase in data quality between 2007/8 and 2009/10. However, during our analysis stage we will be mindful of the issues raised in the reports.

The overall coverage in 2009/10 is believed to be very good. Only three providers have been identified as having significant number of missing records. Data for these providers will be treated with caution and maybe excluded from the analysis. Whilst NHS HES data has been historically poor, several initiatives have driven up quality including Payment by Results, regular audits and increased examination of HES data by clinical staff. Since 2007, the accuracy of HES data is assessed by the Audit Commission's Payment by Results (PbR) Data Assurance project. Since the start of the programme average clinical coding errors at trusts have decreased by 5 per cent from 16 to 11 percent⁴.

Trust codes, denoting the organization that provided the treatment, are nearly 100% completed and believed to be highly accurate as they are required to submit for financial purposes?. In 2009/10, three providers have failed to submit trust codes. However, the impact to the total records of the providers above is relatively small. The reconfiguration of a number of trusts during the period under investigation will require careful handling. Hospital site codes are less well complete. In some cases these can be inferred (e.g. when a trust has only one hospital), however, this may require analysis to be limited to trust and not hospital level. Specific problems of completeness and validity of demographics details in HES are believed to be rare. However, patient's demographics are not checked as part of the Audit Commission's audit for accuracy.

The HES data quality report suggests a few known problems. For instance, one provider has been unable to submit data of birth in 2009/10. This organization is the provider of a PCT and is therefore outside the scope of this study. The completeness and validity of diagnostic coding is reviewed in the HES Data quality notes. Previous studies have demonstrated that the depth of diagnostic coding has increased. Our

⁴ It is acknowledged that the purpose of this programme was primarily designed is to audit data for compliance with the PbR financial framework rather than for clinical or research purposes. Nevertheless, considerable improvement has been noted in data quality of the fields examined as part of the programme.

recent report on failure to Rescue (Jones et al 2010) further confirms that coding depth has increased markedly over the past decade and also suggests that it is not highly correlated with either HSMR or failure to rescue. More on depth and accuracy of coding

NHS Information Centre Workforce Dataset

The variables that will be accessed from workforce data are employment status (full-time or part-time working); staff specialties, age, earnings, salary scales, staff vacancies and turnover:

Working hours format: 1-10 hours, 11-20 hours, 21-30 hours, 31-36 hours and 37+ hours at host presented as Full-time Equivalent hours (FTE). Some statistics are expressed in terms of full-time equivalents (FTE). For this purpose, numbers of part time staff are converted into an equivalent number of 'full time' staff, by taking account of the weekly number of hours or sessions in their contract. The maximum FTE for all staff within the census is 1.28.

The component grades of medical staff are Specialist Trainee 1, SpR grade 2, Specialist Registrars 3-7 and some non-career grades and Specialty Doctors, and other staff working at equivalent grades that are not in an educationally approved post. and other staff working at equivalent grades that are not in an educationally approved post. Due to changes to pay scales following the introduction of the new consultant contract in April 2003, it is no longer possible to produce an accurate split between staff in the hospital and community sectors.

Currently there are nine grades for all non medical staff in the NHS other than senior managers. Nursing and care support staff are found on the full spectrum with band 5 and above generally representing the cut off point between unregistered and professionally registered professional staff. Job titles are inconsistent although generally it is relatively trivial to distinguish clinically qualified nurses and allied health professionals from others. However even then anomalies can occur as evidenced by the presence of healthcare assistants at band 5 and above. We will consult with operational managers to develop mappings from job titles and grades in the workforce data to broader categories of professionally qualified staff, assistant practitioners and care assistants.

This statistical data relates to staff paid by NHS organisations via The Electronic Staff Record (ESR). The ESR is a payroll and Human Resources (HR) system which has been rolled out across the NHS and was completed in April 2008. The statistics relate to payments to staff during periods ending June 2011.

NHS Information Centre Workforce Dataset Quality

Workforce statistics in England are compiled from data supplied by around 400 NHS organisations, and on behalf of around 8,200 GP practices. This data set has information on the NHS and social care workforce. This is drawn from systems which feed workforce statistics (NHS payroll, practice payments and human resources system). They are produced in accordance with the "*Framework for National Statistics*" (ISD, 2009) and comply with the principles embodied in the NHS "*Code of Practice*" (ISD, 2009). The NHS Information Centre for health and social care (NHS IC) liaises with these organisations to encourage complete data submission, and to minimise inaccuracies and the effect of missing and invalid data.

