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Analysis of Caesarean section utilisation: Unravelling variations, investigating the impact of policy change, and evaluating Enhanced Recovery pilot

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Declaration of Authorship

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

Signed: Konstantinos Koutsouradis

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Abstract

Caesarean section (C-section) is one of the most common surgical procedures performed in the world. The rates of the procedure have been increasing globally, while considerable variations are observed across space (areas and healthcare providers) and time. Maternal and newborn health stands as a cornerstone of a thriving society and a resilient future. The well-being of mothers and their infants is not merely a medical concern; it is a reflection of a society's commitment to compassion, equity, and the preservation of life's most precious moments.

This study analyses several aspects of C-section utilization, unravelling patterns of variations, investigating the impact of a policy change and evaluating the effect of Enhanced recovery pilot after C-section. This study examines a timeframe, extending up to 2016. For that reason, the reference justifications and supporting sources are reported around that period of time (given the timeframe that these analyses were conducted and the availability of data). However, the subjects under analysis and the study remain highly relevant and importan until this present time, since C-section rates are continuously rising and variations are reported worldwide. More specifically, global C-section rates have increased to 21% (Angolile, 2023)[1] - an increase that exceeds the optimal rate of 10%–15%, as this is suggested by WHO – and variations in the utilisation of the procedure are reported constantly up to this day (Shalash et al, 2022)[2]. In Scotland the rates of C-section have risen to nearly 35% over the last years (Scottish Government 2021[3]; Public Health Scotland, 2021[4]), compared to approximately 9%

[1] Angolile CM, Max BL, Mushemba J, Mashauri HL. Global increased cesarean section rates and public health implications: A call to action. Health Sci Rep. 2023 May 18;6(5):e1274. doi: 10.1002/hsr2.1274. PMID: 37216058; PMCID: PMC10196217.

[2] Shalash, A., Wahdan, Y., Alsalman, H.M.M. *et al.* Variation of caesarean section rates in Palestinian governmental hospitals. *BMC Pregnancy Childbirth* **22**, 943 (2022). https://doi.org/10.1186/s12884-022-05275-w

[3] The Scottish Government (2021) *The best start - caesarean section rates: Review report*, *Scottish Government*. Available at: https://www.gov.scot/publications/best-start-review-caesarean-section-rates-scotland/pages/3/ (Accessed: 20 August 2023).

[4] Public Health Scotland,. (2021) *Births in Scotlandyear ending 31 march 2021*, *Births in Scottish hospitals - Year ending 31 March 2021 - Births in Scotland - Publications - Public Health Scotland*. Available at: https://publichealthscotland.scot/publications/births-in-scotland/births-in-scottish-hospitals-year-ending-31-march-2021/ (Accessed: 21 August 2023).

in 1976 and 32% by 2017, while significant variations are reported across hospitals (Public Health Scotland, 2021). This study consists of three chapters.

The first chapter explores variations in the use of Caesarean-sections in Scotland with the aim to unravel the driving forces that contribute to these patterns. Multilevel regression analysis was employed (using 2-level logistic regression models, as well as 3-level) to disentangle the variation and understand the contribution of hospital, primary and secondary healthcare professionals in the observed variation that cannot be explained by patient characteristics and clinical risk factors. The data used in this chapter were sourced from the Scottish Morbidity Records (SMR02), provided by ISD Scotland (now Public Health Scotland), covering all public hospital births between 2009 and 2016. Understanding the driving forces of variations in order to mitigate them is very important and stands as a central objective pursued by governmental bodies and policymakers in order to establish targeted strategies and achieve equity in healthcare, quality improvements, cost efficiency and evidence-based practices. The contribution of this research is significant as this is one of the few papers using multilevel analysis taking hospitals as groups of the analysis, rather than geographic regions and one of the few that employs multilevel regression modelling. The advantage of using hospitals over regions is that hospitals represent the actual decision-making units where clinical practice is implemented, offering more granular insights into provider-level variation. Moreover, it's the first study that controls for such an extended range of possible factors that could explain the decision of having a C-section (including maternal and fetal clinical risk factors, maternal characteristic, socioeconomic factors and policy changes). Furthermore, it is the first one that examines all possible healthcare providers that could theoretically influence the decision for having a C-section (including the primary care sector) and the first one that is employing a 3-level multilevel regression to unravel healthcare variations.

The second chapter aims to examine the effect of NICE guidelines, that were implemented in November 2011, on C-section rates in Scotland and explore how the availability of treatment option to women with no medical need could impact the rates of C-section. Specifically, these NICE guidelines stated that elective C-sections should be available to women upon request even in the absence of a medical indication, following appropriate counselling and support. To do so, a synthetic control method was employed, using German regions as the "donor pool" for the construction of the synthetic control unit. The results of this research could imply the association between the availability of treatment options could increase the maternity care utilization when there is no medical necessity for a specific treatment. This study contributes to the literature, as it is the first one that evaluates the health policy reform that was introduced by NICE, regarding the availability of elective C-sections to women with no medical indication for the procedure. Moreover, it is one of the few studies where synthetic control method has been applied in a UK context, examining the effect of health-related policy changes and the first one in Scotland.

Finally, the third chapter evaluates the effect of the enhanced recovery pilot after C-section. The study primarily focuses on mothers who underwent elective C-section with the main goal to evaluate the effect of the pilot on maternal length of stay post operation. Twin births were excluded from the analysis to ensure comparability and avoid confounding effects. This exclusion is consistent with prior literature focusing on elective C-section utilisation. To investigate the hypothesis that mothers treated under the pilot, with shorter hospital stays post-delivery, are more prone to subsequent readmissions, we conduct a parallel analysis to determine whether those with lower average post-birth hospital stays had differing probabilities of being readmitted. While the primary emphasis of the pilot centres on mothers who underwent elective C-sections, an exploration will also be undertaken to assess the impact of the pilot on mothers who underwent emergency C-sections. To examine the above research objectives, propensity score matching (PSM) was employed along with a series of matching methods was employed, including Nearest Neighbour Matching, Inverse Probability Weighting (IPW), and Augmented IPW Regression Adjustment. Lastly, leveraging local audit data, we will compare the compliance with enhanced recovery elements to the length of hospital stay (measured in hours) following delivery. This study contributes to the literature by providing novel evidence on the impact of the Enhanced Recovery pilot in Scotland, evaluating its effect on maternal length of stay and the likelihood of hospital readmission following elective Caesarean sections. Additionally, it contributes to the literature by offering new insights into how adherence to specific elements of the pilot influences variation in postnatal length of stay.

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List of Abbreviations

CS/C-section:	**Caesarean Section**
ERP:	**Enhanced Recovery pilot/programme**
LOS:	**Length of stay**
PRM:	**Princess Royal Maternity unit**
PS/PSM:	**Propensity Score Matching**
RA:	**Regression Adjustment**
IPW:	**Inverse probability weighting**
AIPW:	**Augmented Inverse probability weighting**
IPWRA:	**Inverse probability weighted regression adjustment**
NN:	**Nearest neighbor**
SD:	**Standard Deviation**
HC:	**Healthcare**
LOS:	**Length of stay**
OR:	**Odds Ratio**

I. Chapter I: **VARIATIONS IN CAESAREAN-SECTION ACROSS HEALTHCARE PROVIDERS IN SCOTLAND**

1. INTRODUCTION

Headline statistics show that substantial variation exists across Scotland in the rates of Caesarean-section (C-sections) across different hospitals, as well as different NHS Health Boards. In 2015, the rate of C-section at the Princess Royal maternity hospital in Glasgow was 37.2%, while at the New Royal Infirmary of Edinburgh it was only 25.2% (ISD Scotland, 2016). Indeed, examination of aggregated data suggests that these patterns in the data are persistent over time, with significant differences in the performance of the procedure being observed between different healthcare providers across Scotland. These differences are widening and reveal unwarranted variation that needs to be further examined and addressed.

Maternity care is a crucial area of the healthcare system and one of the most highly utilised areas of the NHS. It involves the important event of a child's birth – a life-changing time for the mother and the whole family. Unwarranted variations in maternal care and clinical practice regarding the decision-making for the birth delivery could reveal inefficiencies in the healthcare system in the allocation of the procedure, as well as healthcare spending that could be avoidable. Maternal services are expected to be consistent among the mothers-to-be, high quality and efficient, while the treatment choices are expected to be based on informed patient choice and what is considered as best for the mother and the baby. This makes understanding the drivers of the observed differences in the rates of C-section essential and will be the focus of this chapter.

A substantial literature has explored different dimensions of healthcare variations (Groenewege, 2004; de Jong, 2008; Hanley, 2010; Fisher, 2013) stemming in large part from the work of Wennberg (1982). This literature identifies a number of key explanations for the emergence and persistence of variations in healthcare utilisation and outcomes. More specifically, variations in healthcare could be explained to some extent by differences in the patient characteristics (de Jong, 2008; Schulman et al., 1999), patient preferences (Gilligan et al., 2002; Lu-Yao et al., 1993), individual clinical risk factor associated (Groenewege, 2004, de Jong, 2008, Baicker, 2006). However, in most cases variation cannot be explained by the individual clinical risk factors and could be influenced by different clinical patterns developed between geographical regions or hospitals (Hueston, 1996; Westert, 1999; Westert, 2015; Glutten, 2003; Wennberg, 2010). A smaller strand of literature considers variation in C-sections (Bragg 2010; Sinnot 2016), across England and the Republic of Ireland respectively using cross-sectional data. They provide a quantification of the degree of unexplained (that cannot be explained by differences in patient characteristics or clinical risk factors) variation systematically driven by which hospital the mother is treated.

In this paper, we extend the existing literature in a number of different ways. Our study of variations in the use of C-sections utilises a very detailed set of Scottish data, including all the births that took place in Scottish public hospitals from 2009 to 2016. The aim of the research is to disentangle the driving forces of variations in the C-section rates across Scotland and identify their contribution to the unwarranted variation that cannot be explained by patient characteristics and clinical risk factors. Firstly, we identify the influence that primary care might have on variation in C-sections, given that an expectant mother's first interaction with the healthcare system is via primary care (either GP or midwife). Then, we quantify the contribution of secondary care. To do so, we examine both the contribution of hospitals and secondary healthcare professionals. Finally, we explore trends in medical variation over time, utilising our repeated cross section data covering the period 2009 – 2016, to better understand the evolution of variation in C-section rates in Scotland over time. This is the first study that attempts to identify and quantify the contribution of all these possible sources of variation in the performance of C-sections while controlling for a wide range of patient characteristics and clinical risk factors that could explain the decision-making for a C-section, as well as the first one that examines the variation in medical care, utilising both longitudinal and cross-sectional data.

The rest of this chapter is structured as follows in table below:

Table I.1 Structure of the Chapter

Section 2	**In this section, we present some background information on C-section in Scotland and explore the trends in the aggregate data**
Section 3	In Section 3, we review the literature on medical variation in general, including discussing why variation emerges and persists in medical treatment and outcomes, before reviewing the existing literature on medical variation in C-section. Furthermore, we outline in more detail the different methods which have been used to date to explore variations in healthcare, providing the motivation for the empirical approach taken in this paper
Section 4	In Section 4, we discuss the data that were used in the empirical study, as well as the methodological approach and the design of the analysis

Section 5	In Section 5, we present our results
Section 6	The final section discusses the results and concludes

2. BACKGROUND – HEALTH CARE VARIATIONS

Maternity care is one of the most highly utilised areas of NHS, which involves the important event of a child's birth – a life-changing time for the mother and the whole family. Services are expected to be consistent among the mothers-to-be, high quality and efficient, while the treatment choices are expected to be based on informed patient choice and what is considered as best for the mother and the baby.

In this section we provide some important background information to the reader on C-sections in the UK and review the aggregate data on variations in C-sections.

2.1. C-SECTIONS IN THE UK

Caesarean-section (C-section) is the surgical operation that takes place for the delivery of one or more babies. A C-section is often necessary when a vaginal delivery would put the baby or mother at risk (OWH, 2017) This may include obstructed labour, twin pregnancy, high blood pressure in the mother, breech birth, or problems with the placenta or umbilical cord (ACOG, 2014). Conventionally, Caesareans are classified as elective if they are planned in advance or emergency, based on the urgency of the procedure. Elective C-sections can be planned based on medical obstetrical indication or because of medically non-indicated maternal request (CDMR – Caesarean delivery on maternal request), while Emergency C-sections are carried out when a vaginal delivery was planned initially but medical indications for a C-section have since developed. (cRCOG, 2011; NIH, 2006).

Since the 1970s, there is a significant increase in the rates of C-sections across many developed countries (Althabe, 2006; Information Centre, 2009; Betrán, 2016; OECD, 2017; NHS, 2017). More specifically, in Scotland, the rates of C-section increased from 20.7% in 2000 to 32.4 in 2015 (ISD Scotland, 2016). Several reasons have been suggested for this growth in the rate of C-sections, including changes in maternal characteristics (such as rising maternal age) and a rising number of women who have previously had a C-section, technological advances that have reduced the medical risks of the operation, organizational and cultural changes, as well as changes in clinical practice (Churchill, 2006; Betran et al., 2016).

Nevertheless, C-section rates continue to evoke worldwide concern because of their steady increase (see Appendix A, table I.18), lack of consensus on the appropriate C-section rate and the associated additional short- and long-term risks and costs, new guidelines were proposed by NICE regarding giving birth. The new policies that were published in November 2011, suggested that C-section will be available even to women who are capable of giving birth naturally, making every mother-to-be eligible for the procedure if it is pre-arranged (NICE, 2011). However, a C-section is costlier than a vaginal delivery and is calculated to cost about £800 more than a natural delivery (planned/elective C-section versus planned vaginal delivery) (NICE, 2011). It is estimated that decreasing the rate of C-sections in the UK by one percent each year could save the NHS about £5 million (Easter, 2015), avoiding substantial cost implications for the health care system, especially in the case of adverse outcomes and complications.

From a medical standpoint, C-sections are vital and often lifesaving for mother and baby in cases of labour complications such as stalled labour, fetal distress, uterine rupture, or prolapsed umbilical cord. However, both underuse and overuse can negatively impact maternal and infant mortality (Porreco, 1996). The World Health Organization recommends an ideal national C-section rate between 10% and 15%, noting that rates above this do not improve mortality outcomes (WHO, 2015), while other evidence suggests benefits up to 19% (Molina, 2015).

Despite its generally low risk, the procedure can lead to complications. Maternal risks include infection, hemorrhage, and thrombosis, while infant risks include respiratory distress, pulmonary hypertension, iatrogenic prematurity, and bonding or breastfeeding difficulties (Shorten, 2007). A multi-country study in 24 nations between 2004 and 2008 linked C-sections with increased maternal and infant risks (Souza, 2010).

Thus, Caesarean-section should not be seen as an equal alternative to spontaneous vaginal delivery; decisions regarding its use should be evidence-based and made with caution (Mylonas, 2015). Elective C-sections have been associated with higher maternal morbidity compared to vaginal deliveries (Hannah, 2000), though complications are 50% lower than those seen in emergency C-sections (Bergholt, 2003). Infants born via Caesarean-section face increased risks of respiratory issues such as respiratory distress syndrome and transient tachypnea (Tita, 2009; De Luca, 2009). While often mild, these complications may require short-term observation or admission to special care units, extending hospital stays.

Beyond immediate complications, C-sections have been linked to long-term infant health concerns, including bronchial asthma (Bager, 2008; Thavagnanam, 2008), allergic rhinitis (Bager, 2008; Koplin, 2008), food allergies (Gladstone, 2010), diabetes mellitus (Cardwell, 2008), and autism (Gialloreti, 2014). However, the complex pathophysiology of these conditions warrants further investigation into causality. Breastfeeding may also be affected; women undergoing C-sections often experience difficulties (Vestermark, 1991; Hauck, 2011). Although findings are mixed—some studies show no association (Kohlhuber, 2008; Patel, 2003), others report negative effects (Ever Hadani, 1994; Hauck, 2011)—delayed mother-infant contact and neonatal special care admissions may contribute to breastfeeding challenges (Mylonas, 2014)

2.2 TRENDS IN C-SECTIONS IN SCOTLAND

In Scotland, the health care provision is mainly publicly funded, provided by the national In Scotland, the healthcare provision is mainly publicly funded, provided by the national public health service, NHS Scotland. The health system is an integrated service under the management of 14 geographically based local NHS Boards, which are responsible for the provision of healthcare (along with 7 national special Health Boards). Local authority nominees were added to board membership to improve coordination of health and social care. Secondary care provided in hospitals is managed by the acute division of the NHS Boards. Primary care services (such as GPs, midwives and pharmacies) are contracted through the NHS Boards but are also considered part of the remit of Health and Social Care Partnerships (HSCPs). HSCPs are structures jointly run and based largely on the NHS and local authority boundaries in each locality.

As part of this publicly funded and integrated system, pregnant women in Scotland receive antenatal and postnatal care through the NHS. After discovering their pregnancy, women typically have their first appointment with a midwife, either at their GP practice or at home.

This initial visit is a crucial opportunity for the mother-to-be to ask questions about her pregnancy and receive guidance on available care options and the next stages of care. Standard practice includes blood tests and information on screening for both the mother and baby. Over the course of the pregnancy, women usually attend 8 to 10 appointments. When admitted to a maternity unit for delivery, a healthcare professional is assigned to oversee the mother's care. If admission is to an Alongside Midwifery Unit (AMU) or Freestanding Midwifery Unit (FMU), a midwife is the responsible professional; if admitted to an Obstetric Unit, a consultant takes responsibility (ISD Scotland; NHS Scotland).

Despite this comprehensive and structured care provision, there are significant variations across Scotland, particularly within smaller regional areas of NHS Boards and council areas (Audit Scotland, 2012). These unwarranted variations include disparities in deprivation, health inequalities, clinical practice, and treatment outcomes (Audit Scotland, 2012; NHS Scotland, 2015). Often, such variation is not attributable to patient needs; instead, differences in treatment may reflect the clinical preferences or decision-making styles of healthcare providers, rather than genuine regional differences in disease prevalence, risk profiles, or patient preferences (NHS Scotland, 2015; Wennberg, 2010).

One of the Scottish Government’s key health policy aims is to tackle such variations by embedding the principles of the 'Realistic Medicine' agenda. This approach seeks to reduce waste, harm, and unwarranted variation while supporting a personalised and value-based care system. In doing so, it acknowledges that some degree of variation is inevitable in a person-centred healthcare system. However, identifying and addressing variation in clinical procedures that do not improve patient outcomes or lack an evidence base is crucial. Such insights can inform more targeted and equitable policy interventions, ultimately aiming to reduce systematic differences in care across Scotland.

Large variations in the Caesarean-section rates can be observed between Scottish maternity units. More specifically, the Princess Royal maternity hospital in Glasgow had a C-section rate of 37.2% in 2015, while the New Royal Infirmary of Edinburgh had 25.2%, This difference in the total C-section rates mainly derived from elective C-sections based on data from ISD Scotland. (ISD Scotland, 2016). Similar differences in the rates Caesarean-sections exist in other maternity units of the same size and with similar total births per year. This may suggest that GP’s clinical views differ in different areas, and so their influence on women who are going to give birth or that women's preferences vary in different areas of Scotland (Glasgow versus Edinburgh). In addition, while the New Royal Infirmary of Edinburgh was reducing each Caesarean-section rates every five years (2005,2010,2015), the Princess Royal maternity hospital was increasing its total C-section rates, suggesting that different hospital policies.

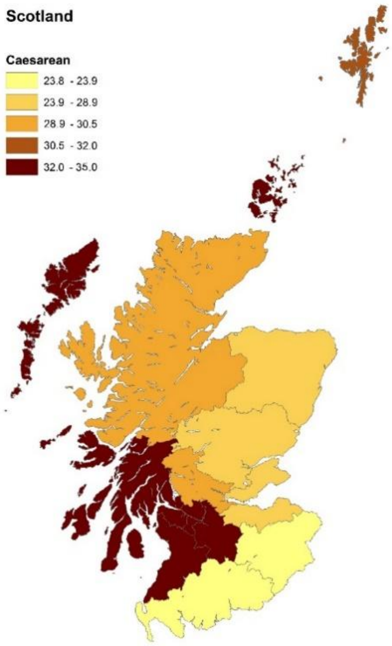
2.1.1. VARIATION IN C-SECTIONS ACROSS SCOTTISH NHS HEALTH BOARDS

In an initial attempt to examine the variations in Caesarean-sections across Scotland, we created maps to visualize geographical variations between Scottish health boards. Aggregated data were sourced from ISD Scotland[5]. They concern deliveries performed in 2016, in every Health Board of Scotland (Highland; Grampian; Tayside; Fife; Lothian; Borders; Forth Valley; Greater Glasgow and Clyde; Lanarkshire; Ayrshire and Arran; Dumfries & Galloway; Orkney; Shetland; Western Isles).

Figure I.1 shows the geographical variation of total C-sections across Scottish Health Boards. It is obvious that the rates of deliveries performed via C-section are quite high, reaching up to 35%. Differences in the usage of the operation do exist, with Orkney, Lothian, Ayrshire and Arran, Western Isles, as well as Greater Glasgow and Clyde having the largest rates. The existence of a spatial pattern in the performance of the procedure suggests that spillover effects in the clinical practice might take place which could possibly affect the physician's approach to birth delivery, or that patient's preferences regarding birth delivery differ according to the place of residence.

[5] Data were retrieved from ISD Scotland – available online: http://www.isdscotland.org/Health-Topics/Maternity-and-Births/Births/

Figure I.1 Geographical Variations in total C-sections across Scotland



Figures I.2 and I.3 represent the spatial variations in elective and emergency C-sections respectively. The variations in elective and emergency C-sections do not follow the same pattern.

***Figure I.2* Geographical Variations in Elective C-sections**

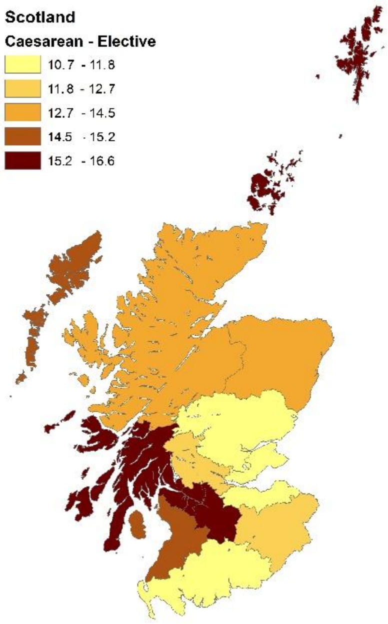
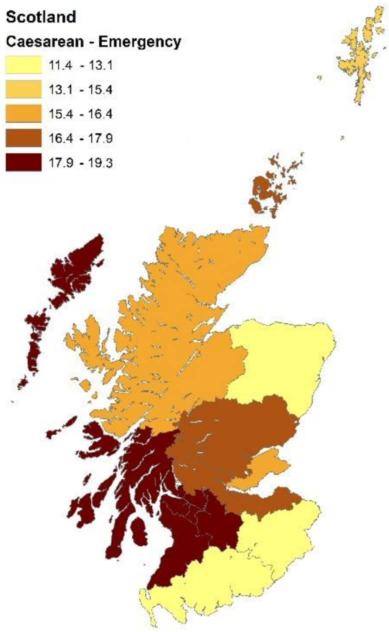


***Figure I.3* Geographical Variations in Emergency C-sections**



Thus, areas with high emergency C-section rates do not have high elective C-section rates as well and vice versa (e.g. Tayside, Fife, Lothian, Forth Valley, Shetland), suggesting that it might worth looking at them separately. In the case of elective C-section spillover effects might occur at the patient level (mothers adopt preferences due to external factors), as well as at the clinical level (physicians/hospitals adopt specific practice styles).