The NHS IC seeks to minimise inaccuracies and the effect of missing and invalid data but responsibility for data accuracy lies with the organisations providing the data. Methods are continually being updated to improve data quality. The 'Data Quality Six Steps' national plan produces monthly reports and establishes NHS specific data quality reports. The data quality reports focus specifically on Medical and Non medical staff and are signed off by Finance and Human Resource Directors.

NHS Workforce data covers staff all post across all disciplines by grade, hours worked, gender, ethnicity, and doctors in training compliance with the European Working Times Directives and students in training – intakes and attrition rates. It also provides information in relation to equality and diversity, sickness absence, staff turnover and agency and bank usage in midwifery. The data held in relation to NHS staff is therefore extensive and draws upon all personal and professional data held within the workforce data system. The statistical data will be extracted from IView system.

Care Quality Commission

Derived Data from the CQC women's survey on women's experience of care (CQC 2010) will provide measures of quality identified by Midwifery 2020 (2010) and National Childbirth Trust (Dodwell and Newburn 2010). 1) Continuity of care 2) Trusting relationship with midwives, 3) Choice of place of birth (information, access, support) 4) One to one midwifery care in labour, 5) Good birth environment 6) Access to choice of pain relief 7) Women's experience of intrapartum care - feeling safe, nurtured, supported, satisfaction with birth experience 8) Overall satisfaction with intrapartum care 9) feeding support 10) Overall satisfaction with postnatal care.

Care Quality Commission Data Quality

Data from the Care Quality Commission is available from the UK Data Archive which includes the following:

- A mandatory web-based maternity questionnaire completed at trust level (Data reported are for the year 2006/07).
- A trust-level survey of women who had recently given birth in 2007. Almost 45, 000 women were invited to take part in the survey about their recent experiences of maternity care services provided by 151 NHS Trusts in England. Women who had given birth in February 2007 were sent a postal questionnaire approximately three months after the birth. Over 26, 000 women responded to the survey, representing an adjusted response rate of 59%. A 2010 survey of women who had given birth in February 2010, of women's experiences of maternity services which involved 142 NHS acute trusts and 2 primary care trusts (PCTs) in England. Over 25,000 women responded, representing a response rate of 52%. Topics covered included: baby birth dates and weights; antenatal care and check-ups; tests and scans; choices of care; medical problems and pregnancy care; antenatal classes; labour and delivery, including medical care; midwives and other healthcare staff; home births; hospital care after birth; infant feeding; special care and neonatal units; home care after birth; and respondents' demographic characteristics.

Data Analysis Methods

Phase 1

Phase 1 will primarily be led by RG who will extract and compile the data from the sources outlined above. The data will be cleaned, checked for quality and a number of exploratory statistical analyses will be performed to determine the most suitable

variables for measures such as patient safety and patient output. GC will compile the economic data.

We will use multi-level regression models suited to explore the relationships between staffing levels, skill mix, patient safety and outcomes. We will adjust for differences between the types of centres using the level of neonatal care (level 1, 2 or 3), and the number of births provided at Trust level using groupings outlined in the review *Safer Childbirth*⁵ (<2,500; 2,500–4,000; 4,000–5,000; 5,000–6,000 and > 6,000 deliveries). In addition we will adjust for the different types of women giving birth in each unit, and the case-mix and severity using the Index of multiple deprivation, age and ethnicity of the population at Trust level. Current co-morbidity indices used in general health care such as the Charlson or Elixhauser co-morbidity index are not appropriate for childbearing women, and we will explore and test alternatives. The resulting index would prove valuable in future work as the load of co-morbidity increases in this population.

We will control for patient characteristics using the variables described in Bottle and Aylin (2008) which include diagnosis, age, gender, procedure and co-morbidity. Catchment areas will be identified using the adaptive radius method described in Cooper et al (2010). Trusts which appear to be outliers in each year will be scrutinised to determine if there are specific factors which might account for their status and to identify important factors that might not be fully considered in the model.