In the case of emergency Caesarean-sections healthcare professionals might adopt specific practice styles according to how they perceive the medical need for the operation. This can be explained if we take a look at figures I.4 and I.5 which represent variations in induced and breech deliveries respectively. The existence of variations in these modes of delivery might suggest that healthcare professionals in specific areas evaluate the medical need for a Caesarean-section differently. The fact that different rates appear to have a spatial pattern could suggest that the choice of having induced or breech delivery instead of an emergency Caesarean-section (which a lot of times is the option to go, especially in breech position), might occur due to supply factors (see. Supply-sensitive unwarranted variations) or due to clinical preference (see preference-sensitive unwarranted care). For instance, in Shetland

Figure I.4 Geographical Variations in Induced[6] Deliveries

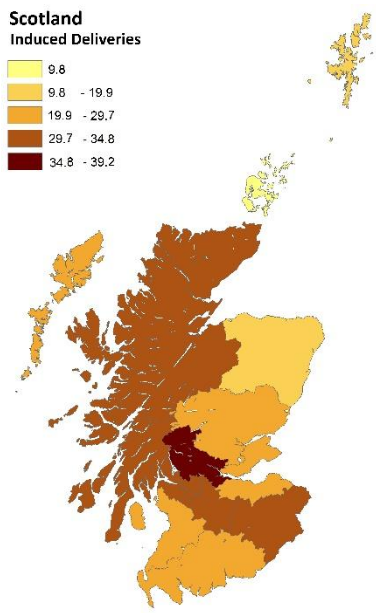
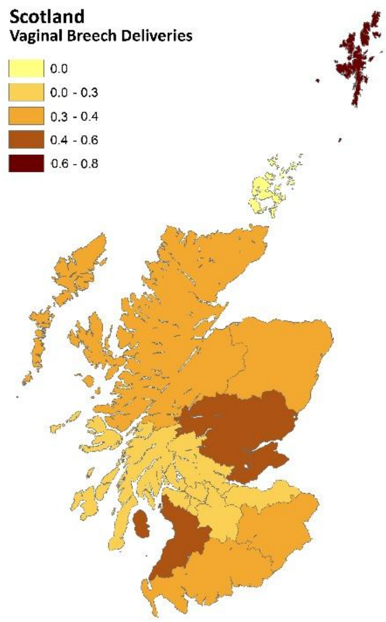


Figure I.5 Geographical Variations in Breech[1] Deliveries



[6] Induced Delivery: If the labor does not start normally, physician can use medication or other methods in order to speed up and help the birth delivery.

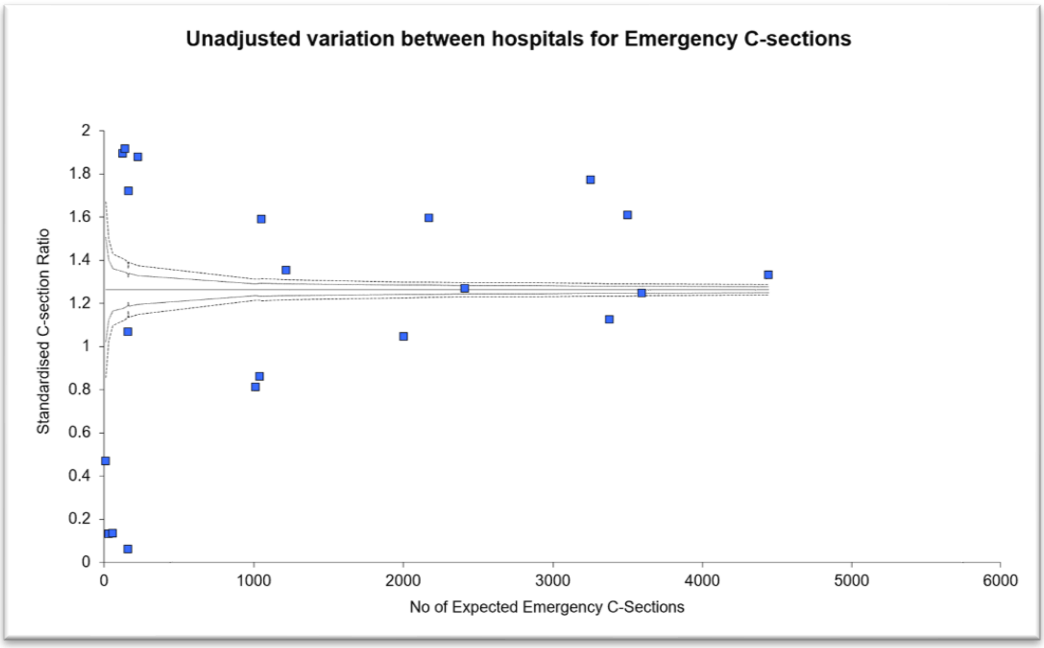
there is a high rate of breech deliveries while the rates of Caesarean-sections performed are small compared to other health boards in Scotland.

2.1.2. VARIATION BETWEEN SCOTTISH MATERNITY UNITS

In order to further explore the variation between maternity units in Scotland, we constructed funnel plots of unadjusted[7] proportions for elective and emergency C-sections separately.

Data on Scottish C-sections from 2009 to 2016 were used, provided by ISD Scotland (SMR02 dataset). To construct the funnel plots with the unadjusted proportions of elective and emergency C-sections, we plotted the standardised C-section ratios and the number of expected C-sections (emergency or elective). The plots were facilitated by the inclusion of 95% and 99.8% confidence intervals to highlight the heterogeneity and thus the variation in the utilisation of the procedure. More specifically, in the absence of significant variation, 95% of the dots which represent the different hospitals, should lie within the dotted line.

Figure I.6 Unadjusted Variation between Scottish maternity units for Emergency C-sections

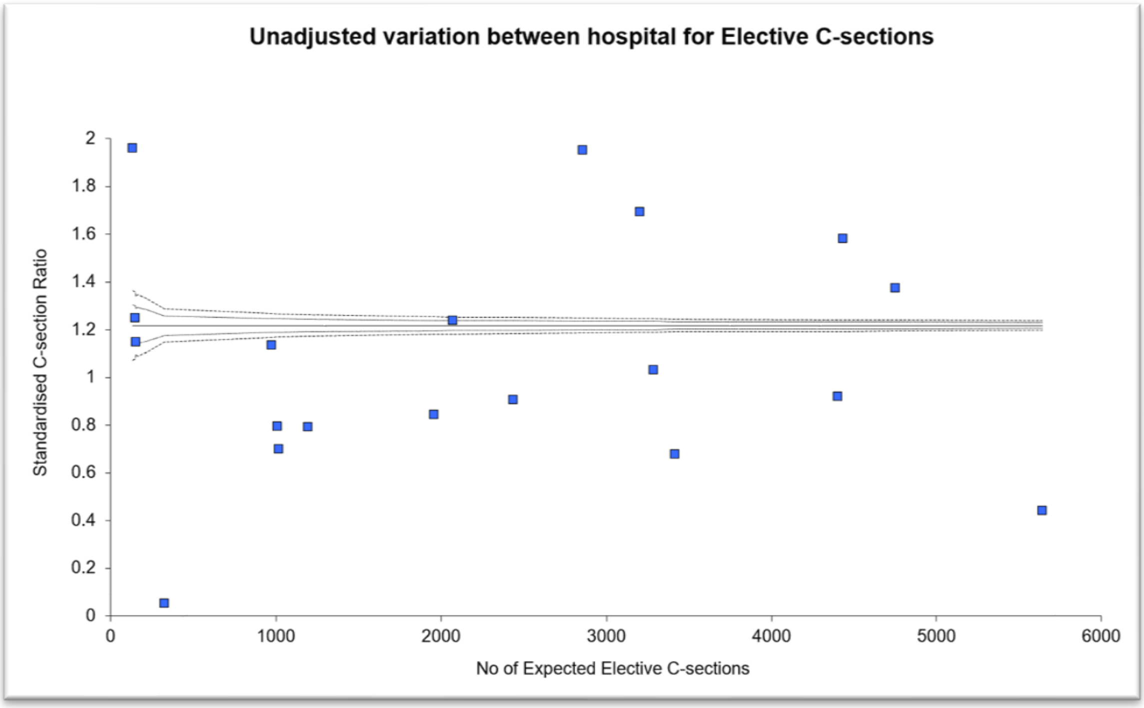


[7] Unadjusted: The rates of elective and emergency C-sections were not adjusted based on patient characteristics, clinical risk factors or any other predictors.

Large differences in the performance of emergency C-sections among Scottish hospitals are shown in Figure I.6, indicating an extremely large variation that needs to be further explored. Similarly, in Figure I.7 large variation between Scottish hospitals which provide elective C-section can be seen. In the case of elective C-sections slightly more hospital lie within the confidence interval lines, compared to emergency C-sections.

The existence of significant variation in the utilisation of the procedure among maternity units could indicate inefficiencies in the allocation of the treatment. Thus, investigating these variations further and controlling for patient characteristics and risk factors is necessary.

Figure I.7 Unadjusted variation between Scottish maternity units for Elective C-sections



3. LITERATURE REVIEW

Having provided the necessary background on C-section in the UK and reviewed the aggregate data on C-section utilisation in Section 2, in this section we review the existing literature on healthcare variations in general, the possible reasons behind this variation and also specifically on variations in maternal mode of delivery. This literature review therefore takes two parts.

3.1. VARIATIONS IN HEALTHCARE UTILISATION

Variations in healthcare is not a problem of recent times but consistently exists and has been raising concerns over the last 80 years. Glover (1938) analysed small-area variations in medical practice by examining rates of tonsillectomy, revealing 20-fold variation across London boroughs, making clear that apart from larger geographical areas, the place where you live within this area plays a significant role when we investigate variations in medical treatment choice.

In 1973, Wennberg and Gittelsohn published their pioneering work on variations in health care. Since then, Wennberg (1982, 1984, 1990, 1993, 1998) has provided a rich strand of knowledge in small area variations in health care delivery and clinical practice, followed by other studies (Evans, 1990; McPhersion, 1994; Chassion 1993; Goel et al 1997; McKee, 1995; Westert, 1999) which try to understand the causal path and the results of healthcare and medical practice variation that cannot be explained on the basis of illness, patient preferences, or medical evidence (Wennberg, 2014).

The main explanatory theories that arise from this literature regarding the influence of the healthcare variation include factors that could be both internal and external to the physician (Wennberg, 1984). Such factors could include uncertainty regarding best practice, ignorance of clinical evidence among physicians (Wennberg, 1984; McPherson 1994; Evans, 1990), differences in the clinical judgment based on beliefs and training (Chassin, 1993; Goel et al, 1997; McKee, 1995), as well as wider contextual effects that could influence physician’s behaviour such as supplier-induced demand (Wennberg 1982; Eisenberg, 1985) and social, environmental and organisational conditions which influence and impact clinical practice (Westert, 1999).

Despite the efforts to decrease the unnecessary differences in clinical practice patterns, it has been a challenge to overcome (Soni, 2016). Over the last 40 years, wide variations in the healthcare utilisation have been systematically documented worldwide, across regions and healthcare providers (Swart et al., 2008; Busato et al., 2008), highlighting their association with poorer health outcomes, inequalities in healthcare, quality issues, as well as increased healthcare spending (Greenfield, 1992; McGlynn, 2003). Variations in medical practices and healthcare utilisation have been studied across the US, Canada, Australia and Europe (Hux et al., 2003; Badley et al., 2004; Ghali et al., 2006; NHS Right Care, 2011; VPM Atlas Group, 2009), suggesting that the findings of those studies and understanding the causality behind these variations is very important in a global level. According to Fisher (2013), three of the main findings in studies on healthcare utilisation and medical practice variation are: (i) the fact that regional variations in healthcare utilization and spending are significant, systematic-not just random, extensive and constant over time, (ii) adjusting for patients' characteristics and clinical risk factors partly explains variation, leaving a significant portion of variation unexplained and (iii) healthcare utilization and spending are not correlated with health care quality or health outcomes.

Examining unexplained variation, on a disaggregated regional level, in healthcare utilisation provides critical insights into potential inefficiencies and inequities, guiding targeted interventions and evidence-based reforms (Dartmouth Atlas of Health Care, 2012). As a result, it can be a valuable tool for researchers, clinicians and policy makers. More specifically, the high policy relevance that comes with these studies is that they could reveal inefficiencies in a health care system, equity and quality issues, decreased or increased healthcare utilisation, as well as increased healthcare spending which is not associated with better health outcomes and could be avoidable. Finally, there should be no variations in medical practice across a country, which cannot be explained by differences in the case-mix (patient preferences, clinical risk factors), when the scientific evidence of care is not clear.

3.2. THE ORIGINS OF VARIATIONS IN HEALTHCARE

As Bob Evans (1990) has noted: 'If variations represent evidence of inappropriate care, which care is inappropriate? Are the regions, or institutions, or practitioners with high rates over-providing, or are the low ones under-providing?'

Variations in healthcare utilization and medical treatment choice can arise from three principal sources, as suggested by de Jong (2008): differences in patient characteristics and clinical risk factors, differences in clinical practice, and differences across larger organisational units such as geographical areas or hospitals. These factors interact to shape the observed patterns in healthcare delivery.

Differences in patient characteristics, including age, lifestyle, gender, and specific clinical risk factors, influence the selection of appropriate medical treatment. C-section, for instance, has been shown to vary in use depending on these characteristics (Brag et al., 2010; Paranjothy et al., 2005; Corallo et al., 2014). Ethnicity has also been identified as a key determinant in treatment decisions and health outcomes across a range of conditions, such as in the management of diabetes (Schulman et al., 1999; Harris, 2001). Beyond clinical indicators, patient preferences shaped by socio-economic status, education, income, residence, and cultural beliefs can also influence treatment uptake. Evidence of such variation in preferences can be found in studies on radical prostatectomy (Lu-Yao et al., 1993) and breast-conserving surgery (Gilligan et al., 2002).

However, patient-related and clinical factors only partially account for the variability observed in healthcare practices. A considerable proportion of variation arises from non-clinical influences. Wennberg (2010) asserts that the bulk of geographical variations in health care are attributable not to patient need or preferences, but rather to differing clinical practices among providers. According to Wennberg (2012), these variations often reflect physician preference for certain interventions and a systemic failure to promote informed patient choice.

The enduring nature of variation in clinical practice that cannot be attributed to patient-level differences suggests that provider preferences play a crucial role. This perspective can be understood through two interrelated dimensions: individual practice styles and institutional or regional characteristics. Practice styles vary between physicians due to differences in training, clinical beliefs, and tolerance for uncertainty. These personal attributes shape how providers assess treatment options and make clinical decisions. The lack of universally accepted clinical guidelines or clear evidence for some treatments further contributes to this diversity in practice (Roos, 1988; McPherson, 1988). Gerrity (1990) posits that such clinical uncertainty can be considered a personality trait, with varying tolerance levels leading to divergent approaches in care. Eddy (1986) adds that, when faced with uncertainty, physicians may over-rely on diagnostic tests or imitate peer practices.

The second dimension involves differences at the institutional or regional level. Over time, certain regions or hospitals may develop prevailing clinical patterns due to physician enthusiasm for particular treatments or because they attract physicians with similar clinical philosophies (Groenewege, 2004; Chassin, 1993; Wright, 1999). These persistent institutional patterns are sometimes referred to as a "surgical signature," a term coined by Wennberg and Gittelson (1982). These patterns are remarkably stable unless disrupted by staff turnover or systemic change. In addition to individual and institutional preferences, local infrastructure and resource availability also influence clinical decision-making. Characteristics of the working environment, organisational policies, and the availability or sharing of medical resources help form informal norms and clinical standards within particular settings (Westert, 1992; 1993; Groenewege, 2004).

Large variations in medical practice often coincide with differences in healthcare capacity, clinical norms, and physician training. These factors can lead to discretionary treatment decisions and even supplier-induced demand, where services are provided based on supply availability rather than patient need (Greenfield, 1992; Selby, 1999). Understanding the root causes of such unwarranted variations is critical, as it can inform the development of more equitable and effective healthcare policies.

To further conceptualise the sources of variation, Dartmouth researchers, led by Wennberg (2002), have categorised healthcare variation into three types. The first, effective care, includes interventions that clearly offer benefits significantly outweighing any risks. In these cases, nearly all eligible patients should receive the intervention. Childhood immunisation is an example of effective care, with studies affirming the high benefit-risk ratio (Rammohan, 2015; Devasenapathy et al., 2016). The second category is preference-sensitive care, which includes treatments that involve trade-offs in risks and benefits. The decision to undergo such treatments depends on the informed preferences of patients, ideally supported by physician guidance. The third type is supply-sensitive care, where the availability of specific resources – such as ICU beds, physicians per capita, or local hospital capacity – heavily influences the use of services. In such cases, variations reflect the supply environment more than clinical indications or patient preferences.

C-section exemplifies a medical procedure subject to both preference-sensitive and supply-sensitive variation. For example, a mother's preference or a physician's clinical judgment may determine the delivery method in borderline cases, while in other instances, the availability of operating facilities and staff ratios may be the decisive factors (Wennberg, 2002). Variations in C-section use are thus not fully explained by maternal clinical need or choice. Provider-related variables such as specialty, professional preference, institutional norms, and hospital type (e.g., teaching versus community hospital) play a significant role (Hueston, 2001; Linton, 2005; Baicker, 2006; Hanley, 2010). Recognising and addressing these sources of variation is important for improving maternal healthcare consistency and ensuring the cost-effective use of maternity services.

In sum, variation in healthcare utilisation arises from a complex interplay of patient needs, provider preferences, institutional norms, and systemic capacity. While individual and clinical differences account for some of this variation, a substantial portion is unwarranted and amenable to intervention. Addressing these variations is essential for improving health outcomes, promoting equity, and ensuring efficient use of healthcare resources.

Many medical and surgical interventions suffer from unclear boundaries between evidence-based protocols and patient or provider discretion. This ambiguity is especially problematic when multiple treatment options yield similar outcomes, but the evidence for comparative effectiveness is limited. One advantage of studying C-section practices, however, is that the available treatment pathways are relatively well-defined. Clinical guidelines outline when a C-section is indicated, and elective C-sections requested by the mother are recognised as a distinct category. This clarity supports more robust investigation into the patterns and drivers of variation in C-section use.

3.3. VARIATIONS IN CAESAREAN-SECTION

The increase in C-section rates is not homogeneous. There is wide evidence of considerable variations in C-section rates between and within many countries, including the UK (Rabilloud et al, 1998; Corallo et. al., 2000, Paranjothy, 2000; Liberro et al., 2000; Fantini, 2006; Bragg, 2010; Sinnott, 2016), which is persistent over time and could indicate a lack of consensus in terms of the optimal level for performing the operation and the best way of birth delivery or inefficiencies in the allocation of the treatment. Baicker et al (2006) examined the geographic variation in the appropriate use of caesarean delivery. In his study, Baicker investigated how birth and socioeconomic status (SES) characteristics correlate with unadjusted country-level Caesarean-sections by using ANOVA; how the average appropriateness of patients who received the procedure correlates with risk-adjusted area-level variations in caesarean usage rate; and how variations in the intensity of the use of caesareans correlates with the maternal and infant mortality across areas. The results suggested that the performance of the procedure varied geographically fourfold between regions and can be only partly explained by maternal characteristics and the country's socioeconomic status, leaving a fairly large portion of this variation unexplained. Also, the intensity of the caesarean usage is not relevant to the appropriateness of the operation and more-aggressive areas (in terms of the caesarean usage) tend to perform the operation for deliveries that are less medically needed. Similarly, multiparous C-section rates varied six-fold across regions in another US study (Brennan, 2009).

In 2010, the rates of C-section that were performed for singleton pregnancies in different NHS Trusts units in England and Wales varied substantially, ranging from 10% to 43% (Bragg, 2010) and after adjusting for maternal characteristics and clinical risk factors, the variation was persistent with NHS Trust vary 2-fold between NHS trusts. Studies have shown that there are no clear patterns in the decision-making process of performing a Caesarean-section (Libero et al, 2000; Clark et al, 2007). However, variations in the rate of a treatment that are not driven by differences in the clinical characteristics of the mother to be, could potentially suggest some degree of inefficiency in the allocation of treatment. Also, unexplained variation in medical practice and treatment choice is important and needs further examination as it could possibly increase health care costs without improving outcomes (Lee et al., 2000).

Moreover, variation in the performance of Caesarean-section could possibly show a lack of consensus about the best mode of delivery under certain circumstances, as well as the absence of conformity to maternity care standards and evidence-based guideline that could result to either overuse or underuse of services (Kozhimannil, 2014). Taking into account the rising Caesarean-section rates and the professional guidelines, variation in the use of the procedure seems to mainly be a problem of overuse (Queenan, 2011; Kozhimannil, 2014), and national remedies in regard to adopting consistent and evidence based obstetric care guidelines and maternity protocols are required (Markus, 2010; Robson, 2013; American College of Obstetricians and Gynecologists, 2014). Therefore, comprehensive data and evidence are needed in order to provide updated clinical and policy implications to decrease unnecessary use of the procedure, which could possibly result in more consistent and high-quality obstetric care worldwide. Thus, carefully reviewing the motives for these variations in Caesarean-sections could result in improvements for the consistency of care for pregnant women and for more efficient and cost-effective maternal services.

3.4. CONTRIBUTING FACTORS TO VARIATIONS IN CAESAREAN-SECTION

As it was mentioned in the previous sections, variations in healthcare utilization can be the result of different patient characteristics and clinical risk-factors; differences in the clinical practice; differences between larger units, such as geographical areas or hospitals (de Jong, 2008). In an attempt to explore the reasons behind variations in C-sections, we explicitly review the literature around the factors that could contribute to the differences in the utilisation of the procedure.

3.4.1. MATERNAL CHARACTERISTICS

Maternal and foetus risk profiles differ and can determine the necessity of performing a Caesarean-section. Over the years, changes in these risk profiles have been documented and attributed as contributing factors for the rising Caesarean-section rates (Franz, 2010; Briand, 2012; Guihard, 2001). However, there is a paradox where although the maternal clinical risk factors are decreasing due to improvements in medical and treatment approaches, the rates of Caesarean-section are still rising (Bailit JL, 2004).

The increasing maternal age is a significant factor associated with the use of the procedure (Murphy, 2003; Bragg, 2006; NICE, 2011; Haas, 2014; Lapinsky, 2013; Sinnott; 2016), as well as clinical risk factors such as diabetes mellitus, maternal obesity, multiple gestation, maternal obesity, preterm labor, gestational diabetes, or hypertension (Declercq, 2011; Queenan, 2011; Sakala C, 2013). Therefore, variations in Caesarean-section have been partially linked to patient clinical characteristics (Bragg, 2010; Paranjothy, 2005; Corallo, 2014). However, the variability that is being observed in the use of the procedure is not fully explained by these factors and only a portion of this is accounted by those factors. An analysis that carried out in the UK, showed that about one third of the variation between NHS Trusts was attributable to patient case mix (Bragg, 2010).