Phase 2: Economics

Phase 2 will use the dataset compiled in Phase 1 to answer the remaining two research questions in turn. The analysis will be led by GC, with statistical support from TM, and will adopt accepted econometric tools from production economics

Firstly, we will explore the economic relationship between the different staff inputs and hospital output. In particular, we want to establish to what extent the different roles are substitutes or complements. We will use maternity episode data from HES to measure the output of trust's maternity services. The unit of analysis will be at trust level. The inputs will be each of the labour variables taken from the Workforce Dataset and a proxy measure of hospital capital being the number of available maternity beds. In addition, a series of controls will be included such as a dummy for teaching hospital status and case-mix controls. A full set of controls will be identified in Phase 1 and will be informed by the team's previous experience, the extant literature and an exploratory data analysis. In economics, a production function describes the mechanism for converting a vector of inputs (X) into output (Y). 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. However, this function assumes all inputs to be substitutes (solely due to the absence of cross-products). The advance in production function analysis of the 1970s gave rise to two flexible econometric specifications which allow us to relax this overly strict assumption. Berndt and Christensen (1973) introduced the transcendental-logarithmic (translog) production function and Diewart

⁵ Royal College of Obstetricians and Gynaecologists, Royal College of Midwives, Royal College of Anaesthetists, Royal College of Paediatrics and Child Health (2007). *Safer Childbirth: Minimum standards for the organisation and delivery of care in labour*. London: RCOG Press.

(1971) introduced the generalized linear production function (also known as the Allen, McFadden and Samuelson production function). Using either of these functions we will be able 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). The advantage of the Diewart 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. The result of this production function analysis will enable us to understand the effect of each staffing group on maternity output. It will also enable us to examine the effect of reconfiguring the skill mix on maternity output.

The production function assumes that the organization is technically efficient which is not a reasonable assumption. A common approach is therefore to include a decomposed error term which captures random error and the inefficiency of the organization, hence the method is called *Stochastic Frontier Analysis*. SFA has a long history in economics (see Aigner et al., 1977, Meeusen and van Den Broeck, 1977) and in health economics (Newhouse, 1994). By extending of production function to capture inefficiency we can investigate the effect of characteristics on inefficiency. Stochastic frontier analysis will allow us to investigate the impact of skill mix and reconfigurations to the skill mix on productivity, rather than simply output levels.

Newhouse (1994) critiqued the use of frontier methods based upon the problem of capturing quality heterogeneity. Recognising that output heterogeneity may masquerade as inefficiency, most studies of efficiency that employ frontier analysis include additional covariates to control for case-mix, structural quality or outcomes. Rosko and Mutter (2010) review different strategies that have been adopted to control for output quality. These controls can have a significant impact upon the inefficiency estimates. For instance, Zuckerman et. al. (1994) found that including output quality characteristics reduced the mean inefficiency estimate from 18.8% to 13.4%.

However, none of these approaches sit well with the underlying economic theory of production. Low quality healthcare will see a rise in the number of adverse events including readmissions, tears, drug errors, hospital acquired infections and mortality. To address our research question we extend the traditional single output production frontier to allow for the simultaneous production of a “bad” (e.g. drug error) and a “good” (e.g. hospital consultations) outcome. Minimising the production of “bads” will use scarce resources and, we predict, reduce “good” output. By incorporating the production of adverse events directly into the hospital production function we will be able to model the effect of inputs on the production of goods and bads simultaneously to answer a number of policy relevant questions. In particular, we will be able to identify the shadow cost of patient safety in terms of forgone production and to establish whether it is possible to improve patient safety without reducing output or, increase output without increasing adverse events. We will follow the method described in Fernandez et. al (1999; 2000) which incorporates the undesirable output into the output side of the stochastic frontier model by proposing a new, Bayesian, transformation function.

Extending the traditional single output stochastic frontier model in this way will enable us to investigate the extent to which patient safety and maternity output are trade-offs

(if at all), and to measure the impact of skill mix changes on both “outputs” simultaneously.

Phase 3: Dissemination of findings

Phase 3 will run concurrently with the end of Phase 2 as indicated in the flow diagram (section 12) and in the timetable (section 6). During Phase 3 we will disseminate our findings through a number of channels and to a range of audiences. We will communicate our results with the academic community through peer-reviewed articles in leading journals and through conference presentations. More broadly we will communicate directly with managers and decision makers through the use of innovative web-based tools and policy seminars

We will explore the potential of developing a web-based tool to disseminate the findings and analyses. This will enable trusts and managers to explore and compare findings and to model the potential consequences of planned workforce changes. The tool will be interactive and will be hosted on a publically available website. It will be implemented using the PHP development environment. The tool will remain functional for at least two years with this function to be ongoing pending future funding or alternatively integrating the tool into the NHS Information Centre tool base. The website tools will enable decision makers and managers to (i) understand the findings of this study in a non-technical manner, and (ii) to apply the findings themselves. For example, they could visualize the impact of changing their skill mix on output, safety and efficiency.

Research outputs

The research outputs would have both academic and practical significance in particular for healthcare users, managers, clinical directors, directors of strategy and finance, relevant Royal Colleges, Service commissioners, GP consortia and policymakers. Key research outputs include:

1. Review and analysis of quality indicators for maternity
2. Information on the optimal staff mix for efficient production of quality outcomes in particular information on the optimal input of midwives
3. Understanding on the degree of complementarity and substitutability of midwives, doctors and support workers.

Plan of investigation and timetable

The project will last 18 months from 1st March 2012 to 31st August 2013.

Activity	Month	Output
Project Management		
Ethical approval	1	Approval granted
Team Meetings	1,3,9,12,15,18	
Phase 1: data collection		
Extract Data	1-3	
Data cleansing & manipulation	4-6	

Variable creation	6	
Multilevel modelling	7-9	
Phase 2: economic modelling		
Build econometric model	6-7	
Production Function analysis	7-9	
Stochastic Frontier Analysis	10-12	
Multioutput analysis	13-15	
Phase 3: dissemination		
Reports to SDO	6, 12, 18	
Conference and seminar presentations	15-18	
Publish journal articles	15-18	
Interactive website	12-18	

Approval by ethics committees

This study uses secondary data to address questions relating to the relationships between staffing, patients outcomes and productivity in the English NHS. As indicated in Section 4.2, this project will use data from three main sources:

1. Health Episode Statistics for outcome data, control variables and output measures
2. Workforce Database for wage and staffing data from the Information Centre
3. Dr Foster Quality Accounts for patient safety variables
4. Care Quality Commission Trust and Women's Survey

The data for parts 2-3 are publically available data and are not confidential or sensitive, and have been made available for research purposes. We will of course comply with any requirements made by the data providers. In contrast, all aspects of the HES data are confidential (as they relate to people's health) and some aspects are sensitive (e.g. legal status under mental health legislation). Additionally, some variables recorded in HES potentially allow identification of individuals (e.g. date of birth and postcode). The team has significant experience of working within the data protection protocols that have been established for HES data. In this research no patient identifiable data will be required in our extract from HES (see Section 4.2.1 for a list of the variables that we will extract).

However, we will maintain our rigorous procedures for ensuring the security of the HES data which will be deleted at the end of the project. The RGF applies to activities that are managed as research. Other activities such as audit, service development, local service evaluation and public health surveillance are not presented or managed as research within the NHS. Therefore we have been advised that the nature of this research, and the fact that no patient identifiable data will be used in the study that NHS REC permission is not required. However local policy at KCL requires ethical approval for all research and so we have made a local application to the ethics committee of the host university to ensure external ethical scrutiny.

Project management

Professor Jane Sandall, as Chief Investigator, will provide overall leadership for the project responsible for project completion and delivery. Dr Kirstie Coxon will act as project manager throughout the 18 months of the project. Responsibilities will include coordinating activities and providing progress reports. The study will use recognised project management methodology including project initiation, planning, monitoring, and delivering. A project initiation document will define all aspects of these activities and will be produced before the project commences. The research team will meet every quarter to ensure that goals are met and timelines are maintained. A project advisory group will be established with input from organisations such as Bliss, NCT, SANDS and Tommy's and representatives from ChiMat and experts in maternity data use and managers and commissioners/service planners. This will also include recent service users.

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