Apart from the clinical risk factors, patient characteristics and demographics could also play a role in the increased rates of Caesarean-section and the variation of them. A few studies have linked ethnicity to the likelihood of having a Caesarean-section (Sinnott, 2016; Edmond, 2014). Feng et al. (2011) investigated the factors that are responsible for the increase in C-section rates in China between 1988 and 2008. A Poisson regression approach was taken, controlling for clustering at the city, county, and village level, and potential stratification. Adjusted Relative Risks (RRs) were derived for rural and urban areas separately. The adjustment of RRs controlled for per capital income, access to health insurance, the mother's educational level, maternal age, and the number of antenatal visits. The results suggested that having a C-section was influenced more by the socioeconomic characteristics of the region of residence rather than the socioeconomic (SES) characteristics of the mother to be, making it a more significant determinant. This conformity effect suggests that a spatial pattern exists. Also, advances in the household income and/or access to health insurance can only partly explain the increase of C-sections in rural areas of China, while improvements in household income and mother's education cannot be associated with the increase of the Caesarean-section rate in urban areas of China from 1988 to 2008.

All in all, the rise in Caesarean-section rates and the variation in these rates across different regions and hospitals cannot be fully explained by differences in patient characteristics and clinical risk factors, indicating that clinical patterns and different medical approaches could be the driving forces (Baicker, 2006; Bragg, 2010; Queenan, 2011; Kozhimannil, 2013).

3.4.2. PRIMARY CARE

In the UK, after a woman discovers that she is pregnant, her antenatal care starts with booking an appointment with her General Practitioner (GP) or directly with her midwife. According to a study from National Perinatal Epidimiology Unit (2003), 83% of pregnant women visit their GP first. Similar findings were shown by another study where the proportion of women who access maternity care by visiting their GP initially was 78% (Commission for Healthcare Audit and Inspection, 2007). However, these reports are relatively old, as the healthcare sector changes rapidly. In reality, most of the pregnant women nowadays seem to visit their midwife first or being referred to a midwife after they contact their GP. As a result, midwifes (and GPs in some cases) seem to act as the gatekeepers to secondary maternity care for pregnant women. Taking this into account we hypothesize that primary healthcare professionals might influence the decision making of a woman having an elective Caesarean-section (upon maternal request) or evaluate the need for an elective C-section differently and therefore a proportion of the observed variations in the rates of the procedure could be attributable to them. At this point we need to clarify that we consider the influence of primary healthcare professionals possible exclusively for elective/planned Caesarean-sections, as the decision of a woman undergoing an emergency/unplanned Caesarean-section occurs in the secondary care level.

Studies have examined the contribution of primary healthcare in variations, in other contexts. According to Shackelton-Piccolo (2011) what happens in the primary care level is very crucial as it concerns the first point of care for the majority of population which is presented for care or treatment; it’s a determinant factor for healthcare spending and health outcomes and is the gateway to the health care system. In general, a primary healthcare professional should provide guidance to the patient through a process of engagement and discussion with the patient in order to well inform him/her about the available treatments and clinical options that best suit patient’s preferences and values, as well as medical need. The referral, treatment and medical options that a patient receives should primarily be based on the medical need and be independent of physician's individual preferences and practice style. However, patients differ in their characteristics, their preferences and the way they shape their decisions and so do GPs. Thus, variations in primary care and clinical patterns among its professionals do exist (Westert et. al., 2015).

In November 2011, NICE introduced new guidelines about elective(planned) Caesarean-section, making it available even to women with no medical need[8]. This relaxation in the availability of treatment options could potentially change the way that primary healthcare professionals influence women on the decision making for the procedure or the encouragement towards certain patient preferences. According to Van der Berg et. al. (2009), who performed a multilevel analysis, large variations among GPs (and thus primary care sector) exist in the adherence to guidelines. Taking this into account, primary healthcare professionals could also interpret guidelines differently and adjust their clinical approach based on the guidelines and the availability of treatment options, resulting to variations.

Wide variations between primary care providers have been captured in Norway and Denmark (Grytten, 2003; Kristensen, 2014). Moreover, studies on how physicians in primary care treat the same patient have shown significant variations across the U.S. (Sirovich, 2008; Cutler, 2013), while a correlation between the physicians' beliefs and the healthcare spending was revealed. Despite the fact that clinical guidelines for the management of low back pain are available, substantial variation in referral rates to hospital for lumbar spine X-Ray have been shown among GPs in the UK (Baker et al., 2006).

Consequently, the fact that primary healthcare professionals act as the gatekeepers to secondary maternity care for pregnant women, along with evidence from the literature on variations in primary care, suggest that their contribution in variation in elective C-sections should be explored in our analysis.

[8] Women with no medical need are identified as those undergoing elective C-sections without documented medical indications (e.g. breech presentation, placenta previa, hypertension, diabetes) that could justify the decision for undergoing the procedure.

3.4.3. SECONDARY CARE

3.4.3.1. HOSPITALS

As a pregnant woman enters the secondary care, variations in C-sections could be the result of differences between hospitals. Apart from differences in maternal and fetuses clinical risk factors, patient characteristics and preferences, C-section rates are possible to vary across different maternity units due to differences in hospital resources, the level of obstetric and neonatal care specialization (MacDorman, 2008; Freeman et al., 2003; Kozhimannil, 2003). Moreover, the policy of the maternity unit and the hospital environment might apply some degree of influence on the physician's choice in a determined Caesarean-section (Andres et. al, 2015). A recent report from the RCOG (2016) investigated the patterns of maternal care among different maternity units in England in 2013-2014. The report revealed differences in the care that mothers receive and variations in emergency C-sections among different NHS Trusts.

Bragg et al (2010) tried to determine if the variation in the rates of C-section between different NHS trusts in England can be associated with maternal characteristics and clinical risk factors. Using cross sectional episode data routinely collected from hospitals, Bragg et al (2010) employed a multinomial logistic regression approach to examine how maternal attributes (ethnicity, woman's age, education, socioeconomic status) as well as clinical factors (breech presentation, previous C-section, fetal distress) drive the likelihood of having a C-section. Adjusted Relative Risks were calculated separately for each NHS trust and funnel plots were used to demonstrate potential variation among NHS trusts in both crude and risk adjusted rates of C-section. Bragg supported although maternal characteristics differ among NHS trusts and at some degree variations might reflect different patient preferences, after adjusting for maternal characteristics and clinical risk factors, C-rates varied 2-fold between NHS trusts, while the emergency Caesarean-section rates varied more than elective C-section rates.

Furthermore, a recent study from Sinnott et. al. (2016), examined the variations in performing C-sections in different maternity units of Ireland. The study employed multilevel (hierarchical) models, controlled for patient, sociodemographic, clinical, as well as organizational variables. The results showed that although C-section was associated with history of previous miscarriage or stillbirth and increasing maternal age, similarly to Bragg's (2010) results, the variation between maternity units was still persistent after controlling for detailed patient characteristics and clinical risk factors, suggesting that the lack of evidence-based guidelines, the different medical practices and organisational factors could contribute to the observed variation in Caesarean-section rates.

3.4.3.2. SECONDARY HEALTHCARE PROFESSIONALS

However, variations in C-sections between maternity units could be the result of differences between healthcare professionals within the maternity units, apart from hospital characteristics and the hospital's policy itself on the general clinical approach. Health care professionals within the hospital could also drive variations in maternity services, due to the selective attraction of physicians in hospitals or regions (Groenewege, 2004; Chassin, 1993; Wright, 1999), resulting to a clinical pattern that seems to be persistent over time (Wennberg and Gittelson 1982), unless physicians leave the area (or hospital) or new physicians enter it.

Several studies have pointed out that between hospital variations in Caesarean-section rates could be associated with factors like defensive medicine (Dubay et al, 1999), doctor's demand for leisure (Brown; Mossialos et al. 2005), changes in the clinical practice, changes in mothers' attitudes towards C-sections (Lo, 2003; Lo, 2008), as well as financial incentives (especially in the private sector). Arrieta et. al. (2016) found that Caesarean-sections are increasing in small and medium size hospitals when the physician demand for leisure increases and that when hospital capacity increases, the probability of Caesarean-sections decreases.

Finally, another study on variations of the procedure for fetal distress showed that the rates of Caesarean-section varied based on institutional and other non-clinical risk factors. It was observed that Caesarean-section rates for fetal distress increased during night-time hours, suggesting that this might be influenced by physician or patient fatigue and raises matters of convenience in regards with the operation (Hueston, 1996).

3.5. PRIOR RESEARCH AND COMPARISON

After carefully reviewing the existing literature, it is apparent that considerable variations in C-section rates across many countries, including the UK, do exist. (Rabilloud et al, 1998; Corallo et. al., 2000, Paranjothy, 2000; Liberro et al., 2000; Fantini, 2006; Baicker, 2006; Kozhimannil, 2014; Andres, 2015; Bragg, 2010; Sinnott, 2016). These variations are persistent over time and could indicate lack of consensus in terms of the optimal level in performing the operation and the best way of birth delivery. Table I.2 illustrates relevant studies on variation in Caesarean-section, describing their data, methods, and main findings.

Table I.2 Comparison of Relevant Studies

Comparison of Relevant Studies			
Study	**Data and Methods**	**Main Outcomes**	**Author**
Geographic Variation in The Appropriate Use of Caesarean Delivery	Years covered: 1995-1998 198 U.S. states ANOVA analysis on the basis of patient-level characteristic, country-level SES factors, country-level characteristics and state-level medical mal-practice liability	4-fold variation in adjusted C-section rates between regions Partly explained by maternal characteristics while large portion of the variation remained unexplained	Baicker, 2006
Variation in rates of caesarean section among English NHS trusts after accounting for maternal and clinical risk: cross sectional study	Year covered: 2008 England and Wales (NHS Trusts) Multiple logistic regression on the basis of maternal characteristics and clinical risk factors	2-fold variation in adjusted rates of C-section between NHS Trusts Emergency C-section rates varied more than elective	Bragg, 2010
Maternal Clinical Diagnoses and Hospital Variation in the Risk of Cesarean Delivery	Years covered:2009-2010 U.S. (hospitals) Multilevel logistic regression on the basis of patient characteristics, clinical risk factors and hospital factors	Between hospital-variation was 14% in both adjusted (for demographics clinical or hospital characteristics) and unadjusted C-section rates	Kozhimannil, 2014

Hospital Variation in Cesarean Delivery: A Multilevel Analysis	Year covered: 2007 Colombia Multilevel logistic regression on the basis of maternal characteristics, clinical risk factors and hospital factors	20% of the variation was attributable to hospitals and 1/3 to the regions	Andres, 2015
National Variation in Caesarean Section Rates: A Cross Sectional Study in Ireland	Year covered:2009 Ireland Multilevel analysis adjusted for patient characteristics, clinical risk factors and organizational factors	Proportion of variation attributable to hospital was higher for elective C-sections	Sinnott, 2016

Baicker et. al. (2006) examined the geographic variation in Caesarean-section rates among 198 U.S. states. Baicker (2006) employed an analysis of variance (ANOVA) on the basis of patient-level characteristic, country-level SES factors, country-level characteristics and state-level medical mal-practice liability. It is worth noting that ANOVA is an approach that partitions the variation in the Caesarean-section rates among its different sources, between and with the 198 states that were examined. This approach generalises the t-test to compare means across multiple groups (in this case geographic regions) and it is improper in our research to handle covariates (Bottle and Aylin, 2017 page 28). Another approach that has been used in order to explore variation in Caesarean-section rates among English NHS Trusts was multiple logistic regression on the basis of patient characteristics and clinical risk factors. However, this methodological approach considers the units of the analysis as independent observations, neglecting the original hierarchical structure of the data with the risk of underestimating the standard errors of the regression coefficients which can lead to higher statistical significance (Bottle and Aylin, 2017). In our case, this would result to the underestimation of the hospital-level variables which is the higher level of our analysis. In contrast with the cross-sectional studies of Bragg (2010) and Sinnott (2016), we draw conclusions and policy implications from a longitudinal analysis and a set of cross-sectional models. By employing a longitudinal analysis, we are able to ensure validity and effectively determine the likelihood patterns of clinical risk-factors for C-sections over time, using a large number of observations.

In accordance with other studies on variation in Caesarean-section rates (Kozhimannil, 2014; Andres, 2015; Sinnott, 2016) our methodological approach is going to use a multilevel analysis with random intercept. This approach will be beneficial for our research as multilevel models can correct inferences in contrast with traditional multiple regression models; they take into account the substantive interest that exists in group effects (interest centres on obtaining 'value added' GP effects and hospital effects on mother's decision of having a Caesarean-section); it can estimate group effects and effects of group level predictor variables simultaneously (in contrast with fixed effects models) and it can treat the groups as a random sample from a population of groups, allowing inferences to be made to a population of groups.

Table I.3 Limitations of relevant studies using multilevel analysis

Study Title and Author	Limitations
Maternal Clinical Diagnoses and Hospital Variation in the Risk of Cesarean Delivery: Analyses of a National US Hospital Discharge Database (Kozhimannil, 2014)	Limited range of clinical risk factors: no gestational age information and no parity
Hospital Variation in Cesarean Delivery: A Multilevel Analysis (Andres, 2015)	Data collection from a single insurer database – lack of homogeneous and complete national data (lack of national representativeness)
National Variation in Caesarean Section Rates: A Cross-Sectional Study in Ireland (Sinnott, 2016)	Limited range of clinical risk factors: no gestational age information and no BMI

Table I.3 describes the limitations of studies on variation in Caesarean-section rates using a multilevel methodological approach. The choice of these three studies was based on the relevance to ours in terms of the scope, methodological approach and/or dataset used.

In contrast with other studies (Sinnott, 2016; Baicker, 2006), the dataset that we are going to use concerns episode-level data for every patient that goes in for an obstetric event from 2009 to 2016. In our study, we are going to use a wide range of clinical risk factors that could determine the decision of having a Caesarean-section in accordance with previous relevant studies (Baicker, 2006; Bragg, 2010; Sinnott, 2016) and individual characteristics such as marital status and ethnic group. Although organizational variables such as private or public care model; academic hospital (Sinnott, 2016) and bed size; location; teaching status

(Kozhimannil, 20014) have been taken into account in previous studies, information on the healthcare professionals has never been examined before at the hospital-level. Moreover, one of the main contributions of our study is that there is not a study so far that is that is taking GPs as group of analysis in order to examine the possible influence of the primary care in the likelihood of a woman having an elective/planned C-section. Finally, similarly to the studies mentioned above, we are going to use case-mix adjusted rates. As Bragg (2010) showed, the characteristics of women who give birth in NHS Trusts differ and attempts to use unadjusted rates would not be the appropriate approach. Indeed, statistical adjustment is very important in order to eliminate the confounding effects of extraneous confounding factors (Kasim; Rottman, 1998).

To our knowledge, this is one of the few papers using multilevel analysis taking hospitals as groups of the analysis (Kozhimannil, 2014; Andres, 2015; Sinnott, 2016), rather than geographic regions and the first one that is taking primary healthcare professionals in order to examine the possible influence of the primary care professionals in the variation in elective/pre-planned, as well as secondary healthcare professionals in order to examine the contribution to the variation in elective and emergency Caesarean-sections.

4. METHODS AND DATA

4.1. SCOPE AND METHOD

After carefully reviewing the existing literature, we consider variations in Caesarean-sections across Scotland as the possible result of a multifactorial framework. Taking into account the fact that the decision-making for an elective(planned) and an emergency C-section take place at different time points in the pregnancy, we are going to examine them separately. In the case of an emergency C-section this framework could include a) maternal characteristics, b) healthcare professionals who are responsible for the procedure and c) hospital factors. In the case of an elective C-section this framework could include a) maternal characteristics, b) primary care sector sections and c) hospital factors.

In Scotland, the National Health Service (NHS) provides pregnant women antenatal and postnatal care. After a woman discovers her pregnancy, her first appointment will be with a midwife either at her GP practice or at home. This appointment is very important and is a chance for the mother-to-be to ask all her questions regarding her pregnancy, as well as to be provided with guidance and relevant information about the care options and the next stages of her pregnancy. Blood tests and information about screening tests for the mother-to-be and the baby will be offered. Over the course of a pregnancy 8 to 10 appointments will take place. Once the mother is admitted to a maternity unit a healthcare professional is assigned to her, who is responsible for her care on the original admission to the unit. If the mother is originally admitted under the care of a midwife in an Alongside Midwifery Unit (AMU) or Freestanding Midwifery Unit (FMU), then the healthcare professional responsible will be midwife, while if the mother is originally admitted to an Obstetric Unit the healthcare professional responsible will be a consultant (ISD Scotland; NHS Scotland).

Consequently, the decision for having a C-section is a complicated one and the observed variation in its rates could be driven by many factors. In the case of an emergency C-section the decision-making could be based on: the patient's obstetric history, clinical risk factors and characteristics; the hospital facilities/resources and its medical approach; the healthcare professionals within the hospital, their clinical approach, education, beliefs and training. In the case of elective C-sections, the decision could be driven by: patient's obstetric history, clinical pre-labour risk factors, patient characteristics or preferences (maternal request); the influence of the primary care professionals and their recommendations towards options and patient preferences; the hospital facilities/resources and its medical approach; the healthcare professionals within the hospital, their clinical approach, education, beliefs and training.

This research is an exploratory study of variations in the use of Caesarean-sections in Scotland with the scope to comprehend their driving forces. Multilevel analysis (hierarchical modelling) is a methodological approach that can help us disentangle the variation and understand the contribution of hospital, primary and secondary healthcare professionals in the observed variation in C-section usage that cannot be explained by patient characteristics and clinical risk factors that could determine the decision for the procedure.

4.2. DATA

The source of the data that are used for this research is ISD Scotland. The dataset used in this study is the Scottish Morbidity Record (SMR02), collected and maintained by ISD Scotland (now part of Public Health Scotland). The SMR02 captures all maternities in NHS Scotland hospitals, using standardised electronic health record systems and clinical coding protocols. The data were extracted, cleaned, and anonymised by ISD staff before being provided for analysis. The dataset under study included all obstetric inpatients and day cases from Scottish maternity units, concerning singleton births. Twin births were excluded from the analysis to ensure comparability and avoid confounding effects arising from the distinct clinical pathways and delivery risks associated with multiple gestations. The data span from 2009 to 2016, with a total of 382,793 after cleaning (information about the data cleaning and the exclusion criteria can be found in Appendix A, Tables I.16, I.17). The births per year range from 36,430 to 51,517.

Data on the woman's marital status, socioeconomic deprivation measures, ethnicity, weight and height along with birthweight, gestational age, obstetric history and parity were sourced from ISD Scotland, the main source of data on all births in Scotland. Moreover, data on the delivery plan place, hospital id, GP practice id, healthcare professionals who were responsible for the care of the mother to be sourced from ISD Scotland. The dataset also included records data on all discharges in all 46 public maternity units, information on the GP practice code and the healthcare professional who was responsible for the care of the mother to be. Diagnosis codes and procedure codes are recorded using the Australian Modification of ICD-10 codes (ICD-10-AM). Information is also collected on the woman’s age, intermediate zone, data zone, as well as breastfeeding.

The outcome variables in these analyses are elective C-Sections and emergency C-Sections. The comparison group in both cases was vaginal deliveries (spontaneous and instrumental). Elective CS was defined as a CS carried out as a planned procedure before the onset of labour or following the onset of labour, when the decision was made before labour (Royal College of Obstetricians and Gynaecologists, 2011). Emergency CS was defined as a CS required because of an emergency, such as dystocia or fetal distress. Explanatory variables included maternal age, maternal ethnicity, maternal socioeconomic deprivation measures and marital status. Clinical variables were antenatal factors: hypertension, diabetes (mellitus and gestational) and eclampsia. Intrapartum difficulties included were dystocia, fetal distress, restricted fetal growth, and excessive fetal growth along with placenta praevia abruption, breech presentation and other forms of malpresentation. Prior stillbirth, prior C-sections and parity were included as indicators of obstetric history (Royal College of Obstetricians and Gynaecologists, 2011).

The group-level variables that are going to be used in our analyses include the hospital id, the primary care professional id (coded as GP practice code) that the mother-to-be attended and the healthcare professional within the hospital who was responsible for the care of the mother-to-be (coded consultant/healthcare professional responsible for the care).

Table I.4 describes the variables of the dataset, divided into 4 main categories: General variables; maternal characteristics (which include mother, baby characteristics and clinical risk factors); Primary healthcare variables; Secondary healthcare variables.

Table I.4 List of Variables that are included in our dataset

<table>
<tr><th colspan="3">General Variables</th></tr>
<tr><td rowspan="4">General variables</td><td>Variable</td><td>Additional information (where needed)</td></tr>
<tr><td>Date of delivery</td><td></td></tr>
<tr><td>Mode of delivery</td><td>(Vaginal deliveries, elective C-Section, emergency C-section)</td></tr>
<tr><td>Delivery Plan Place</td><td></td></tr>
<tr><th colspan="3">Maternal Characteristics Variables</th></tr>
<tr><td colspan="3">Maternal and fetus risk profiles differ and can determine the necessity of performing a Caesarean-section. attributed as contributing factors for the rising Caesarean-section rates (Franz, 2010; Briand, 2012; Guihard, 2001). The increasing maternal age is a significant factor associated with the use of the procedure (Murphy, 2003; Bragg, 2006; NICE, 2011; Haas, 2014; Lapinsky, 2013; Sinnott; 2016), as well as clinical risk factors such as diabetes mellitus, maternal obesity, multiple gestation, maternal obesity, preterm labor, gestational diabetes, or hypertension (Declercq, 2011; Queenan, 2011; Sakala C, 2013).</td></tr>
<tr><td></td><td>Variable</td><td>Additional information (where needed)</td></tr>
<tr><td rowspan="7">Mother Characteristics</td><td>Age</td><td rowspan="4">In order to examine how maternal characteristics could explain differences in the proportion of women who have C-section and the contribution that these characteristics could have in the observed variations.

Evidence from Baicker, 2006; Bragg (2010); Feng, 2011; Sinnot, 2016</td></tr>
<tr><td>SIMD</td></tr>
<tr><td>Ethnic Group</td></tr>
<tr><td>Marital Status</td></tr>
<tr><td>Weight</td><td rowspan="3">Studies have shown that increased maternal BMI is associated with increased C-section rates (Roman, 2008; Kyvernitakis, 2015).</td></tr>
<tr><td>Height</td></tr>
<tr><td>BMI</td></tr>
<tr><td rowspan="6">Baby characteristics</td><td>Gestational Age (estimated gestation)</td><td>Postmature babies could affect the choice of having a C-section</td></tr>
<tr><td>Birthweight</td><td rowspan="2">These factors could also affect the decision of having a C-section and be considered as clinical risk factors</td></tr>
<tr><td>Baby presentation at delivery</td></tr>
<tr><td>Main condition</td><td rowspan="2">Information on clinical risk factors, such as obstructed labour (dystocia); eclampsia or pre-eclampia; breech position, other forms mal-presentation; fetal distress; restricted fetal growth; excessive fetal growth; placental abruption; preterm delivery, was extracted using ICD-10 classification coding</td></tr>
<tr><td>Other condition</td></tr>
<tr><td>Presentation at delivery</td><td></td></tr>
</table>

<table>
<tr><td></td><td>Diabetes mellitus (pre-existing or gestational)</td><td></td></tr>
<tr><td></td><td>Total previous pregnancies</td><td></td></tr>
<tr><td></td><td>Total previous stillbirths</td><td></td></tr>
<tr><td></td><td>Induction of Labour</td><td></td></tr>
<tr><td></td><td>Number of births in this delivery</td><td></td></tr>
<tr><td></td><td>Previous Caesarean-section</td><td></td></tr>
<tr><td colspan="3">Primary Healthcare Care Variables</td></tr>
<tr><td colspan="3">Midwifes (and GPs in some cases) seem to act as the gatekeepers to secondary maternity care for pregnant women. Taking this into account we hypothesize that primary healthcare professionals might influence the decision making of a woman having an elective Caesarean-section (upon maternal request) or evaluate the need for an elective C-section differently and therefore a proportion of the observed variations in the rates of the procedure could be attributable to them.
Studies have examined the contribution of primary care sector in healthcare variations in other contexts. (Grytten, 2003; Kristensen, 2014; Van der Berg et al, 2009; Sirovich, 2008)</td></tr>
<tr><td rowspan="2">GP</td><td>Variable</td><td>Additional information (where needed)</td></tr>
<tr><td>GP Practice Code</td><td>Midwifes are also captured under this variable</td></tr>
<tr><td colspan="3">Secondary care Variables</td></tr>
<tr><td colspan="3">Apart from differences in maternal and foetuses clinical risk factors, patient characteristics and preferences, C-section rates are possible to vary across different maternity units due to differences in hospital resources, the level of obstetric and neonatal care specialization (MacDorman, 2008; Freeman et al., 2003; Kozhimannil, 2003).
Health care professionals within the hospital could also drive variations in maternity services, due to differences in training, personal beliefs, clinical approach, as well as factors like defensive medicine (Dubay et al, 1999), doctor’s demand for leisure (Brown; Mossialos et al. 2005), changes in the clinical practice and financial incentives.</td></tr>
<tr><td rowspan="3">Hospital</td><td>Variable</td><td>Additional information (where needed)</td></tr>
<tr><td>Hospital id</td><td></td></tr>
<tr><td>Consultant/healthcare professional responsible</td><td>The healthcare professional who carries clinical responsibly for the mother’s care</td></tr>
</table>

Using these data described above, we can control for patient characteristics, as well as maternal and baby clinical risk factors in order to identify the variation that lies at each group (primary care sector; hospitals; secondary healthcare professionals nested within hospital).

4.3. METHODS

4.3.1. INTRODUCING MULTILEVEL ANALYSIS

Multilevel modelling (or hierarchical modelling) has been widely used in many fields of research, such as education (Bryk, 1992), demography (Hermalin, 1986; Mason et. al., 1983), and sociology (DiPrete, 1990) as a methodological approach in order to provide information about both group-level and individual level effects on individual level outcomes, simultaneously. The last two decades, the use of hierarchical modelling in order to examine public healthcare problems has become popular (Diez-Roux, 1998; Duncan et. al.,1998; Von Korff, 1992). Multilevel analysis has been used in public health to investigate the effect of group-level and individual-level variables on health outcomes. Geographical areas, schools, workplaces, families and healthcare providers have been used as groups in order to examine their contribution on health outcomes (Duncan C, 1999; Entwisle, 1986; Gatsonis, 1993; Hedeker et al., 1994; Sixma, 1998; Soderdeldt B, 1997; Wilcox Routree, 1999). The hierarchical structure of the data, where each level is nested within the other, is commonly observed in social and behavioural sciences. In these sciences, exploring the relationships between individuals and the social context is very important, making the dependence of data rally interesting and important for the research.

The reason for this growth in the use of multilevel analysis in the health sector is that macro-level, sociological-level, ecological-level and group-level factors could potentially be determinants of health-related issues, as well as the fact that the way that individuals are interacting and are related to each other within groups could help understand how healthcare outcomes are distributed and vary across different places (Diez-Roux, 1998; Duncan et. al., 1992; Schwartz, 1994; Susser, 1994). Another reason for this growth has been the advancements in statistical methods and the development of accompanying software (Diev-Roox, 2000) that can allow the use of clustered data structures. With the help of these methods and software, we are able to disentangle the causality of health-related and public health issues that could be influences by factors from different levels.

4.3.2. RATIONALE FOR THE USE OF MULTILEVEL ANALYSIS

4.3.2.1. REASONS FOR USING MULTILEVEL ANALYSIS

In order to explore the variations in emergency and elective C-sections and quantify the contribution of different factors to these variations, we employed a multilevel modelling approach.

The rationale behind this conceptual model is that apart from women's preferences and maternal characteristics (individual characteristics and clinical risk factors), hospitals' policy and professional environment (consultants who are responsible for the procedure) may exert a considerable influence on the healthcare professionals' choice in a determined Caesarean-section, which we will refer as hospital variation. Moreover, primary care providers (such as GPs and midwifes) could influence the mother's decision on the mode of delivery. As a result, our data are clustered into three levels: a) maternal characteristics that include individual characteristics of the patient and clinical risk factors); b) primary and secondary healthcare professionals; c) hospital factors.

When we investigate health outcomes, it is important to take into account the social context of individuals, as the factors that determine health cannot be characterized only by individualization (Blalock, 1984; DiPrete, 1994; Hox JP, 1994; Huber, 1991; van der Eeden, 1982). The fact that our data are structured hierarchically into two and three levels results to the dependency of level-1 units within level-2 and level-2 units within level-3 (patients nested within healthcare professionals, nested within hospitals). Consequently, the employment of standard regression models for this research is not appropriate, since they would potentially miss important factors that could contribute to the outcome. According to Roli and Monari (2014), another possible approach in the case of more than one levels data is to aggregate the micro-level (level-1) data to the macro-levels (for instance averaging by macro-units) (Roli and Monari, 2014). However, this approach has serious risks of errors, such as "shift of meaning" and "ecological fallacy". Furthermore, aggregation transforms the original data structure, and it is not possible to investigate the potential cross-level interaction effects (Snijders, 1999). On the other hand, by employing a multilevel methodological approach we are able to use the data by their hierarchical structure and represent each of the three levels of our research by its own sub-model and, therefore, achieve many purposes of this kind of study (Roli and Monari, 2014):

- It can improve the estimation of the patient-level effects (all the information at each of the three levels is efficiently used to exploit both the group features and the relations existing in the overall sample)
- It can evaluate the cross-level effects (how variables measured at one level affect relations that take place at another level)
- It can decompose the variance–covariance components across the three levels of our study
- It can generalize standard methods

Finally, the hierarchical structure of the data cannot be disregarded, as this would raise serious risk of wrong conclusions and the dependency of clustered data is "neither accidental nor ignorable" (Snijders et. al., 1999; Goldstein, 1999).

4.3.2.2. DIFFERENCES BETWEEN MULTILEVEL ANALYSIS AND OTHER APPROACHES

When we explore individual-level data that are nested within groups (mothers nested within healthcare professionals, nested within hospitals), we could approach methodologically our analysis in several ways. Firstly, when we examine the variations in Caesarean-sections, we could ignore the healthcare professionals-level and hospital-level membership and focus only on inter-individual variation and on mother-level attributes. The difficulty with this option would be that group-level attributes such as healthcare professionals and hospital factors could play an important role on individual-level outcomes and ignoring their influence might lead to incorrect inference. Additionally, if the delivery mode outcomes for mothers within groups are correlated, the assumption of independence of observations is violated and as a result the standard errors would not be correct, while the estimates would not be efficient (Diggle et. al., 1997). Another approach could be to focus only on inter-group variation and on data aggregated to the group level (Diez-Roux, 2000). This option solves the drawback of non-independence that was described in the previous approach. However, the problem would be that it ignores the importance of patient-level factors that influence the outcome. In both of these methodologies the data are treated at the same level, ignoring that they are clustered into three levels (mother, primary and secondary healthcare professionals, hospitals).

An alternative approach is to run different regressions for each level separately. This method could let regression coefficients vary from level to level, but the problem is that it doesn't show how specific group-level characteristics could influence patient-level outcomes or interact with individual-level variables. A final option could be the inclusion of group membership in individual-level specifications as dummy variables and the interactions of these dummy variables with individual-level independent variables (Bafumi, 2006). However, this approach will not show us what group characteristics of each level could explain the decision of performing a Caesarean-section. allow examination of exactly what group characteristics may be important in explaining the outcome.

As a result, using hierarchical modelling in our research is the appropriate approach and the differences with the approaches that were described above are that:

- We can test simultaneously the effects of group-level (mother, primary and secondary healthcare professionals, hospitals) and individual-level predictors,
- We can account for the non-independence of observations within groups
- We can examine the contribution of mother, primary and secondary healthcare professionals and hospital factor to the observed variations and we are able to investigate the inter-individual and inter-group variation can be examined (Snijders et al., 1993).

4.3.3. MODELLING

In our analysis, we employed a multilevel logistic random intercept model approach. In these models, intercepts are allowed to vary. As a result, the outcomes on the dependent variable for every patient observation are predicted by the intercept that varies across the different groups (Garson, 2012). In random intercept models, we assume that slopes do not differ across different contexts (they are fixed). Moreover, we can get information about intra-class correlations (ICC) (Fidell, 2007) or variance partition coefficient (VPC).

The data that we used in our analysis are clustered into two and three levels. Therefore, trying to fit a single-level regression model to these data will give us wrong answers. Random intercept model is a combination of variance components and regression models. Variance components models are a way to estimate the amount of variation in a dependent variable that is associated with one or more random-effects variables, assessing the variability accounted for by each level of the hierarchy. In that way, we can understand how much variation exists at each level, while also including explanatory variables.

The goal of using a logistic random intercept modelling approach is to predict the probability, Pi, that a C-section occurs for the mother i in function of a specific combination of variables. In that way we model the Caesarean-section outcome as a function of some observables, $\beta_0 + \beta_1 X_{idh}$, which is the fixed part and the parameters that we estimate are coefficients and some un-observables, v_h, u_d, t_m, which is the random part and the parameters that we estimate are variances, thus we are able to calculate the odds ratio (OR) with a 95% confidence interval (95% CI). Since the outcome variable in our analyses is binary (having or not having an elective or emergency C-section, the values of Pi range from 0 to 1. However, since a regression analysis is better performed on values between −∞ and +∞, we transform probability Pi in logit, which is comprised of values between −∞ and +∞ (Hosmer, 2002).

In our statistical analysis, the random effects are assumed normally distributed and independent across levels and units. We assume that there is no selection and women of certain characteristics do not choose specific GPs or consultants within the hospital and/or hospital to give birth. Our model is specified as follows:

$$\log\left(\frac{p_{ih}}{1-p_{ih}}\right) = \beta_0 + \beta_1 X_{ih} + \beta_2 X_{2ih} + \ ... + \beta_k X_{kih} + v_h \quad (1)$$

$$v_h \sim N(0, \sigma_v^2)$$

Where the unexplained variation at hospital level is σ_v^2 and measures the extent to which Caesarean-sections vary between hospitals

Similarly, for secondary healthcare professionals:

$$\log\left(\frac{p_{id}}{1-p_{id}}\right) = \beta_0 + \beta_1 X_{id} + \beta_2 X_{2id} + \ldots + \beta_k X_{kid} + u_d \quad (2)$$

$$u_d \sim N(0, \sigma_u^2)$$

Where the unexplained variation at secondary healthcare professional level is σ_u^2 and measures the extent to which Caesarean-sections vary between secondary healthcare professionals.

While for primary healthcare professionals, the model is specified as:

$$\log\left(\frac{p_{im}}{1-p_{im}}\right) = \beta_0 + \beta_1 X_{im} + \beta_2 X_{2im} + \ldots + \beta_k X_{kim} + t_m \quad (3)$$

$$t_m \sim N(0, \sigma_m^2)$$

Where the unexplained variation at primary healthcare professional level is σ_m^2 and measures the extent to which Caesarean-sections vary between primary healthcare professionals.

In the case of the three-level analysis, the model is specified as below:

$$\log\left(\frac{p_{idh}}{1-p_{idh}}\right) = \beta_0 + \beta_1 X_{idh} + \beta_2 X_{2idh} + \ldots + \beta_k X_{kidh} + u_d + v_h \quad (4)$$

$$u_d \sim N(0, \sigma_u^2)$$

$$v_h \sim N(0, \sigma_v^2)$$

Where the unexplained variation at hospital level is σ_v^2 and measures the extent to which Caesarean-sections vary between hospitals, while the unexplained variation that lies at secondary healthcare professional level is σ_u^2 and measures the extent to which Caesarean-sections vary within hospitals, between secondary healthcare professionals.

Next, from the two-levels logistic random intercept models we will estimate the intraclass correlation coefficient (ICC) or variance partition coefficient (VPC) which will measure the proportion of the total response variance that lies at hospital, primary and secondary healthcare professionals level.

The variance partition coefficient (VPC) expresses the proportion of the total observed individual variation in the response that is attributable to between-group variation. In the case of a continuous outcome, the VPC is specified as follows:

$$VPC_v \equiv ICC_v = \frac{\sigma_v^2}{\sigma_v^2 + \sigma_e^2}$$

Where, σ_v^2, σ_e^2 denote the between-mother and between-hospital or between-healthcare professional variation. In simple clustered data like mothers nested within hospitals or nested within healthcare professionals, the VPC coincides with the intraclass correlation coefficient (ICC). The ICC measures the expected correlation between units from the same group. In these hierarchical structures, VPC and ICC offer two different interpretations of the same statistic.

On the other hand, in a logistic multilevel regression model, where the response outcome is binary, the between-subject residual variance (in this case mothers) cannot be directly estimated. In a binary outcome, the variance of a binomial distribution is estimated by the mean. For example, consider the following multilevel Bernouilli model:

$$y_{ij} \sim \text{Binomial}(1, P_{ij})$$

where,

$$\log(P_{ij}) = \text{X}_{ij}\beta + u_j, u_j \sim \text{N}(0, \sigma_u^2)$$

so, the variance of the Bernouilli distribution, thus the level 1 variation is $\text{P}_{ij}(1 - \text{P}_{ij})$. As a result, the VPC will be a function of our predictor variables. In other words, it is more difficult to estimate the VPC due to the different scale of the level-1 (between-subject) variance and level-2 (between-cluster) variance (Goldstein, 2002).

To overcome this problem in the case of a binary response and convert both level-1 and level-2 variances to the same scale, there are three approaches, including model linearization, the simulation method, and the latent approach (Goldstein, 2002; Merlo, 2006; Browne, 2005; Li, 2008). Traditionally, the approach that is most commonly used for the estimation of the VPC is the latent approach, which gives a constant VPC (Austin and Merlo, 2017).

In this approach, we consider our observed binary outcome (the decision-making for having or not a C-section) as a threshold of advantages and disadvantages (a thresholded continuous latent variable), where we observe 0 below the threshold and 1 above. The standard logistic distribution, with scale parameter equal to one, has variance $\frac{\pi^2}{3} = 3.29$ (Evans, 1993). Thus, we take this as the level-1 (between-mothers) variance and both level-1 and level-2 (between-cluster) variances are on the same scale. As a result, the VPC for each group of our analysis is specified as follows.

$$VPC_v \equiv ICC_v = \frac{\sigma_v^2}{\sigma_v^2 + \frac{\pi^2}{3}} \quad (4)$$

Where VPC_v represents the variance between hospitals, and thus the variation in C-section rates that is attributable to them.

$$VPC_u \equiv ICC_u = \frac{\sigma_u^2}{\sigma_u^2 + \frac{\pi^2}{3}} \quad (5)$$

Where VPC_t represents the variance between primary healthcare professionals, and thus the variation in C-section rates that is attributable to them.

$$VPC_t \equiv ICC_t = \frac{\sigma_t^2}{\sigma_t^2 + \frac{\pi^2}{3}} \quad (6)$$

4.3.4. STATISTICAL ANALYSIS DESIGN

In this section and after elaborating on the modelling of our statistical analysis, using multilevel logistic random intercept model approach, we are going to describe the design and structure of our analysis in terms of the models that are going to be used.

Our statistical analysis includes all singleton births that took place in Scotland from 2009 to 2016 within a Scottish hospital (excluding home births and unknown cases). It consists of two main analyses, a longitudinal and a set of cross-sectionals, which are further described in the two following sections (section 5.7.1 and 5.7.2).

Both longitudinal and cross-sectional models were used to triangulate findings and ensure robustness. The longitudinal models exploit repeated yearly data to capture temporal variation, while the cross-sectional models allow deeper insight into between-provider variation at a fixed point in time. Random intercepts were used in both approaches to account for clustering at the hospital and provider level.

In the longitudinal analyses two different models were explored, where appropriate[9], referred to as a 'basic' and as an 'extended' model. More specifically, in two-level models, two different sets of baseline characteristics were employed, referred to as a 'basic' and as an 'extended' model. In addition to each basic model, the extended model controls for maternal BMI and the 2011 NICE policy change.

The reason for employing different sets of baseline characteristics is that the 'basic' model includes the combination of predictors that has been systematically used in the literature for the study of variations in C-section rates (Bragg, 2010; Sinnott, 2016). In that way we can produce results that are comparable with existing literature.

On the other hand, the 'extended' model controls for further predictors that haven't been used in prior literature. Although both birthweight in grams and gestational age in days are good predictors in assessing labour issues (Salas, 2017), due to collinearity with the birthweight, gestational age wasn't used in the baseline characteristics of the extended model.

The 'basic' model investigates the variation in C-section rates between the group under investigation (hospitals, primary healthcare professionals, secondary healthcare professionals), after controlling for the factors described in table I.5.

Table I.5 List of Predictors used in the "basic" model.

Predictor Variables	
Variable	**Further information (where needed)**
Breech position	Clinical Risk factors
Restricted fetal growth	
Excessive fetal growth	
Fetal distress	

[9] The appropriateness of the use of the extended model was based on practical aspects. The use of the extended model was not possible in the case of three-level models as it was increasing the complexity of the model which failed to be completed.

Dystocia	
Induction	
Malpresentation	
Placenta abruption	
Preterm delivery	
Eclampsia	
Hypertension	
Diabetes	
Previous C-sections	
Previous stillbirths	
Parity	
Age Group	Categorised as: <20; 20-24; 25-29; 30-34; 35-39; >=40
Ethnicity	Categorised as: White; Asian; Afro-Caribbean; Mixed-Arab; Not provided; Unknown
Marital Status	Categorised as: Married; Not married; Other; Unknown
Birthweight	Categorised as: 500-1499; 1500-2499; 2500-2999;
Delivery year	2009 to 2016
SIMD (2016)[10]	SIMD16 is the Scottish Government's fifth edition since 2004, ranging from 1 (most deprived to 10 (least deprived)
Additional Predictor variables	
Variable	**Further information (where needed)**
Maternal BMI	
Gestation	Gestational age in weeks, categorised as: <33; 33; 34; 35; 36; 37; >=38
Policy change	

4.3.4.1. LONGITUDINAL ANALYSIS

Our longitudinal analysis includes 7 models that are described in Table I.6 below. These models consist of 2-level random intercept models and a 3-level random intercept models. Two-level models were employed to calculate the variation that lies at each group of analysis (hospitals, secondary care healthcare professionals and primary care professionals).

[10] SIMD16 combines seven aspects of deprivation, including income; employment; health; education, skills and training; geographic access to services; crime; and housing.

Table I.6 Longitudinal analysis – Models Description

Model			Description	Scope	No. of obs
2-level	**Model 1**	Hospitals	Between Hospitals Basic model Emergency/Elective	Examine the unexplained variation attributable to hospitals after adjusting for basic baseline characteristics	380,944 381,398
	Model 2		Between Hospitals Extended model Emergency/Elective	Examine the unexplained variation attributable to hospitals after adjusting for basic baseline characteristics; BMI; policy change	299,899 300,316
	Model 3	Secondary HC professionals	Between Secondary Healthcare professionals Basic model Emergency/Elective	Examine the unexplained variation attributable to secondary healthcare professionals after adjusting for basic baseline characteristics	382,793
	Model 4		Between Secondary Healthcare professionals Extended model Emergency/Elective	Examine the unexplained variation attributable to secondary healthcare professionals after adjusting for main baseline characteristics; estimated gestation, BMI; policy change	301,468
	Model 5	Primary HC professionals	Between Primary Care professionals Basic Model Elective	Examine the unexplained variation attributable to primary healthcare professionals after adjusting for main baseline characteristics	375,518
	Model 6		Between Primary Care professionals Extended Model Elective	Examine the unexplained variation attributable to primary healthcare professionals after adjusting for main baseline characteristics; estimated gestation, BMI; policy change	303,752
3-level	**Model 7**		Between Hospitals, between secondary healthcare professionals within hospital Baisc model Emergency/Elective	Examine the unexplained variation attributable to hospitals; secondary healthcare professionals nested within hospitals after adjusting for main baseline characteristics	381,944 380,161

4.3.4.2. CROSS-SECTIONAL ANALYSES

Finally, basic models, as described in the previous paragraph, were performed for each group of analysis, stratified by year of delivery, in order to examine the level of variation year by year. The same random intercept multilevel model described previously was applied to the cross-sectional analyses, adjusted for year-specific fixed effects. This approach accommodates provider-level heterogeneity while maintaining comparability with the longitudinal framework. The models are described in the table below (Table I.7).

Table I.7 Cross-sectional analyses – Models Description

<table>
<tr><th colspan="3">Model</th><th>Description</th><th>Scope</th><th>No. of obs</th></tr>
<tr><td rowspan="3">2-level</td><td>Model 8</td><td>Hospitals</td><td>Between Hospitals
Basic model
Emergency/Elective</td><td>Examine the unexplained variation attributable to hospitals after, adjusting for basic baseline characteristics, stratified by year</td><td>380,944
381,398</td></tr>
<tr><td>Model 9</td><td>Secondary HC professionals</td><td>Between Secondary Healthcare professionals
Basic model
Emergency/Elective</td><td>Examine the unexplained variation attributable to secondary healthcare professionals, after adjusting for basic baseline characteristics, stratified by year</td><td>382,793</td></tr>
<tr><td>Model 10</td><td>Primary HC professional</td><td>Between Primary Care professionals
Basic Model
Elective</td><td>Examine the unexplained variation attributable to primary care professional, after adjusting for basic baseline characteristics, stratified by year</td><td>375,518</td></tr>
</table>

5. RESULTS

Our initial dataset includes 444,065 records of births in Scotland, from 2009 to 2016, which were reduced to 382,793 after applying a data cleaning strategy as described in Appendix A. The national total Caesarean-section rate in Scotland from 2009 to 2016 based on our dataset is 28.57% (12.7% for elective and 15.87% for emergency. The national total C-section rate according to aggregated data of ISD in Scotland under the same review period is 28.96% (12.73% for elective and 16.23% for emergency).

The baselines characteristics of our main model and the population of its sample is described in table I.8.

The assumptions of the multilevel logistic regression models were assessed and found to be met. Linearity of the logit for continuous variables was checked. Multicollinearity was examined using Variance Inflation Factors (VIFs), all of which were below 5. The hierarchical structure of the data justified the use of random intercepts to account for clustering within hospitals and provider groups. Between-group variance was statistically significant, supporting the use of multilevel modelling.

Table I.8 Descriptive characteristics of study population

	2009-2016			2009			2010			2011			2012			2013			2014			2015			2016		
	Emergency	elective	Vaginal	Emergency	elective	Vaginal	Emergency	elective	Vaginal	Emergency	elective	Vaginal	Emergency	elective	Vaginal	Emergency	elective	Vaginal	Emergency	elective	Vaginal	Emergency	elective	Vaginal	Emergency	elective	Vaginal
	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%
Clinical Risk Factors																											
breech	4519/7.42	6697/13.75	12138/3.14	508/8.04	758/17.17	126/0.39	632/8.78	843/15.40	119/3.27	571/7.85	859/15.44	112/0.32	558/8.12	858/15.85	120/0.35	556/7.05	840/13.36	113/0.32	585/6.80	835/11.91	143/0.39	591/6.92	863/12.01	98/0.28	525/6.33	841/11.42	91/0.27
Restricted Fetal Growth	1572/2.58	708/1.45	5259/1.90	141/2.26	62/1.40	477/1.48	149/2.07	76/1.39	529/1.46	169/2.32	52/0.93	554/1.63	157/2.28	61/1.13	584/1.71	200/2.54	83/1.32	642/1.84	197/2.29	105/1.50	668/1.84	277/3.24	123/1.71	803/2.32	282/3.40	146/1.98	1002/2.94
Excessive Fetal Growth	573/0.94	295/0.61	927/0.33	62/1	27/0.61	101/0.31	46/0.64	25/0.46	87/0.24	59/0.81	42/0.76	103/0.30	84/1.22	38/0.70	106/0.31	64/0.81	32/0.51	110/0.31	61/0.71	32/0.46	99/0.27	95/1.11	43/0.60	133/0.38	102/1.23	56/0.76	188/0.55
Fetal Distress	12126/19.91	828/1.70	37936/13.69	1399/22.45	97/2.20	4775/14.84	1339/18.60	86/1.57	5170/14.31	1364/18.75	91/1.64	4930/14.23	1380/20.08	79/1.46	4744/13.91	1511/19.16	93/1.48	4484/12.82	1660/19.30	113/1.61	4476/12.32	1652/19.35	150/2.09	4591/13.28	1821/21.95	119/1.62	4766/13.98
Dystocia	4390/7.21	560/1.15	6249/2.26	369/5.92	65/1.47	763/2.63	464/6.44	64/1.17	896/2.48	541/7.44	73/1.31	826/2.38	586/8.53	72/1.33	839/2.46	592/7.51	64/1.02	677/1.94	559/6.50	63/0.90	755/2.08	626/7.33	63/0.88	695/2.01	653/7.87	96/1.30	798/2.34
Induction	24163/39.67	392/0.80	79355/28.64	2221/35.64	32/0.72	9887/23.08	2555/35.49	38/0.69	8691/24.05	2672/36.73	26/0.47	8269/23.87	2556/37.19	25/0.46	8900/26.10	3159/40.05	43/0.68	10113/28.91	3670/42.66	52/0.74	11500/31.65	3679/43.08	65/0.90	11976/34.65	3651/44	111/1.51	12272/35.99
Malpresentation	13702/22.5	3061/6.28	17641/6.37	1453/23.32	221/5.01	2203/6.85	1742/24.19	317/5.79	2664/7.37	1620/22.27	384/6.90	2492/7.19	1611/23.44	338/6.24	2375/6.96	1756/22.26	346/5.50	2023/5.78	1818/21.13	466/6.65	2012/5.54	1868/21.88	499/6.95	1884/5.45	1834/22.10	490/6.65	1988/5.83
Placenta Praevia Abruption	774/1.27	425/0.87	324/0.12	84/1.35	22/0.5	48/0.15	75/1.04	32/0.58	41/0.11	88/1.21	44/0.79	44/0.13	93/1.35	40/0.74	31/0.09	88/1.12	59/0.94	39/0.11	109/1.27	76/1.08	46/0.13	107/1.25	76/1.06	42/0.12	130/1.57	76/1.03	33/0.1
Preterm Delivery	1128/1.85	247/0.51	2557/0.92	273/4.38	51/1.16	691/2.15	195/2.71	30/0.55	448/1.24	81/1.11	15/0.27	155/0.45	43/0.63	7/0.13	119/0.35	124/1.57	35/0.56	308/0.88	157/1.83	38/0.54	294/0.81	142/1.66	40/0.56	282/0.82	113/1.36	31/0.42	260/0.76
Eclampsia	1931/3.17	281/0.58	2103/0.76	188/3.02	39/0.88	271/0.84	229/3.18	43/0.79	284/0.79	236/3.24	36/0.65	299/0.86	241/3.51	30/0.55	309/0.91	255/3.23	37/0.59	265/0.76	250/2.91	28/0.40	202/0.92	267/3.13	38/0.53	24/0.7	265/3.9	30/0.41	231/0.68
Hypertension	5142/8.44	1301/2.67	9815/3.54	562/9.02	128/2.90	1299/4.04	569/7.90	167/3.05	1204/3.33	637/8.76	144/2.59	1233/3.53	672/9.78	152/2.81	1380/4.05	664/8.42	175/2.78	1218/3.48	722/8.39	167/2.38	1168/3.21	660/7.73	190/2.64	1173/3.39	656/7.91	178/2.42	1150/3.37
Diabetes	2606/4.28	2606/5.42	4869/1.76	194/3.11	163/3.69	309/0.96	204/2.83	191/3.49	386/1.07	223/3.07	231/4.15	388/1.12	266/3.87	306/5.65	580/1.70	365/4.63	355/5.65	692/1.98	457/5.31	431/6.15	791/2.18	445/5.21	434/6.04	831/2.4	452/5.45	529/7.18	892/2.62
previous CS	9002/14.78	28871/59.27	9356/3.38	944/15.15	2737/61.99	1170/3.64	1111/15.43	3362/61.43	1385/3.83	1095/15.05	3225/57.98	1202/3.47	1046/15.22	3161/58.39	1177/3.45	1236/15.67	3595/57.19	1145/3.27	1254/14.58	4018/57.33	1100/3.03	1188/13.91	4293/59.75	1087/3.14	1128/13.60	4480/60.83	1090/3.20
previous stillbirths	461/0.76	762/1.56	1473/0.53	56/0.90	57/1.29	191/0.59	62/0.86	105/1.92	192/0.53	45/0.62	104/1.87	224/0.65	54/0.79	80/1.48	159/0.47	59/0.75	97/1.54	177/0.51	48/0.56	103/1.47	174/0.48	59/0.69	98/1.36	182/0.53	78/0.94	118/1.60	174/0.51
Parity (multiparous)	31167/51.17	42205/86.65	184254/66.51	2998/48.11	3800/86.07	20541/63.82	3649/50.68	4777/87.28	23783/65.82	3749/51.54	4800/86.3	22933/66.21	3614/52.59	4695/86.72	23116/67.79	4177/52.95	5505/87.58	23789/68	4495/52.26	6111/87.20	24482/67.38	4374/51.22	6249/86.97	23074/66.76	4111/49.55	6269/85.11	22536/66.08
Agegroup																											
<20	2555/4.20	495/1.02	16689/6.02	352/5.65	70/1.59	2490/7.74	392/5.44	70/1.28	2707/7.49	337/4.63	67/1.20	2407/6.95	293/4.26	68/1.26	2149/6.30	318/4.03	59/0.94	2019/5.77	303/3.52	47/0.67	1862/5.12	308/3.61	55/0.77	1591/4.6	252/3.04	59/0.80	1464/4.29
20-24	9383/15.41	4433/9.10	53406/19.28	1041/16.71	456/10.33	6835/21.24	1118/15.53	542/9.90	7272/20.13	1219/16.76	541/9.73	6902/19.93	1139/16.57	514/9.49	6664/19.54	1230/15.59	573/9.12	6824/19.50	1293/15.03	595/8.49	6725/18.51	1207/14.14	603/8.39	6213/8.39	1136/13.69	609/8.27	5971/17.51
25-29	16394/26.92	11084/22.76	79476/28.69	1648/26.45	1024/23.19	9223/28.66	1900/26.39	1266/23.13	10253/28.38	1954/28.86	1229/22.10	9729/28.09	1802/26.22	1215/22.44	9847/28.88	2155/27.32	1396/22.21	9919/28.35	2325/27.03	1605/22.90	10567/29.08	2320/27.17	1677/23.34	10104/29.23	2290/27.6	1672/22.7	9834/28.84
30-34	18572/30.49	16687/34.26	80001/28.88	1767/28.36	1435/32.5	8172/25.39	2094/29.08	1780/35.52	9765/27.03	2125/29.21	1864/33.51	9634/27.81	2072/30.15	1838/33.95	9789/28.71	2431/30.82	2204/35.06	10355/29.6	2670/31.04	2427/34.63	11061/30.44	2726/31.92	2536/35.30	10573/30.59	2687/32.39	2603/35.34	10652/31.24
35-40	10980/18.03	12398/25.45	39545/14.27	1128/18.10	1116/25.28	4538/14.10	1339/18.60	1339/25.56	5161/14.28	1262/17.35	1455/26.16	4923/14.21	1216/17.69	1391/25.69	4673/13.70	1349/17.1	1571/24.99	4809/13.75	1588/18.46	1792/25.57	5109/14.06	1564/18.32	1810/25.19	5155/14.91	1534/18.49	1864/25.31	5177/15.18
>40	3019/4.96	3611/7.41	7920/2.86	295/4.73	314/7.11	926/2.88	357/4.96	416/7.60	975/2.70	377/5.18	406/7.30	1041/3.01	350/5.09	388/7.17	978/2.87	405/5.13	483/7.68	1060/3.03	423/4.92	542/7.73	1009/2.78	414/4.85	504/7.01	927/2.68	398/4.80	558/7.58	1004/2.94
Ethnicity																											
White	37761/62.36	31884/65.85	171163/62.06	1970/31.67	1337/30.33	8993/27.97	3456/48.13	2743/50.25	17679/49.06	4453/61.43	3512/63.45	21445/62.14	4453/65.15	3607/66.88	22111/65.13	5491/70.15	4486/72.04	24381/70.08	5943/69.63	5186/74.52	25587/70.89	6132/72.36	5438/76.33	25712/74.83	5863/71.19	5575/76.24	25255/74.5
Asian	2046/3.38	1402/2.90	7844/2.84	135/2.17	59/1.34	477/1.48	175/2.44	94/1.72	699/1.94	230/3.17	165/2.98	958/2.78	235/3.44	160/2.97	948/2.79	300/3.83	211/3.39	1158/3.33	323/3.78	230/3.31	1288/3.57	325/3.84	262/3.68	1166/3.39	323/3.92	221/3.02	1150/3.39
Afro-Caribean	763/1.26	574/1.19	2062/0.75	70/1.13	25/0.57	164/0.51	88/1.23	49/0.90	266/1.94	72/0.99	52/0.94	217/0.63	89/1.3	57/1.06	204/0.6	117/1.49	87/1.4	341/0.98	126/1.48	103/1.48	316/0.88	106/1.25	109/1.53	274/0.8	95/1.15	92/1.26	280/0.83
Mixed/Arab	377/0.62	287/0.59	1585/0.57	22/0.35	13/0.29	86/0.27	34/0.47	18/0.33	151/0.42	32/0.44	24/0.43	145/0.42	26/0.38	19/0.35	136/0.4	48/0.61	29/0.47	189/0.54	55/0.64	48/0.69	237/0.66	69/0.81	56/0.79	316/0.92	91/1.10	80/1.09	325/0.96
Not Provided	8184/13.51	6017/12.43	38979/14.13	691/11.11	510/11.57	3778/11.75	684/9.53	573/10.50	3961/10.99	790/10.9	634/11.45	4318/12.51	1100/16.09	847/15.71	6052/17.83	1220/15.59	862/13.84	5728/16.46	1357/15.9	942/13.54	5922/16.41	1191/14.05	808/11.34	4710/13.71	1151/13.98	841/11.5	4510/13.3
Unknown	11427/18.87	8253/17.05	54166/19.64	3333/53.58	2464/55.90	18654/58.02	2744/38.21	1982/36.31	13283/36.86	1672/23.07	1148/20.74	7429/21.53	932/13.64	703/13.04	4497/13.25	651/8.32	552/8.86	2995/8.61	731/8.56	450/6.47	2744/7.6	651/7.68	451/6.33	2183/6.35	713/8.66	503/6.88	2381/7.02
Marital Status																											
Married	10021/16.45	11605/23.83	46790/16.89	1476/23.69	1326/30.03	7231/22.47	1418/19.69	1531/27.97	7159/19.81	1273/17.5	1399/25.15	5732/16.55	1088/15.83	1200/22.16	5445/15.97	1298/16.46	1571/24.99	5988/17.12	1179/13.71	1624/23.17	5508/15.16	1198/14.03	1519/21.14	5076/14.69	1091/13.15	1435/19.48	4651/13.64
Not Married	16446/27	12179/25	75214/27.15	1665/26.72	893/20.23	8551/26.57	2035/28.26	1307/23.88	10448/28.92	1807/24.84	1195/21.49	9057/26.15	1816/26.43	1258/23.24	8791/25.78	2224/28.19	1663/26.46	10125/28.94	2260/26.27	1881/26.84	9714/26.74	2323/27.2	1944/27.06	9176/26.55	2316/27.91	2038/27.67	9352/27.42
Other/Not Provided	14787/24.28	11420/23.45	65367/23.6	1400/22.47	969/21.95	6643/20.64	2006/27.86	1399/25.56	9815/27.16	2508/34.48	1817/32.67	11129/32.13	2119/30.84	1673/30.9	10123/29.69	1853/23.49	1463/23.27	7982/22.81	1783/20.73	1399/19.96	7393/20.35	1611/18.87	1367/19.03	6322/18.29	1507/18.16	1333/18.10	5960/17.48
Unknown	19649/32.26	13504/27.72	89666/32.37	1690/27.12	1227/27.79	9759/30.32	1741/24.18	1236/22.58	8711/24.11	1686/23.18	1151/20.69	8718/25.17	1849/26.91	1283/23.7	9741/28.57	2513/31.86	1589/25.28	10891/31.13	3380/38.29	2104/30.02	13718/37.76	3407/39.9	2355/32.78	13989/40.47	3383/40.77	2559/34.75	14139/41.46
Birthweight																											
500-1499	1458/2.39	201/0.41	1321/0.48	145/2.33	20/0.45	178/0.55	167/2.32	25/0.46	181/0.5	202/2.78	29/0.52	140/0.4	147/2.14	21/0.39	171/0.5	193/2.45	25/0.4	159/0.77	214/2.49	23/0.33	191/0.53	193/2.26	28/0.39	149/0.43	197/2.37	30/0.41	152/0.45
1500-2499	5209/8.55	1738/3.57	9932/3.59	537/8.62	157/3.56	1156/3.59	590/8.19	186/3.40	1318/3.65	651/8.95	183/3.29	1279/3.69	549/7.99	187/3.45	1204/3.53	658/8.34	238/3.79	1240/3.54	701/8.15	237/3.38	1272/3.5	785/9.19	258/3.59	1246/3.61	738/8.89	292/3.96	1217/3.57
2500-2999	8010/13.15	6291/12.92	39614/14.3	798/12.81	638/14.45	4583/14.24	910/12.64	735/13.43	5074/14.04	923/12.69	744/13.38	4854/14.01	898/13.07	661/12.21	4736/13.89	1049/13.3	793/12.62	4904/14.02	1151/13.38	903/12.89	5361/14.76	1138/13.33	886/12.33	5031/14.56	1143/13.78	931/12.64	5071/14.87
3000-3499	16898/27.75	17371/35.66	99125/35.78	1634/26.22	1582/35.83	11656/36.22	1933/26.85	2016/36.84	12968/35.89	1963/26.99	1959/35.22	12345/35.64	1889/27.49	1910/35.28	12032/35.28	2223/28.18	2287/36.38	12501/35.73	2456/28.55	2515/35.89	13064/35.96	2454/28.74	2558/35.6	12332/35.68	2346/28.28	2544/34.54	12227/35.85
3500-3999	18367/30.16	16033/32.92	91081/32.88	1887/30.28	1351/30.6	10413/32.35	2216/30.78	1756/32.08	11836/32.76	2156/29.64	1809/35.52	11342/32.75	2104/30.62	1817/33.56	11444/35.56	2397/30.39	2081/33.11	11523/32.94	2527/29.38	2365/33.75	11868/32.66	2553/29.9	2404/33.46	11404/32.99	2527/30.46	2450/33.27	11251/32.99
4000-4499	8750/14.37	5789/11.89	30970/11.18	975/15.65	528/11.96	3600/11.19	1101/15.29	613/11.2	4095/11.33	1083/14.89	684/12.3	3999/11.55	984/14.32	670/12.38	3884/11.39	1111/14.08	710/11.29	3978/11.37	1247/14.5	806/11.50	3970/10.93	1149/13.46	852/11.86	3817/11.04	1100/13.26	926/12.57	3627/10.64
>4500	2211/3.63	1285/2.64	4994/1.8	255/4.09	139/3.15	598/1.86	283/3.93	142/2.59	661/1.83	296/4.07	154/2.77	677/1.95	301/4.38	148/2.73	629/1.84	257/3.26	152/2.42	681/1.95	306/3.56	159/2.27	607/1.67	267/3.13	199/2.77	584/1.69	246/2.96	192/2.61	557/2
simd																											
1	7831/12.86	5825/11.96	36070/13.02	771/12.37	462/10.46	4000/12.43	888/12.33	604/11.04	4556/12.61	855/11.75	622/11.18	4421/12.76	761/11.07	608/11.23	3980/11.67	1025/12.99	770/12.25	4674/13.36	1125/13.08	895/12.77	5070/13.95	1245/14.58	953/13.26	4722/13.66	1161/13.99	911/12.37	4647/13.63
2	7372/12.1	5398/11.08	34213/12.35	713/11.44	486/11.01	4026/12.51	871/12.1	595/10.87	4428/12.25	955/13.13	597/10.73	4371/12.62	891/12.97	622/11.49	4192/12.29	982/12.45	709/11.28	4311/12.32	1037/12.06	746/10.64	4514/12.42	1000/11.71	810/11.27	4151/12.01	923/11.12	833/11.31	4220/12.37
3	6763/11.1	5021/10.31	30923/11.16	695/11.15	472/10.69	3554/11.04	765/10.63	530/9.68	4020/11.13	823/11.31	604/10.86	3911/11.29	731/10.64	545/10.07	3859/11.31	905/11.47	623/9.91	3941/11.26	984/11.44	714/10.19	4082/11.23	952/11.15	766/10.66	3881/11.23	908/10.94	767/10.41	3675/10.78
4	6441/10.58	4834/9.92	29005/10.47	638/10.24	409/9.26	3370/10.47	776/10.78	525/9.59	3815/10.56	773/10.63	554/9.96	3629/10.54	753/10.96	506/9.35	3712/10.89	858/10.88	652/10.37	3664/10.47	882/10.25	750/10.7	3701/10.19	895/10.48	687/9.56	3686/10.66	866/10.44	751/10.2	3408/9.99
5	6282/10.31	4699/9.65	28012/10.11	662/10.62	441/9.99	3306/10.27	758/10.53	555/10.14	3665/10.14	718/9.87	546/9.82	3566/10.3	728/10.59	562/10.38	3500/10.26	785/9.95	599/9.53	3528/10.08	870/10.11	654/9.33	3673/10.11	889/10.41	670/9.32	3308/9.57	872/10.51	672/9.12	3466/10.16
6	5762/9.46	4652/9.55	26200/9.46	598/9.6	454/10.28	3114/9.68	663/9.21	513/9.37	3421/9.47	725/9.97	540/9.71	3245/9.37	656/9.55	508/9.38	3365/9.87	726/9.2	628/9.99	3259/9.32	816/9.49	642/9.16	3342/9.2	772/9.04	645/8.98	3231/9.35	806/9.71	722/9.8	3223/9.45
7	5525/9.07	4631/9.51	25606/9.24	570/9.15	422/9.56	3059/9.5	641/8.9	547/9.99	3336/9.23	673/9.25	583/10.48	3159/9.12	679/9.88	522/9.64	3168/9.29	675/8.56	582/9.26	3199/9.14	804/9.35	633/9.03	3311/9.11	724/8.48	673/9.37	3245/9.39	759/9.15	669/9.08	3129/9.18
8	5331/8.75	4634/9.51	23824/9.24	587/9.42	472/10.69	2929/9.1	656/9.11	574/10.49	3106/8.60	604/8.3	495/8.9	2971/8.58	602/8.76	522/9.64	2888/8.47	709/8.99	583/9.27	2980/8.52	756/8.76	649/9.26	3086/8.49	708/8.29	678/9.44	2935/8.49	709/8.55	661/8.97	2929/8.59
9	5035/8.27	4676/9.6	22587/8.15	535/8.59	435/9.85	2743/8.52	623/8.65	531/9.7	2934/8.12	588/8.08	524/9.42	2774/8.01	545/7.93	530/9.79	2771/8.13	603/7.64	581/9.24	2769/7.91	692/8.04	688/9.53	2967/8.17	728/8.53	671/9.34	2800/8.1	721/8.69	736/9.99	2829/8.3
10	4561/7.49	4338/8.91	20597/7.43	462/7.41	362/8.2	2093/6.47	559/7.76	499/9.12	2852/7.89	560/7.7	497/8.94	2569/7.42	526/7.65	489/9.03	2665/7.82	620/7.86	559/8.89	2661/7.61	636/7.39	657/9.38	2587/7.12	626/7.33	632/8.8	2604/7.53	572/6.89	643/8.73	2576/7.55

5.1. Variations in Caesarean-sections between hospitals.

There are 46 hospitals across Scotland where birth deliveries were taken place from 2009 to 2016. Out of those hospitals, 26 provided at least one C-section (emergency or elective). More specifically, 25 hospitals performed emergency C-sections from 2009-2016, while 22 performed at least one elective C-section. A potential concern is that very small hospitals with unavailability of the procedure, thus zero C-section rates, influence the amount of variation that appears to be attributable to the hospital. For that reason, we excluded hospitals that didn't provide at least 1 emergency or 1 elective C-section respectively in each analysis. Although including hospitals which don't provide elective or emergency C-sections could reveal information regarding supply-sensitive care variation, this approach could result to unreliable calculation of preference-sensitive care variation.

The unadjusted rates of emergency C-sections varied from 0.09% to 18.54% between hospitals that provided at least 1 emergency C-section from 2009 to 2016, while the rates of elective C-sections varied from 0.02% to 18.59% between hospital with at least 1 elective C-section provided from 2009-2016. After controlling for patient characteristics and clinical risk factors, the proportion of variation in C-sections that is attributable to hospitals is 23.8% for emergency C-sections and 16.13% for elective C-sections (table I.9, model 1).

Table I.9 ICC - Attributable Variation (Model 1 & 2)

Model	**Model 1**		**Model 2**	
CS type	**Emergency**	**Elective**	**Emergency**	**Elective**
ICC	23.75%	16.1%	23.15%	15.21%

Adjusted for all other baseline characteristics of the 'basic' model (model 1, appendix B), the odds of both elective and emergency C-section were higher for women over 35 years old and even higher for women over 39 years old. In higher to lower likelihood order, breech presentation; placenta praevia abruption; history of previous C-sections; other forms of malposition of the baby; eclampsia; diabetes; excessive fetal growth; induction; hypertension; fetal distress; dystocia; history of previous stillbirths were the strongest predictors for an emergency C-section. In addition, babies of very small or very large birthweight were having higher odds of emergency C-section. Women over 35 years old, as well as Afro-Caribbean and Asian women were more likely to have an emergency C-section. Similarly, the strongest predictors for elective C-section were breech presentation, history of previous C-section, placenta praevia abruption, diabetes, history of previous stillbirths, eclampsia, the restricted fetal growth, excessive fetal growth, other forms of malposition of the baby and hypertension. Women over 35 and babies over 4000grams were more likely to have an elective C-section.

Additional adjustment for maternal BMI[11] (Body Mass Index), gestational age and the NICE policy change regarding elective C-sections decreased slightly the proportion of variation in C-sections that is attributable to hospitals (23.15% for emergency C-sections and 15.21% for elective C-sections), (Table I.9, Model 2). Furthermore, underweight, overweight and obese women were having higher odds for both emergency and elective C-section. Premature and postmature babies were more likely to be delivered through an emergency C-section, while birth deliveries prior to 38th week, on the 39th week and after 42nd week were having higher odds for an elective C-section. Finally, the odds ratio of the NICE policy change was 1.03(95% CI 0.93-1.15) for emergency C-sections and 1.09(95% CI 0.93-1.28) for elective C-sections.

Table I.10 shows the proportion of variation attributable to hospitals stratified by year of delivery. The proportion of variation that is attributable to hospital decreased from 7.33% in 2009 to 3.58% in 2016 for emergency C-sections and from 13.26% to 9.66% for elective C-sections respectively.

Table I.10 Variation attributable to hospital stratified by year

Model	Main Model per year							
Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
	(%)							
Emergency ICC	7.33	4.04	3.00	4.29	3.55	4.61	4.29	3.58
Elective ICC	13.26	13.24	14.33	11.81	10.16	9.46	7.16	9.66

[11] BMI: Body Mass Index (BMI) is a measure derived from the mass (weight) and height of a person that is used to broadly categorise, in health terms, a person as underweight; normal weight; overweight and obese. The BMI is defined as the body mass divided by the square of the body height, and is universally expressed in units of kg/m^2.

Figure I.8 Proportion of Variation in C-sections attributable hospitals (across time)

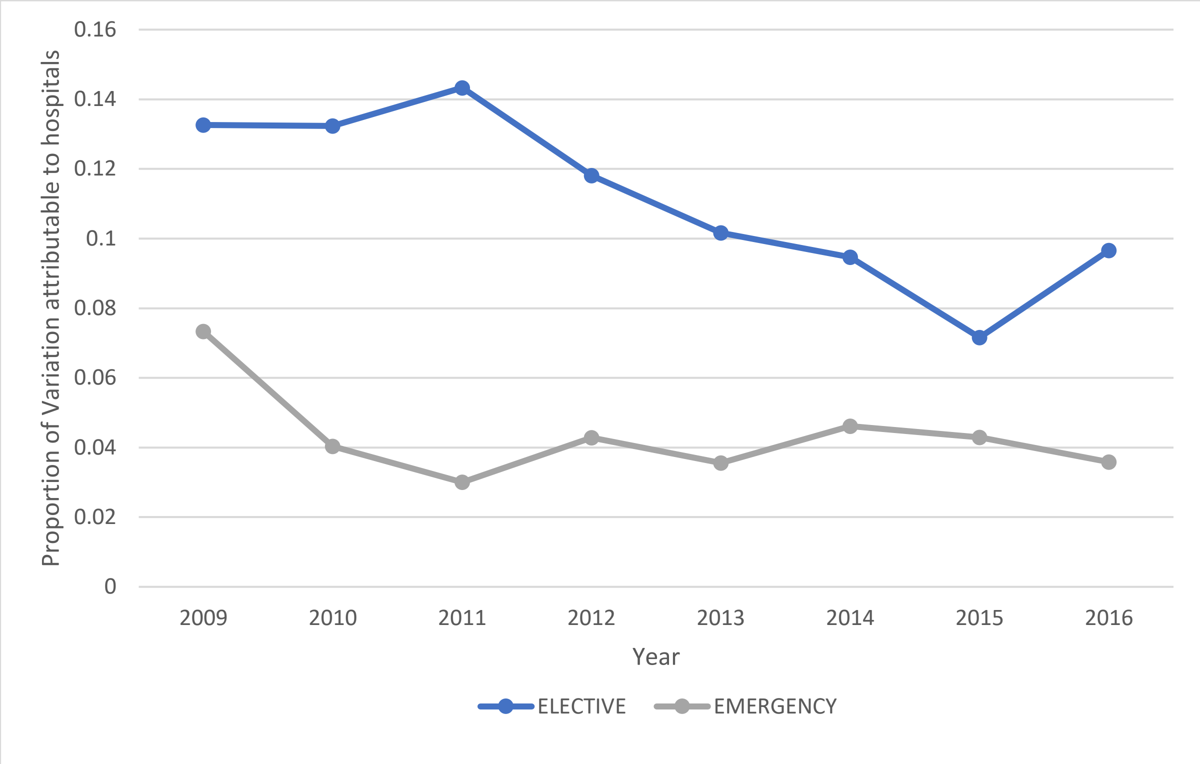


Figure I.8 shows the proportion of variation in C-sections which is attributable to hospital across time.

5.2. Variation in C-sections between Secondary healthcare professionals

The initial dataset includes 646 secondary healthcare professionals nested within hospitals. Following a similar to section 5.1 approach, we excluded secondary healthcare professionals who were not assigned in at least one case of C-section from 2009-2016, resulting to 334 secondary healthcare professionals.

After adjusting for all factor of the main model (table I.9, model 3), the proportion of variation in C-section that is attributable to secondary healthcare professionals is 10.04% for emergency C-sections and 18.89% for elective C-sections. Adjusting for BMI, gestational age and the NICE policy change (table I.11, model 4) slightly decreased the proportion of unexplained variation to 9.87% for emergency C-sections and 17.49% for elective C-sections.

Clinical and patient risk factors follow the same likelihood pattern as in 5.1 section in both emergency and elective C-sections (Appendix B)

Table I.11 Variation attributable to Secondary healthcare Professionals (Model 3&4)

Model	Model 3		Model 4	
CS type	Emergency	Elective	Emergency	Elective
ICC	10.04%	18.89%	9.87%	17.49%

Table I.12 shows the proportion of variation attributable to secondary healthcare professionals stratified by year of delivery. The proportion of variation that is attributable to secondary healthcare professionals increased from 3.89% in 2009 to 6.23% in 2016 for emergency C-sections and from 10.03% to 11.48% for elective C-sections respectively.

Table I.12 Variation attributable to Secondary HC Professionals stratified by year of delivery

Model	Main Model per year							
Year	2009	2010	2011	2012	2013	2014	2015	2016
	(%)							
Emergency ICC	3.89	4.06	3.22	6.24	6.03	6.58	6.89	6.23
Elective ICC	10.03	12.17	13.21	14.44	12.26	11.39	12.16	11.48

Figure I.9 Proportion of Variation in C-sections attributable to Secondary HC professionals across time

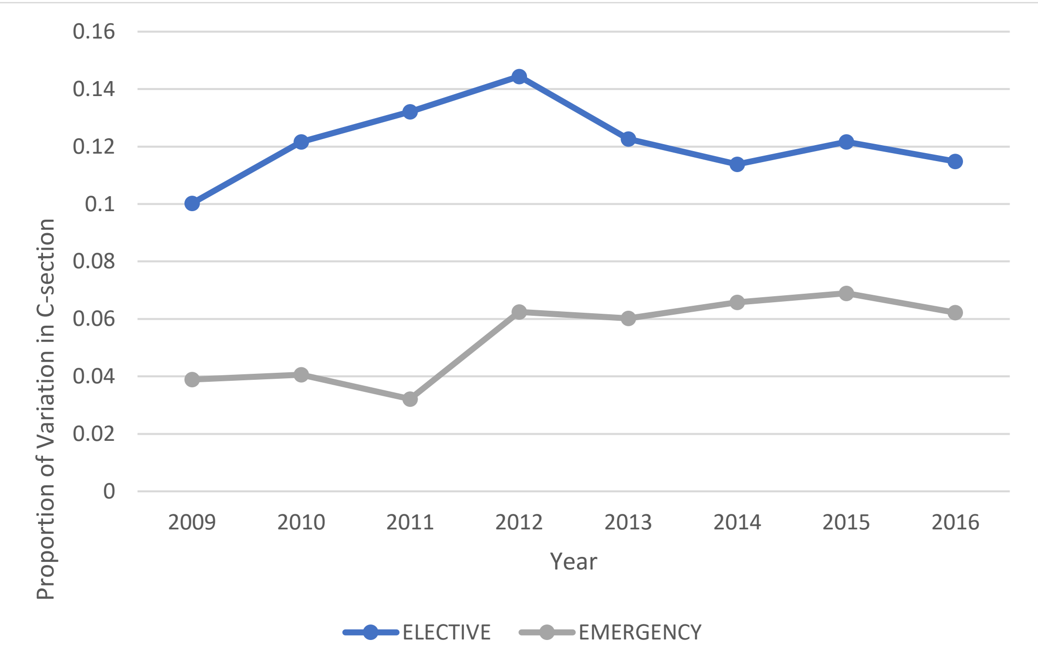


Figure I.9 shows the proportion of variation in C-sections which is attributable to secondary healthcare professionals across time.

5.3. Variations in C-sections between Primary healthcare professionals

After controlling for main model's patient characteristics and clinical risk factors, the proportion of variation in elective C-sections that is attributable to primary healthcare professionals is 4.8% (Table I.13, Model 5) and 4% after additional adjusting for BMI, gestational age and the NICE policy change (Table I.11, Model 6).

Table I.13 Variation attributable to Primary healthcare Professionals (Model 5&6)

Model	Model 5	Model 6
CS type	Elective	Elective
ICC	4.8%	4.0%

Clinical and patient risk factors follow the same likelihood pattern as in 4.1 section in elective C-sections.

Table I.14 shows the proportion of variation attributable to primary healthcare professionals stratified by year of delivery. The proportion of variation in elective C-sections that is attributable to primary healthcare professionals decreased from 5% in 2009 to 2.74% in 2016.

Table I.14 Variation attributable to Primary HC professionals stratified by year of delivery.

Model	Main Model per year							
Year	2009	2010	2011	2012	2013	2014	2015	2016
				(%)				
Elective ICC	5.00	4.71	7.1	6.21	4.18	2.9	3.44	2.74

Figure I.10 Proportion of Variation in C-sections attributable to Primary HC professionals across time

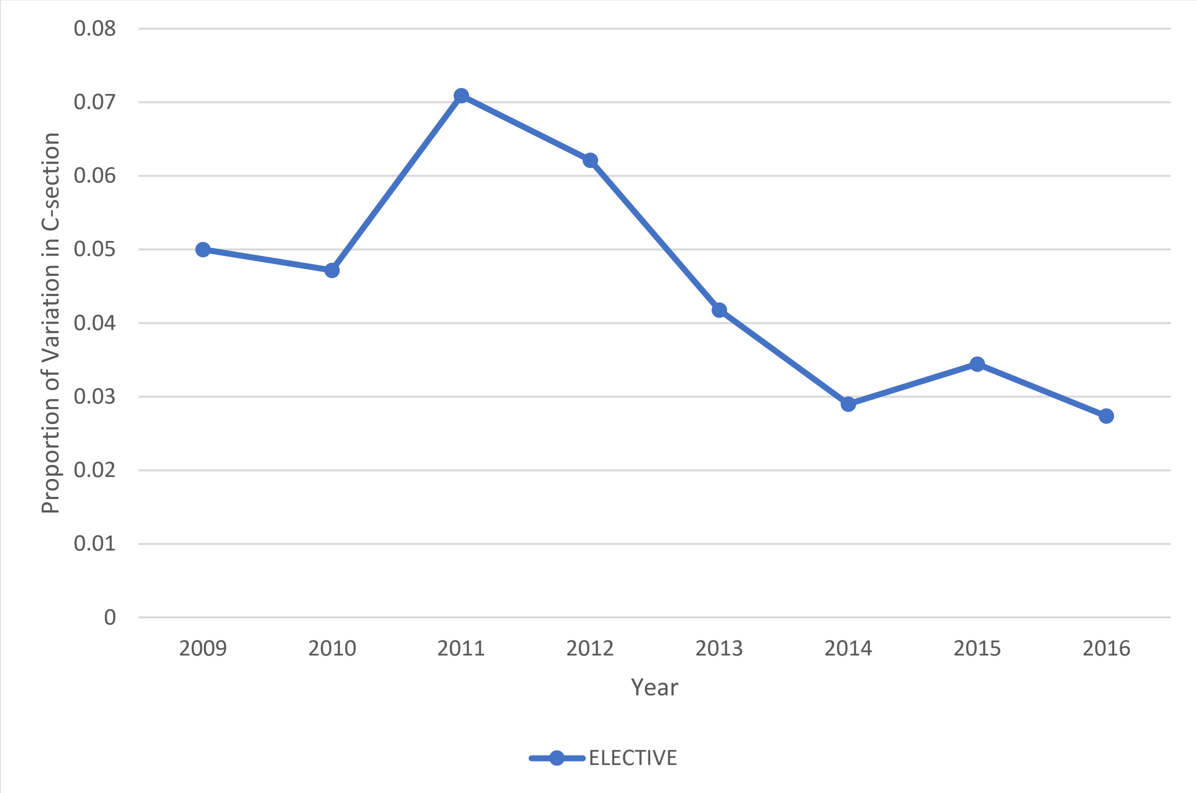


Figure I.10 shows the proportion of variation in C-sections which is attributable to primary healthcare professionals across time.

5.4. Variations in Caesarean-sections between hospitals within consultants

Table I.15 ICC - Attributable Variation (Model 7)

Model	**Model 7**	
CS type	**Emergency**	**Elective**
Hospital ICC	6.26%	9.96%
Secondary HC professionals ICC	9.79%	18.18%

After employing a three-level random intercept model, the proportion of variation in emergency C-section rates that is attributable to hospitals and cannot be explained by patient characteristics and clinical risk factors is 6.26%, while 9.79% is attributable to consultants within the hospital. In the case of elective C-sections 10% of the variation (table I.15).

6. DISCUSSION

6.1. Overview

This chapter investigated variations in Caesarean-section rates across Scotland using both longitudinal and cross-sectional analyses. After adjusting for maternal and clinical risk factors, we found that significant unexplained variation remained, particularly between hospitals and secondary care professionals. In the longitudinal analysis, 23.8% of emergency and 16.1% of elective C-section variation was attributable to hospitals, while cross-sectional results showed persistent variation among secondary care professionals over time. These findings suggest that factors beyond clinical risk—such as provider behaviour and institutional practices—play a key role. Identifying such variation is essential for targeting standardisation efforts in maternity care.

6.1.1. Longitudinal Analysis

In our longitudinal analysis, we sourced more than 380,000 births that took place in Scottish public maternity from 2009 to 2016. Adjusting for patient characteristics and a wide range of clinical risk factors which have been systematically used in similar studies (Bragg, 2010; Sinnott, 2016) and could determine the need for a C-section, we found that 23.8% of the variance for emergency C-section and 16.1% for elective C-section was due to between hospital variation. Taking secondary healthcare professionals as a group of analysis, we found that 10% of the unexplained variation in emergency C-sections was attributable to this group, while 18.9% of the unexplained variation was attributable to elective C-sections. As far as primary care is concerned, we found that 4.8% of the unexplained variation in elective C-sections was attributable to it. Additional adjusting for maternal BMI, gestational age and the NICE policy change in November 2011, slightly decreased proportion of variation attributable to each of the three groups from 0.1-0.6% in emergency C-sections and 0.9-1.4% in elective C-sections. This decrease was mainly because of maternal BMI and the gestational age.

For all the analyses that we performed, our results pointed out that the strongest predictors for an emergency C-section were breech presentation; placenta praevia abruption; history of previous C-sections; other forms of malposition of the baby; eclampsia; diabetes; excessive fetal growth; induction; hypertension; fetal distress; dystocia; history of previous stillbirths and babies of very small or very large birthweight. Similarly, the strongest predictors for elective C-section were breech presentation, history of previous C-section, placenta praevia abruption, diabetes, history of previous stillbirths, eclampsia, restricted fetal growth, excessive fetal growth, other forms of malposition of the baby; hypertension and babies over 4000grams were more likely to have an elective C-section. In contrast with other studies (Murphy, 2013; Feng, 2013), our results did not point to a consistent association between socioeconomic deprivation and the likelihood of having a C-section, echoing the results of other studies (Kolip, 2012; Kenny et al., 2013; Sinnott, 2016). In line with existing literature (Bragg, 2010; Sinnott, 2016), our results showed that increasing maternal age was associated with both emergency and elective C-section. Moreover, Afro-Caribbean and Asian women were more likely to have an emergency C-section, consistent with Sinnott's (2016) study.

The findings of our longitudinal analysis provide evidence of the variation, in the overall clinical approach in maternity care, in Scotland. Primary healthcare professionals are the starting point of the antenatal care for a pregnant woman. The unexplained variation attributable to primary care professionals in elective C-sections could be the result of differences in their practice styles, individual beliefs, training, as well as in the way they shape their decisions (Westert et. al., 2015). Moreover, in November 2011 elective C-sections became available upon maternal request, the communication of this option between the healthcare professional and the mother-to-be, as well as the recommendations and the possible encouragement (or not) of the primary healthcare professional towards that option could also be a source of variation.

Furthermore, our findings are consistent with previous studies on between hospital variation in C-section rates. In an American context, existing literature illustrates the persistent between hospital unexplained variation, after controlling for several factors that could determine the decision-making for a C-section[9, 21]. Similarly, in a UK context, Bragg (2010) revealed a two-fold variation in C-section adjusted rates varied across 146 NHS Trusts in 2008, which could not be explained on the basis of sociodemographic and clinical risk-factors. In addition, Sinnott (2016) found a persistent variation of 3% for emergency C-sections and 11% for elective C-sections attributable to Irish hospitals that could not be explained by differences in maternal and birth factors. Our findings suggest that the significant between hospital variation over time in Scotland could be the result of differences in hospital resources, the level of obstetric and neonatal care specialization (MacDorman, 2008; Freeman et al., 2003; Kozhimannil, 2003), as well as the hospital's policy and clinical approach.

Moreover, variations in C-sections between maternity units could be the result of differences between healthcare professionals within the maternity units, apart from hospital characteristics and the hospital's policy on the general clinical approach. Our results show a significant unexplained variation in C-sections attributable to secondary healthcare professionals who are responsible for the care of the pregnant woman. The unexplained variation was significantly greater in elective C-sections, suggesting differences in the way they evaluate the need of a pregnant woman for a planned C-section. Our findings on between secondary healthcare variation could be due to the selective attraction of physicians (Groenewege, 2004; Chassin, 1993; Wright, 1999) in specific hospitals, resulting to a clinical pattern that seems to be persistent over time (Wennberg and Gittelson 1982). Another possible reason could be associated with factors like defensive medicine (Dubay et al, 1999), doctor's demand for leisure (Brown; Mossialos et al. 2005), changes in the clinical practice, as well as financial incentives.

Taking into account the above results, it is obvious that healthcare professionals nested within the hospital are a significant source of variation in the rates of C-section, especially in the case of elective C-sections. Thus, we consider that incorporating three-level structures in to our analysis is important in the case of secondary care. As different clusters arise in our data, it can lead the higher-level clusters to differ substantially from one another on the decision making for a C-section. Limiting our analysis to only two-levels models in the case of secondary care, where pregnant women are nested within healthcare professionals, nested within hospitals, could lead us to misidentify response variation to the two included levels (van Landeghem et al., 2005; Moerbeek, 2004; van den Noortgate et al., 2005; Tranmer and Steele, 2001). Consequently, this could result in drawing misleading conclusions about the relative importance of different sources of influence on the response, particularly the importance of secondary healthcare professionals in variation in C-section rates. Indeed, our results from three-level analysis in secondary care show that the contribution of secondary healthcare professionals is greater than hospitals in the unexplained variation in C-sections.

6.1.2. Cross-sectional Analysis

While our longitudinal analysis takes advantage of variations in C-sections over time, providing intuition of the influence of primary and secondary care professionals in the C-section rates over time, cross-sectional analysis is very useful in drawing conclusions and policy implications.

Our findings from a set of cross-sectional analyses, adjusted for patient characteristics and clinical risk factors, showed that the proportion of unexplained variation in elective C-sections which was attributable to primary care sector decreased from 5% in 2009 to 2.74%, suggesting that the uniformity of the clinical approach towards the mode of delivery is improving over the years. These results are consistent with the fact that over the last years midwifes attempt to promote natural birth (RCM, 2016). It is worth mentioning that there was a peek in the proportion of variation attributable to that sector between 2011-2012, suggesting that this could possibly be the result of the NICE guidelines implementation, when elective C-sections became available even with no medical indication.

Furthermore, our results showed that the proportion of variation attributable to hospitals was decreased from 7.3% in 2009 to 3.6% in 2016 for emergency C-section and from 13.3% to 9.7%, for elective C-sections respectively. The proportion of between hospital variation in our results was comparable with Sinnott's cross-sectional study in Ireland, suggesting that persistent variation between hospitals is greater in the case of elective C-sections. Factors such as adherence to evidence-based guidelines, the clinical approach or professional practices and the overall hospital policy on care may be contributing to variation.

An interesting point of our results is that after taking secondary healthcare professionals as a different group of analysis, we found that in contrast with all the other groups, unexplained variation attributable to secondary healthcare professionals is increasing over the years in both elective and emergency C-sections, with the proportion of variation being significantly higher for elective C-sections. More specifically, the proportion of variation between secondary healthcare professionals increased from 3.9% in 2009 to 6.2% for emergency C-sections and from 10% to 11.5% in elective C-sections respectively, with a peek in 2011-2012. These findings highlight the importance of this group as an influence of variation in C-section rates, indicating that may be suitable targets for policies with the goal to standardise the C-section rates.

6.2. Contribution

This study makes a valuable contribution to the literature on healthcare variation by quantifying the relative influence of different levels of the health system—hospitals, secondary healthcare professionals, and primary care providers—on unexplained variation in Caesarean section rates. Using a multilevel modelling framework, it advances existing work by disentangling institutional and individual-level effects after adjusting for a comprehensive set of maternal and clinical risk factors.

By identifying the extent to which elective and emergency C-section decisions vary across providers and institutions, the analysis deepens our understanding of supply-sensitive and preference-sensitive care, especially in maternity services. The study further adds to the evidence base by highlighting the increasing role of secondary care professionals in elective procedures over time, underscoring the importance of clinical practice norms and decision-making culture in shaping maternal health outcomes.

Importantly, the inclusion of the primary care sector in this analysis fills a gap in the literature by revealing how early antenatal guidance and communication may influence elective C-section decisions. This work contributes to policy and academic discussions on reducing unwarranted variation, improving standardization of care, and promoting equity in access to appropriate maternity services.

6.3. Strengths and limitations of the study

Our dataset concerns episode-level data for every mother to be that goes in for an obstetric event. The population of the data includes information on all obstetric inpatients and day cases, thus all birth deliveries, in Scottish maternity units.

In contrast with other studies on variations in the rates of C-section (Bragg, 2010; Sinnott, 2016), our dataset has a clear coding for each mode of delivery which is not based on ICD-10 or OPCS codes, avoiding the possibility of inaccuracies in the coding for the method of delivery. Moreover, we adjust for a wide range of clinical risk-factors that could determine the need for a C-section, as well as patient characteristics.

We draw conclusions and policy implications from a longitudinal analysis and a set of cross-sectional models. By employing a longitudinal analysis, we are able to ensure validity and effectively determine the likelihood patterns of clinical risk-factors for C-sections over time, using a large number of observations. Moreover, we are able to adjust for changes over time, such as the NICE policy change in November 2011. On the other hand, cross-sectional models are useful for indicating policy implications.

A limitation of our study concerns the lack of accurate information on the clinician who performed the Caesarean-section. For the use of secondary healthcare professionals as a group of analysis, the variable that was sourced was consultants/HCP responsible. In ISD Scotland's SMR datasets, this variable is described as the healthcare professional who carries clinical responsibility for the care of the mother on original admission to the unit. If the mother was originally admitted under the care of a midwife in an Alongside Midwifery Unit (AMU) or Freestanding Midwifery Unit (FMU), then the midwife should be recorded in this section, irrespective if the mother was then transferred during her care episode, if the mother was originally admitted to an Obstetric Unit then the Consultant initially responsible for her care should be recorded here, irrespective of whether care was primarily provided by midwifery staff. Although in the case of elective C-section this variable is accurate as it is expected the initial proposal for an elective (pre-planned) C-section to be made by this person, in the case of emergency C-sections this variable could be inaccurate as in some cases may refer to a healthcare professional who did not perform the procedure.

Another potential limitation of this study is the use of data up to 2016. At the time the research was conducted, data provision was coordinated through ISD Scotland (now part of Public Health Scotland), and access was secured via a grant application. The latest available data through this arrangement extended to 2016. To ensure methodological consistency, all analyses in this thesis are limited to this period. Although more recent data would undoubtedly enhance temporal relevance, the study remains highly relevant. Recent statistics continue to show persistent variation in C-section rates across Scotland and the UK. For example, C-section rates in Scotland ranged from 27% to 42% across different health boards in 2019/20, indicating persistent variation in maternity service use (Scottish Government, 2021). Similar patterns have been noted in England, where variation across NHS trusts remains a concern (NHS Digital, 2023).

Thus, while the timeframe may be viewed as a limitation, the enduring presence of such disparities supports the continued applicability of this research for informing policy, equity, and clinical practice in maternity care.

6.4. Conclusions and policy implications

Our longitudinal analysis, using data from 2009 to 2016 in Scotland, highlights the importance of secondary healthcare professionals' influence in the variation of C-section rates. There is a significant proportion of variation in both elective and emergency C-sections that cannot be explained by patient characteristics or a wide range of clinical risk-factors that could determine the need for the procedure. Although this between hospital variation can be the result of differences in hospital resources, the level of obstetric and neonatal care specialization (MacDorman, 2008; Freeman et al., 2003; Kozhimannil, 2003) or the hospital's policy and overall view on the way it evaluates the need for the procedure, our results draw attention on the importance of healthcare professionals within the hospital as a source of variation in C-section rates, especially in the case of elective C-sections. Individuals differ, and so their training, their personal beliefs and practice styles.

After employing a set of cross-sectional analyses, our research shows that although the proportion of variation in C-sections, which is attributable to hospital and cannot be explained by differences in patient characteristics or clinical risk-factors, decreases over time in both emergency and elective C-sections, the between hospital unexplained variation is still significant in the case of elective C-sections. Interestingly, taking secondary healthcare professionals as a group of analysis, our results show that the proportion of variation in C-sections is increasing over the years, especially in the case of elective C-sections. Our findings unravel the complexity of variation in C-sections by identifying its possible sources, indicating the need for targeted policies towards secondary care professionals to reduce variation in C-sections and improve the consistency of care for pregnant women.

A promising finding illustrated by our results is that unexplained variation in elective C-sections between primary healthcare professionals is decreasing over the years. This effective decrease could be the result of the promotion campaign by midwives for natural birth.

Finally, an interesting finding in our results concerns the role of the policy change, which was introduced in November 2011 by NICE and made the elective C-section available even when there was no medical indication for the procedure, in the likelihood of a woman having an elective C-section and possibly the variation in C-section rates. Adjusting for the year of delivery, as well as the actual time of the implementation of the policy, our analyses showed that after 2011 the odds of a woman having an elective C-section were higher after 2011. Moreover, the highest proportions of variations in elective C-sections were observed during 2011-2012

What is known about the topic

- Considerable variations in caesarean section rates across many countries, over the last decades (Rabilloud et al, 1998; Corallo et. al., 2000, Paranjothy, 2000; Liberro et al., 2000; Fantini, 2006; Baicker, 2006; Kozhimannil, 2013; Andres, 2015),
- Variations between NHS Trusts in C-section rates that cannot be explained by patient characteristics or clinical risk factors (Bragg, 2010)
- Variation in C-sections, attributable to maternity units in Ireland (Sinnott, 2016)
- Using aggregated data, different patterns of C-section usage were illustrated across Scottish NHS Health Boards
- Variation in C-section rates could be the result of patient characteristics and clinical risk factors, differences in the clinical practice, hospital factors.

What this research adds

- This research unravels the complexity of the sources that influence the variation in C-section rates
- It uses patient characteristics and a wide range of clinical risk factors that could determine the decision-making for a C-section
- Identifies the contribution of secondary healthcare professionals in the unexplained variation in C-sections
- Examines the influence of primary care sector in the variation of elective C-sections
- Illustrates the trajectory of variation in C-section that is attributable to each group of analysis (primary care sector, hospitals, secondary healthcare professionals)

Incentives for Further research

- The impact of NICE guidelines in C-section rates
    - the odds of a woman having an elective C-section were higher after the implementation of the policy
    - the highest proportions of variations in C-section rates were observed during 2011-2012

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8. APPENDIX A

Table I.16 Data Cleaning Process

Action	Remaining duplicates
1. Drop duplicates which are exactly the same based on all 91 variables	31 observations deleted
2. Drop multiple gestations and keep only singletons	This cleaning process ends up with 567 duplicates (281 patient IDs)
3. Drop deliveries that were not taken place within maternity unit	
4. Drop False deliveries (based on three ICD-10 codes)	
5. Drop if antenatal stay was <0 or >99	
6. Drop if simd is missing	
7. Drop if birthweight <500 and >6800	
8. Drop if previous C-sections are missing	
9. Drop if previous stillbirths are missing	
10. Drop if previous neonatal deaths are missing	
11. Dropping nullipara, multipara, marital status, ethnicity if unknown or missing	
12. Create a new variable that counts how many variables are completed in each observation. I then create another variable that counts the maximum variables completed for each patient ID-delivery date. Finally, I drop the observation in each set of duplicates with the lower variables completed and keep the one with the maximum variables completed.	342 duplicates left. Those duplicates concern sets of the same observation (patient ID and delivery date, thus same birth) with differences between them. (Examples of differences are: simd, locID, GP ID, Responsible consultant ID, Discharge type, Discharge transfer to) As a result, you can't distinguish which of the observations in a set is the right one.
13. In order to decrease the duplicates more, there is a choice that can be made between sets of the same observations with different main conditions. I choose to drop those observations that main condition is described as O800 (a general description for spontaneous delivery) while the other same observation has a more descriptive ICD-10 code.	302 duplicates left. (149 patient IDs)
14. As there is no other choice that can be made between same observations with different variables, I drop them	

The table above describes the cleaning process that was followed in order to identify and remove all the potentially duplicated observations

Table I.17 Dataset Exclusion Criteria Flowchart

Initial Dataset - all obstetric inpatients and day cases from Scottish maternity units (444,065)
↓
Step 1: Exclude duplicate observations
↓
Step 2: Exclude multiple gestations (only singletons were included)
↓
Step 3: Exclude deliveries not in maternity units
↓
Step 4: Exclude false deliveries
↓
Step 5: Exclude antenatal stays < 0 days or > 99 days
↓
Step 6: Exclude birthweights < 500gr or > 6800gr
↓
Step 7: Exclude observations with incomplete information (missing predictors)
↓
Final Dataset under analysis (382,793)

The flowchart above visually represents the exclusion process from the initial dataset of 444,065 observations to the final dataset of 382,793 observations:

Table I.18 Focused International C-section rate Comparison in 2016 (final year under study) and 2021 (year of final submission)

Country/Group	**C-Section Rate (%) - 2016**	**C-Section Rate (%) - 2021**	**Source**
Scotland	32	35	Public Health Scotland (2021)
United Kingdom	29	34	NHS Digital (2021)
OECD Average	26	28	OECD Health Data
Global Average	19	21	WHO (Angolile, 2023)
WHO Suggested Rate	10-15 (optimal)	10-15 (optimal)	WHO Guideline

9. APENDIX B

Table I.19 Odds ratios of Caesarean-sections across hospitals, adjusted for patient level characteristics and clinical risk factors

	MODEL 1								**MODEL 2**							
	EMERGENCY				ELECTIVE				EMERGENCY				ELECTIVE			
	OR	**P**	**95% CI**		**OR**	**P**	**95% CI**		**OR**	**P**	**95% CI**		**OR**	**P**	**95% CI**	
Breech	34.33	0.00	31.78	37.08	153.1	0.00	139.6	167.8	33.22	0.00	30.73	35.91	128.3	0.00	116.4	141.5
Restricted fetal growth	0.97	0.45	0.91	1.04	2.84	0.00	2.46	3.29	1.09	0.02	1.02	1.17	2.91	0.00	2.51	3.37
Excessive fetal growth	1.73	0.00	1.53	1.96	2.60	0.00	2.07	3.27	1.76	0.00	1.56	1.99	2.10	0.00	1.64	2.69
Fetal distress	1.50	0.00	1.47	1.54	0.10	0.00	0.09	0.11	1.49	0.00	1.45	1.53	0.13	0.00	0.12	0.14
Dystocia	1.44	0.00	1.37	1.51	0.27	0.00	0.23	0.31	1.44	0.00	1.37	1.52	0.29	0.00	0.25	0.33
Induction	1.62	0.00	1.58	1.65	0.02	0.00	0.02	0.02	1.43	0.00	1.39	1.46	0.02	0.00	0.02	0.02
Malpresentation	4.93	0.00	4.79	5.08	1.37	0.00	1.29	1.46	4.95	0.00	4.81	5.09	1.44	0.00	1.35	1.53
Placenta abruption	10.52	0.00	9.06	12.20	14.90	0.00	12.14	18.29	9.88	0.00	8.51	11.48	12.75	0.00	10.25	15.85
Preterm delivery	0.94	0.18	0.86	1.03	0.36	0.00	0.30	0.44	0.76	0.00	0.70	0.83	0.38	0.00	0.31	0.45
Eclampsia	2.16	0.00	1.99	2.35	3.82	0.00	3.04	4.80	2.11	0.00	1.94	2.29	3.60	0.00	2.85	4.56
Hypertension	1.57	0.00	1.50	1.65	1.28	0.00	1.15	1.42	1.53	0.00	1.46	1.61	1.12	0.04	1.01	1.26
Diabetes	2.14	0.00	2.02	2.26	5.46	0.00	5.02	5.95	1.82	0.00	1.72	1.93	3.09	0.00	2.82	3.38
Previous C-sections	8.45	0.00	8.15	8.76	47.06	0.00	45.40	48.78	8.24	0.00	7.95	8.55	41.96	0.00	40.34	43.66
Previous stillbirths	1.46	0.00	1.29	1.66	4.56	0.00	3.89	5.34	1.33	0.00	1.17	1.51	3.92	0.00	3.33	4.61
Parity (multiparous)	0.35	0.00	0.34	0.36	1.11	0.00	1.07	1.16	0.35	0.00	0.34	0.36	1.00	0.99	0.96	1.04
Age group (ref 30-34)																
<20	0.51	0.00	0.48	0.54	0.31	0.00	0.28	0.35	0.55	0.00	0.52	0.58	0.35	0.00	0.31	0.40
20-24	0.71	0.00	0.69	0.73	0.58	0.00	0.55	0.61	0.72	0.00	0.70	0.75	0.59	0.00	0.56	0.62
25-29	0.86	0.00	0.84	0.88	0.77	0.00	0.74	0.80	0.86	0.00	0.84	0.89	0.75	0.00	0.72	0.79
35-39	1.24	0.00	1.20	1.28	1.34	0.00	1.28	1.39	1.23	0.00	1.19	1.26	1.32	0.00	1.26	1.38
>=40	1.78	0.00	1.69	1.88	2.81	0.00	2.62	3.01	1.85	0.00	1.75	1.94	2.42	0.00	2.26	2.61
Ethnicity (ref White)																

	MODEL 1								MODEL 2							
	EMERGENCY				ELECTIVE				EMERGENCY				ELECTIVE			
	OR	P	95% CI		OR	P	95% CI		OR	P	95% CI		OR	P	95% CI	
Asian	1.16	0.00	1.09	1.23	0.60	0.00	0.55	0.65	1.26	0.00	1.19	1.33	0.60	0.00	0.55	0.66
Afro-Caribbean	1.79	0.00	1.63	1.97	0.99	0.92	0.86	1.15	1.78	0.00	1.62	1.96	0.95	0.55	0.82	1.11
Mixed-Arab	1.07	0.31	0.94	1.21	0.71	0.00	0.59	0.85	1.13	0.07	0.99	1.28	0.74	0.00	0.61	0.90
Not provided	0.94	0.00	0.91	0.97	0.81	0.00	0.77	0.84	0.95	0.00	0.93	0.98	0.82	0.00	0.78	0.86
Unknown	0.99	0.71	0.96	1.03	0.84	0.00	0.80	0.89	1.00	0.94	0.97	1.04	0.89	0.00	0.84	0.93
Marital status (ref mar.)																
Not married	1.10	0.00	1.07	1.14	0.91	0.00	0.87	0.95	1.10	0.00	1.06	1.14	0.93	0.00	0.88	0.97
Other	1.09	0.00	1.05	1.13	0.94	0.01	0.89	0.98	1.10	0.00	1.06	1.13	0.97	0.18	0.92	1.02
Uknown	1.10	0.00	1.06	1.14	0.85	0.00	0.80	0.89	1.12	0.00	1.07	1.16	0.89	0.00	0.84	0.94
Birthweight(3000-3499)																
500-1499	3.87	0.00	3.51	4.27	0.09	0.00	0.07	0.12	2.56	0.00	2.31	2.84	0.09	0.00	0.07	0.12
1500-2499	2.71	0.00	2.59	2.84	0.83	0.00	0.75	0.90	2.08	0.00	1.98	2.19	0.74	0.00	0.67	0.81
2500-2999	1.11	0.00	1.07	1.15	0.85	0.00	0.81	0.89	1.04	0.04	1.00	1.07	0.73	0.00	0.69	0.76
3500-3999	1.23	0.00	1.20	1.26	1.04	0.04	1.00	1.07	1.19	0.00	1.16	1.23	1.34	0.00	1.29	1.40
4000-4499	1.77	0.00	1.71	1.82	1.20	0.00	1.15	1.26	1.61	0.00	1.56	1.67	2.03	0.00	1.92	2.15
4500-6800	2.67	0.00	2.51	2.84	1.91	0.00	1.73	2.11	2.31	0.00	2.17	2.45	3.78	0.00	3.37	4.22
Delivery year ref. 2011																
2009	0.90	0.00	0.86	0.94	0.75	0.00	0.71	0.81	0.90	0.00	0.86	0.94	0.75	0.00	0.70	0.81
2010	0.93	0.00	0.89	0.97	0.90	0.00	0.84	0.95	0.93	0.00	0.89	0.97	0.89	0.00	0.84	0.95
2012	0.96	0.07	0.92	1.00	0.99	0.86	0.94	1.06	0.93	0.20	0.84	1.04	0.90	0.22	0.77	1.06
2013	1.07	0.00	1.03	1.11	1.14	0.00	1.08	1.21	1.05	0.36	0.95	1.17	1.05	0.53	0.90	1.24
2014	1.10	0.00	1.05	1.14	1.28	0.00	1.21	1.36	1.08	0.14	0.97	1.20	1.17	0.06	1.00	1.37
2015	1.11	0.00	1.07	1.16	1.37	0.00	1.29	1.45	1.09	0.10	0.98	1.21	1.20	0.03	1.02	1.41
2016	1.07	0.00	1.02	1.11	1.43	0.00	1.35	1.52	1.05	0.38	0.94	1.16	1.25	0.01	1.06	1.46

	EMERGENCY				ELECTIVE				EMERGENCY				ELECTIVE			
	OR	P	95% CI		OR	P	95% CI		OR	P	95% CI		OR	P	95% CI	
SIMD																
2	1.04	0.09	1.00	1.08	1.11	0.00	1.04	1.18	1.04	0.06	1.00	1.08	1.15	0.00	1.08	1.23
3	1.02	0.45	0.98	1.06	1.13	0.00	1.06	1.20	1.03	0.24	0.98	1.07	1.16	0.00	1.09	1.24
4	1.05	0.01	1.01	1.10	1.19	0.00	1.11	1.27	1.06	0.00	1.02	1.11	1.24	0.00	1.16	1.33
5	1.05	0.02	1.01	1.10	1.10	0.00	1.03	1.17	1.07	0.00	1.03	1.12	1.15	0.00	1.07	1.23
6	1.02	0.44	0.97	1.06	1.13	0.00	1.06	1.21	1.05	0.03	1.00	1.10	1.22	0.00	1.13	1.30
7	0.99	0.60	0.94	1.03	1.14	0.00	1.07	1.22	1.02	0.30	0.98	1.07	1.25	0.00	1.16	1.34
8	0.99	0.67	0.95	1.04	1.14	0.00	1.07	1.22	1.03	0.18	0.99	1.08	1.27	0.00	1.18	1.36
9	0.96	0.08	0.92	1.00	1.21	0.00	1.13	1.29	1.01	0.73	0.96	1.06	1.34	0.00	1.25	1.44
10	0.90	0.00	0.86	0.95	1.17	0.00	1.09	1.25	0.97	0.21	0.92	1.02	1.34	0.00	1.24	1.44
Maternal BMI																
0	-	-	-	-	-	-	-	-	1.68	0.00	1.63	1.72	1.97	0.00	1.89	2.05
1	-	-	-	-	-	-	-	-	0.74	0.00	0.69	0.80	0.81	0.00	0.73	0.90
3	-	-	-	-	-	-	-	-	1.29	0.00	1.26	1.32	1.34	0.00	1.29	1.39
4	-	-	-	-	-	-	-	-	1.15	0.02	1.03	1.29	1.61	0.00	1.34	1.93
Gestation																
1	-	-	-	-	-	-	-	-	1.81	0.00	1.74	1.89	6.35	0.00	5.91	6.82
2	-	-	-	-	-	-	-	-	1.26	0.00	1.21	1.31	9.17	0.00	8.65	9.72
3	-	-	-	-	-	-	-	-	0.99	0.35	0.95	1.02	11.50	0.00	10.95	12.08
5	-	-	-	-	-	-	-	-	1.38	0.00	1.34	1.42	1.06	0.09	0.99	1.14
6	-	-	-	-	-	-	-	-	2.35	0.00	2.22	2.48	5.52	0.00	4.64	6.55
7	-	-	-	-	-	-	-	-	2.09	0.00	1.32	3.32	2.28	0.16	0.73	7.13
Policy Change	-	-	-	-	-	-	-	-	1.03	0.55	0.93	1.15	1.09	0.29	0.93	1.28
Constant	0.09	0.00	0.06	0.14	0.07	0.00	0.05	0.10	0.07	0.00	0.05	0.10	0.01	0.00	0.01	0.01

Table I.20 Odds ratios of Caesarean-sections across secondary HC professionals, adjusted for patient level characteristics and clinical risk factors

	MODEL 3								MODEL 4							
	EMERGENCY				ELECTIVE				EMERGENCY				ELECTIVE			
	OR	**P**	**95% CI**		**OR**	**P**	**95% CI**		**OR**	**P**	**95% CI**		**OR**	**P**	**95% CI**	
Breech	33.50	0.00	31.01	36.19	150.6	0.00	137.3	165.2	32.49	0.00	30.06	35.13	125.3	0.00	113.6	138.2
Restricted fetal growth	0.97	0.37	0.90	1.04	2.81	0.00	2.42	3.25	1.08	0.03	1.01	1.16	2.87	0.00	2.48	3.33
Excessive fetal growth	1.71	0.00	1.52	1.94	2.47	0.00	1.96	3.11	1.74	0.00	1.54	1.97	1.98	0.00	1.55	2.54
Fetal distress	1.48	0.00	1.44	1.52	0.10	0.00	0.09	0.11	1.47	0.00	1.43	1.51	0.12	0.00	0.11	0.14
Dystocia	1.36	0.00	1.29	1.43	0.25	0.00	0.21	0.29	1.37	0.00	1.30	1.44	0.26	0.00	0.23	0.31
Induction	1.57	0.00	1.54	1.60	0.02	0.00	0.02	0.02	1.39	0.00	1.36	1.42	0.02	0.00	0.02	0.02
Malpresentation	4.91	0.00	4.77	5.06	1.36	0.00	1.28	1.45	4.93	0.00	4.79	5.08	1.43	0.00	1.33	1.52
Placenta abruption	10.19	0.00	8.78	11.83	14.27	0.00	11.62	17.54	9.61	0.00	8.28	11.17	12.19	0.00	9.80	15.16
Preterm delivery	0.94	0.18	0.86	1.03	0.36	0.00	0.30	0.44	0.76	0.00	0.70	0.84	0.38	0.00	0.31	0.46
Eclampsia	2.14	0.00	1.97	2.32	3.75	0.00	2.98	4.72	2.09	0.00	1.93	2.27	3.55	0.00	2.80	4.49
Hypertension	1.53	0.00	1.46	1.61	1.21	0.00	1.09	1.34	1.50	0.00	1.43	1.57	1.06	0.27	0.95	1.19
Diabetes	2.06	0.00	1.94	2.18	4.85	0.00	4.44	5.29	1.76	0.00	1.66	1.87	2.78	0.00	2.54	3.06
Previous C-sections	8.09	0.00	7.81	8.39	44.96	0.00	43.36	46.62	7.92	0.00	7.63	8.21	40.28	0.00	38.71	41.92
Previous stillbirths	1.45	0.00	1.28	1.64	4.40	0.00	3.76	5.15	1.32	0.00	1.17	1.49	3.80	0.00	3.23	4.47
Parity (multiparous)	0.36	0.00	0.35	0.36	1.13	0.00	1.08	1.17	0.35	0.00	0.35	0.36	1.01	0.65	0.97	1.05
Age group (ref 30-34)																
<20	0.51	0.00	0.48	0.54	0.32	0.00	0.28	0.36	0.55	0.00	0.52	0.58	0.36	0.00	0.32	0.40
20-24	0.71	0.00	0.69	0.73	0.58	0.00	0.55	0.61	0.72	0.00	0.70	0.75	0.59	0.00	0.56	0.62
25-29	0.86	0.00	0.84	0.88	0.77	0.00	0.74	0.80	0.86	0.00	0.84	0.89	0.75	0.00	0.72	0.79
35-39	1.24	0.00	1.20	1.28	1.33	0.00	1.28	1.38	1.23	0.00	1.19	1.27	1.31	0.00	1.25	1.37
>=40	1.77	0.00	1.68	1.86	2.74	0.00	2.56	2.94	1.83	0.00	1.74	1.93	2.37	0.00	2.20	2.55
Ethnicity (ref White)																

	MODEL 3								MODEL 4							
	EMERGENCY				ELECTIVE				EMERGENCY				ELECTIVE			
	OR	**P**	**95% CI**		**OR**	**P**	**95% CI**		**OR**	**P**	**95% CI**		**OR**	**P**	**95% CI**	
Asian	1.15	0.00	1.09	1.22	0.59	0.00	0.54	0.64	1.25	0.00	1.18	1.32	0.59	0.00	0.54	0.65
Afro-Caribbean	1.79	0.00	1.63	1.97	0.98	0.78	0.85	1.13	1.78	0.00	1.61	1.96	0.94	0.45	0.81	1.10
Mixed-Arab	1.08	0.26	0.95	1.22	0.70	0.00	0.58	0.85	1.13	0.06	0.99	1.29	0.73	0.00	0.60	0.89
Not provided	0.95	0.00	0.92	0.98	0.80	0.00	0.76	0.83	0.96	0.01	0.93	0.99	0.80	0.00	0.77	0.85
Unknown	1.00	0.78	0.96	1.03	0.85	0.00	0.81	0.89	1.00	0.81	0.97	1.04	0.89	0.00	0.84	0.94
Marital status (ref mar.)																
Not married	1.11	0.00	1.07	1.15	0.90	0.00	0.86	0.94	1.10	0.00	1.07	1.14	0.92	0.00	0.87	0.96
Other	1.09	0.00	1.05	1.13	0.93	0.00	0.89	0.98	1.09	0.00	1.05	1.13	0.95	0.07	0.91	1.00
Uknown	1.11	0.00	1.07	1.15	0.84	0.00	0.79	0.88	1.12	0.00	1.08	1.17	0.88	0.00	0.83	0.93
Birthweight(3000-3499)																
500-1499	3.76	0.00	3.41	4.15	0.09	0.00	0.07	0.11	2.52	0.00	2.27	2.79	0.09	0.00	0.07	0.12
1500-2499	2.65	0.00	2.53	2.78	0.80	0.00	0.73	0.88	2.06	0.00	1.95	2.17	0.73	0.00	0.66	0.80
2500-2999	1.10	0.00	1.07	1.14	0.85	0.00	0.81	0.89	1.03	0.07	1.00	1.07	0.72	0.00	0.69	0.76
3500-3999	1.23	0.00	1.20	1.26	1.04	0.04	1.00	1.07	1.20	0.00	1.16	1.23	1.34	0.00	1.29	1.40
4000-4499	1.77	0.00	1.71	1.83	1.20	0.00	1.14	1.26	1.61	0.00	1.56	1.67	2.02	0.00	1.91	2.14
4500-6800	2.67	0.00	2.52	2.84	1.91	0.00	1.73	2.11	2.31	0.00	2.17	2.46	3.75	0.00	3.35	4.19
Delivery year ref. 2011																
2009	0.92	0.00	0.88	0.96	0.78	0.00	0.73	0.84	0.92	0.00	0.88	0.97	0.79	0.00	0.73	0.85
2010	0.94	0.00	0.90	0.98	0.90	0.00	0.84	0.95	0.94	0.00	0.90	0.98	0.90	0.00	0.84	0.96
2012	0.98	0.44	0.94	1.03	1.01	0.83	0.95	1.07	0.95	0.36	0.86	1.06	0.90	0.21	0.77	1.06
2013	1.09	0.00	1.05	1.13	1.15	0.00	1.09	1.23	1.07	0.22	0.96	1.18	1.05	0.56	0.89	1.23
2014	1.12	0.00	1.08	1.17	1.29	0.00	1.21	1.37	1.10	0.07	0.99	1.22	1.15	0.08	0.98	1.36
2015	1.14	0.00	1.10	1.19	1.35	0.00	1.27	1.44	1.12	0.03	1.01	1.24	1.17	0.06	0.99	1.38
2016	1.10	0.00	1.05	1.15	1.40	0.00	1.32	1.49	1.08	0.17	0.97	1.20	1.20	0.03	1.02	1.42

	EMERGENCY				ELECTIVE				EMERGENCY				ELECTIVE			
	OR	**P**	**95% CI**		**OR**	**P**	**95% CI**		**OR**	**P**	**95% CI**		**OR**	**P**	**95% CI**	
SIMD																
2	1.03	0.11	0.99	1.08	1.11	0.00	1.05	1.18	1.04	0.06	1.00	1.08	1.16	0.00	1.08	1.24
3	1.01	0.62	0.97	1.05	1.13	0.00	1.06	1.21	1.02	0.31	0.98	1.07	1.17	0.00	1.10	1.26
4	1.05	0.03	1.00	1.09	1.20	0.00	1.12	1.28	1.06	0.01	1.02	1.11	1.26	0.00	1.17	1.35
5	1.05	0.02	1.01	1.10	1.11	0.00	1.04	1.18	1.07	0.00	1.03	1.12	1.16	0.00	1.08	1.24
6	1.01	0.57	0.97	1.06	1.14	0.00	1.07	1.22	1.05	0.05	1.00	1.09	1.22	0.00	1.14	1.32
7	0.99	0.55	0.94	1.03	1.15	0.00	1.08	1.23	1.02	0.32	0.98	1.07	1.25	0.00	1.17	1.35
8	0.99	0.55	0.94	1.03	1.15	0.00	1.07	1.23	1.03	0.25	0.98	1.08	1.27	0.00	1.18	1.37
9	0.95	0.04	0.91	1.00	1.21	0.00	1.13	1.29	1.00	0.96	0.96	1.05	1.34	0.00	1.24	1.44
10	0.90	0.00	0.86	0.95	1.18	0.00	1.10	1.26	0.96	0.12	0.91	1.01	1.33	0.00	1.23	1.43
Maternal BMI																
0	-	-	-	-	-	-	-	-	1.66	0.00	1.62	1.71	1.95	0.00	1.87	2.03
1	-	-	-	-	-	-	-	-	0.74	0.00	0.69	0.80	0.81	0.00	0.73	0.90
3	-	-	-	-	-	-	-	-	1.29	0.00	1.26	1.32	1.34	0.00	1.29	1.39
4	-	-	-	-	-	-	-	-	1.16	0.00	1.05	1.29	1.54	0.00	1.32	1.81
Gestation																
1	-	-	-	-	-	-	-	-	1.78	0.00	1.71	1.86	6.23	0.00	5.80	6.70
2	-	-	-	-	-	-	-	-	1.25	0.00	1.21	1.30	9.18	0.00	8.66	9.73
3	-	-	-	-	-	-	-	-	0.99	0.35	0.95	1.02	11.57	0.00	11.01	12.15
5	-	-	-	-	-	-	-	-	1.37	0.00	1.33	1.41	1.06	0.14	0.98	1.13
6	-	-	-	-	-	-	-	-	2.31	0.00	2.18	2.44	5.40	0.00	4.55	6.42
7	-	-	-	-	-	-	-	-	2.13	0.00	1.34	3.38	2.16	0.19	0.69	6.78
Policy Change	-	-	-	-	-	-	-	-	1.03	0.54	0.93	1.15	1.12	0.17	0.95	1.32
Constant	0.13	0.00	0.12	0.14	0.07	0.00	0.06	0.08	0.09	0.00	0.08	0.10	0.01	0.00	0.01	0.01

Table I.21 Odds ratios of Caesarean-sections across primary HC professionals, adjusted for patient level characteristics and clinical risk factors

	MODEL 5				MODEL 6			
	ELECTIVE				ELECTIVE			
	OR	**P**	**95% CI**		**OR**	**P**	**95% CI**	
Breech	160.31	0.00	146.25	175.73	132.71	0.00	120.37	146.31
Restricted fetal growth	2.84	0.00	2.45	3.28	2.92	0.00	2.52	3.38
Excessive fetal growth	2.69	0.00	2.14	3.38	2.14	0.00	1.67	2.74
Fetal distress	0.10	0.00	0.09	0.11	0.13	0.00	0.12	0.14
Dystocia	0.24	0.00	0.21	0.28	0.26	0.00	0.22	0.30
Induction	0.02	0.00	0.02	0.02	0.02	0.00	0.02	0.02
Malpresentation	1.38	0.00	1.30	1.46	1.43	0.00	1.34	1.53
Placenta abruption	14.57	0.00	11.87	17.89	12.17	0.00	9.78	15.14
Preterm delivery	0.38	0.00	0.32	0.46	0.39	0.00	0.32	0.47
Eclampsia	3.50	0.00	2.78	4.41	3.26	0.00	2.57	4.13
Hypertension	1.30	0.00	1.17	1.45	1.14	0.02	1.02	1.27
Diabetes	5.56	0.00	5.10	6.06	3.10	0.00	2.83	3.39
Previous C-sections	49.04	0.00	47.30	50.85	43.28	0.00	41.60	45.03
Previous stillbirths	4.63	0.00	3.95	5.42	3.94	0.00	3.35	4.64
Parity (multiparous)	1.09	0.00	1.05	1.14	0.98	0.46	0.94	1.03
Age group								
1	0.30	0.00	0.27	0.34	0.34	0.00	0.30	0.39
2	0.57	0.00	0.54	0.60	0.58	0.00	0.55	0.61
3	0.76	0.00	0.73	0.79	0.75	0.00	0.72	0.78
5	1.33	0.00	1.28	1.39	1.31	0.00	1.26	1.37
6	2.82	0.00	2.64	3.02	2.44	0.00	2.27	2.62

	MODEL 5				MODEL 6			
	OR	P	95% CI		OR	P	95% CI	
Ethnicity								
2	0.65	0.00	0.60	0.71	0.65	0.00	0.59	0.71
3	1.04	0.59	0.90	1.21	1.00	0.95	0.86	1.17
4	0.74	0.00	0.62	0.90	0.77	0.01	0.64	0.94
5	0.80	0.00	0.76	0.83	0.81	0.00	0.77	0.85
6	0.93	0.01	0.89	0.98	0.99	0.78	0.94	1.04
Marital status								
2	0.91	0.00	0.87	0.95	0.92	0.00	0.88	0.97
3	0.84	0.00	0.80	0.88	0.86	0.00	0.82	0.90
4	0.76	0.00	0.72	0.80	0.79	0.00	0.75	0.83
Birthweight								
1	0.09	0.00	0.07	0.12	0.09	0.00	0.07	0.12
2	0.84	0.00	0.77	0.92	0.74	0.00	0.67	0.81
3	0.86	0.00	0.82	0.90	0.73	0.00	0.69	0.77
5	1.04	0.03	1.00	1.08	1.35	0.00	1.30	1.40
6	1.20	0.00	1.14	1.26	2.03	0.00	1.92	2.15
7	1.90	0.00	1.72	2.10	3.81	0.00	3.40	4.26
Delivery year								
2009	0.76	0.00	0.71	0.81	0.75	0.00	0.70	0.81
2010	0.87	0.00	0.82	0.93	0.87	0.00	0.82	0.93
2012	1.01	0.81	0.95	1.07	0.91	0.26	0.78	1.07
2013	1.19	0.00	1.12	1.26	1.08	0.32	0.92	1.27
2014	1.36	0.00	1.28	1.44	1.23	0.01	1.05	1.45
2015	1.44	0.00	1.36	1.53	1.25	0.01	1.07	1.47
2016	1.51	0.00	1.42	1.60	1.30	0.00	1.11	1.53

	MODEL 5				MODEL 6			
SIMD	**OR**	**P**	**95% CI**	**OR**	**P**	**95% CI**	**OR**	**P**
2	1.06	0.08	0.99	1.13	1.10	0.01	1.03	1.17
3	1.05	0.14	0.98	1.12	1.08	0.02	1.01	1.16
4	1.09	0.01	1.02	1.17	1.15	0.00	1.07	1.24
5	1.01	0.85	0.94	1.08	1.05	0.17	0.98	1.13
6	1.03	0.38	0.96	1.10	1.11	0.01	1.03	1.19
7	1.03	0.44	0.96	1.10	1.12	0.00	1.04	1.20
8	1.07	0.05	1.00	1.15	1.19	0.00	1.11	1.28
9	1.12	0.00	1.04	1.20	1.23	0.00	1.14	1.32
10	1.05	0.17	0.98	1.14	1.18	0.00	1.09	1.28
Maternal BMI								
0	-	-	-	-	2.01	0.00	1.93	2.09
1	-	-	-	-	0.82	0.00	0.74	0.92
3	-	-	-	-	1.36	0.00	1.31	1.41
4	-	-	-	-	1.50	0.00	1.31	1.73
Gestation								
1	-	-	-	-	6.60	0.00	6.14	7.09
2	-	-	-	-	9.40	0.00	8.87	9.96
3	-	-	-	-	11.77	0.00	11.21	12.37
5	-	-	-	-	1.05	0.16	0.98	1.13
6	-	-	-	-	5.69	0.00	4.79	6.76
7	-	-	-	-	2.78	0.07	0.93	8.31
Policy Change					1.11	0.22	0.94	1.30
Constant	0.08	0.00	0.08	0.09	0.01	0.00	0.01	0.01

II. Chapter 2: **THE IMPACT OF NICE GUIDELINES (NOVEMBER 2011) ON CAESAREAN-SECTION RATES**

1. BACKGROUND

A Caesarean section (C-section) is a surgical procedure that is performed for the delivery of one or more infants through a surgical incision of the abdomen and womb (ACOG, 2014). The use of C-sections usually takes place when a vaginal delivery could be associated with fetal or maternal risks, such as obstructed labour, multiple gestations, hypertension, mal-presentation or problems related to placenta and umbilical cord (ACOG, 2014; Molina, 2015). Based on the time of decision-making for the performance of the procedure, C-sections can be categorized to two types: a) elective or planned C-section which is planned in advance of the delivery due to medical reasons or preferences upon request of the mother to be; b) emergency C-section which takes place at short notice, during labour, when clinical risk factors make vaginal delivery not appropriate.

The National Institute for Health and Care Excellence or NICE is an executive non-departmental public body which is part of the Department of Health in the UK (Health Committee, 2013). NICE publishes clinical guidelines based on clinical assessments. However, NICE's policy and guidelines are often a subject of controversy, as decisions are made at a national level and some of them could be considered in conflict with the best interest of some groups of patients (Financial Times, 2015; Baldwin, 2016). Until 2011, the NICE's guidelines regarding maternity and the mode of delivery which were issued in 2004 recommended that a C-section could be offered to a woman when the benefits of undergoing the procedure were clear in contrast to vaginal delivery and based on medical evidence. In November 2011, new policies were published, suggested that C-section will be available even to women who are capable of giving birth naturally, making every mother-to-be eligible for having the procedure performed even if there is no medical need (NICE, 2011).

Findings from chapter 1 of our study highlight the role of the policy change, which was introduced in November 2011 by NICE and made the elective C-section available even when there was no medical indication for the procedure, in the likelihood of a woman having an elective C-section. Adjusting for the year of delivery, as well as the actual time of the implementation of the policy, our analyses showed that after 2011 the odds of a woman having an elective C-section were higher after 2011.

1.1. AIM OF THE RESEARCH

The aim of this research is to examine the effect of NICE guidelines that were implemented in November 2011 on C-section rates in Scotland and explore how the availability of treatment options could increase the maternity care utilization.

2. INTRODUCTION

Since the 1970s, there has been a significant increase in the rate of C-sections across many developed countries (Althabe, 2006), including the UK (Information Centre, 2009; Betrán, 2016; OECD, 2017; NHS, 2017), with an absolute increase of 12.4% worldwide from 1990 to 2014 (Betran et al., 2016). More specifically, in Scotland, the rates of C-section increased from 20.7% in 2000 to 32.4% in 2015 (ISD Scotland, 2016). Several reasons have been suggested for this growth, including changes in maternal characteristics (such as rising maternal age) and a rising number of women who have previously had a C-section, technological advances that have reduced the medical risks of the operation, organizational and cultural changes, as well as changes in clinical practice (Churchill, 2006; Betran et al., 2016).

Although attempts have been made globally to reduce increasing C-section rates (Chaillet, 2007; Kozhimannil, 2013), in November 2011, NICE introduced revised guidelines suggesting that C-sections should be available to all women, including those capable of giving birth naturally, provided the decision is pre-arranged (NICE, 2011). These guidelines replaced the pre-existing recommendations issued in 2004. The introduction of these policies could potentially affect C-section rates from the end of 2011 onwards. The rationale is that physicians and healthcare professionals are intrinsically motivated to provide the best possible care, while patients generally desire the highest quality of treatment (Woolf, 1999), which is often equated with more advanced or costly interventions (Ubel, 2009). Consequently, making C-sections available in the absence of medical indications may lead to increased maternity care utilisation and healthcare spending without commensurate improvements in health outcomes.

However, it is important to note that while the potential for overuse and rising healthcare costs is a valid concern, there may also be positive implications of such a policy change. Respecting a woman's autonomy and offering the opportunity to choose her preferred mode of delivery can enhance the overall childbirth experience. Several studies support the view that accommodating maternal preferences may lead to greater satisfaction and more positive birth experiences (Badrinath et al., 2004; Byrom et al., 2015). Elective C-sections on maternal request are typically planned and may help women avoid the uncertainty and stress associated with emergency deliveries or traumatic vaginal births, thereby promoting psychological well-being. This dual perspective—balancing the risks and benefits—is essential in evaluating the implications of the NICE policy.

The behavioural model of healthcare utilisation developed by Andersen (1995) provides a useful theoretical foundation for analysing such changes. Widely accepted in healthcare research (Westert, 1999), the Andersen model suggests that the use of healthcare services is influenced by three types of factors: predisposing characteristics (e.g., demographic and socioeconomic attributes), enabling resources (e.g., financial means and availability of services), and perceived or evaluated need. According to Motlagh et al. (2015), people with certain predisposing characteristics, such as specific demographic or SES profiles, may be more likely to utilise healthcare services than others. In the context of the NICE policy, the removal of clinical necessity as a prerequisite for C-section access may have shifted enabling factors, effectively lowering the threshold for utilisation among women whose preferences previously went unmet. This may lead to an increase in healthcare utilisation that is not necessarily tied to clinical indicators but to preference-driven demand.

In the case of C-sections, there is evidence that fee exemption for pregnant women is associated with increased rates of in-hospital deliveries and earlier antenatal visits (Ridde et al., 2010). Additionally, the implementation of a policy providing free C-sections in Senegal led to a 130% increase in C-section rates within one year (Witter et al., 2008; Witter et al., 2010). While such policies ensure better access to essential maternal health services, their impact also highlights the influence of financial and organisational accessibility on utilisation. These dynamics are particularly relevant when elective procedures are made available without medical indication.

Moreover, research shows that elective C-sections can result from a wide range of factors, including maternal convenience (Keeler, 1993), concerns about pelvic floor trauma linked to vaginal delivery (Wagner, 2000; Minkoff et al., 2003), anxiety over labour pain, or negative past birth experiences (Bettes, 2007). Women with fertility challenges may also perceive caesarean delivery as a safer option for their infants (Ma et al., 2010). However, the preferences of healthcare professionals and institutional logistics can also indirectly shape maternal choices. For example, physicians may favour C-sections due to better predictability and work-hour management, and hospitals may prefer the procedure to optimise resource use and delivery room scheduling (Huesch, 2011).

The overarching goal of this chapter is to empirically assess the impact of the 2011 NICE policy on elective C-section rates in Scotland. The chapter employs a synthetic control approach to construct a counterfactual scenario and quantify the policy's effect on elective C-section trends. These findings are particularly relevant within the broader context of health policy, where utilisation and expenditure are not always aligned with improved outcomes (Fischer, 2013). Thus, the study aims to contribute to a more nuanced understanding of how expanding access to elective C-sections may influence both healthcare resource use and maternal satisfaction.

In conclusion, while expanding access to elective C-sections may raise concerns about overutilisation, it also represents an opportunity to empower patients and improve their childbirth experiences. Understanding how such policies interact with healthcare utilisation patterns, is crucial for designing effective, equitable, and patient-centred maternal health strategies.

3. CONSEQUENCES OF INCREASED RATES OF CAESAREAN SECTION

It is undeniable that when it is clinically justified, C-section is a very important procedure that can be proved lifesaving for the mother or/and the baby in cases where a vaginal delivery is associated with distinct risks, such as labor stalls, exhaustion or fetal distress, prolapsed umbilical cord, uterine rapture or other complications that there is a serious medical need. It is worth mentioning that there is no evidence-based proof which shows that elective C-section is beneficial for women or infants with no medical need for the procedure (WHO, 2015). Since the increase of the C-section rates is persistent and uncontrollable for the last 40 years (Shorten, 2007), the concern about the rates of the procedure is sensible. The reasons for this increase are not fully explained and could involve health systems and providers, clinical preferences, mothers and the social context. However, overusing the procedure could potentially decrease the mother or infant mortality (Porreco, 1996). Moreover, C-section has been associated with short- and long-term implications for the mother and the infant (Petrou, 2013). The World Health Organization suggested that the ideal rate of C-sections performed in a country should be 10-15% and above this level the maternal, neonatal and infant mortality could decline (WHO, 2015). In addition, a C-section is costlier than a vaginal delivery and is calculated that it costs about £800 more than a natural delivery (planned/elective C-section versus planned vaginal delivery) (NICE, 2011). Furthermore, it is estimated that decreasing the rate of C-sections in the UK by one percent each year could save the NHS about £5 million (Easter, 2015), avoiding substantial cost implications for the health care system, especially in the case of adverse outcomes and complications.

3.1. MATERNAL CONSEQUENCES

Although the operation seems to have relatively low risks, it is possible to lead to several complications for both the mother and the baby. Maternal complications could include infections, hemorrhage and thrombosis, while the infant complications could include fetal respiratory distress syndrome, pulmonary hypertension, iatrogenic prematurity, and difficulty with bonding and breast feeding (Shorten, 2007). Increased risks for mother and baby were associated with C-section after studying the adverse maternal and infant outcomes in 24 countries from 2004 to 2008 (Souza, 2010). Thus, C-section should not be considered an equal alternative of spontaneous vaginal delivery and the decision-making for its performance should be taken with caution and when the benefits of the operation are clear (Mylonas, 2015). Moreover, it has been documented that maternal morbidity has increased rates in elective C-section compared to vaginal delivery (Hannah, 2000), while the complications during the procedure are 50% less than those linked to emergency C-sections (Bergholt, 2003). Also, infants that were delivered through C-section seem to have an increased risk of respiratory complications, including respiratory distress syndrome and fetal transitory tachypnea (Tita, 2009; De Luca, 2009). Although complications usually seem to be mild and limited, there is need for short-term observation of the newborn and admission to special care baby unit, resulting to longer hospital stay.

Apart of the complications that could occur during or right after the delivery, long-term effects have been documented and associated with C-section. These long-term effects include bronchial asthma (Bager, 2008; Thavagnanam, 2008), allergic rhinitis (Bager, 2008; Koplin, 2008), several food allergies (Gladstone, 2010), diabetes mellitus (Cardwell, 2008), as well as autism (Emberti Gialloreti, 2014). However, there is a lot of complexity in the pathophysiology of these conditions and further investigation in terms of the causality might be needed. Another issue linked to the C-section is breast feeding, with women going under the procedure facing difficulties (Vestermark, 1991; Hauck, 2011). Although there is a lot of controversy regarding the effect of the procedure on breast-feeding with some studies reporting no association (Kohlhuber, 2008; Patel, 2003) and others a significant negative effect (Ever Hadani, 1994; Hauck, 2011), the fact that there is a delay in mother-baby interaction and their spatial separation when the baby needs admission to special care could possibly have a negative effect on breast feeding (Mylonas, 2014).

3.2. COST CONSEQUENCES

The increasing rates of C-section could result to greater healthcare spending. An important reason for the growth of the procedure rates is the rising rates of women who had previously a C-section, as one of the most common indications for having an elective C-section is a previous caesarean delivery. The cost consequences of C-section compared to vaginal delivery (instrumental or spontaneous, as well as planned trial[12]) have been investigated in several studies, including unselected population, population with low-risk pregnancies and population with clinical indication for the procedure (previous C-section, previous breech position).

[12] In the case of a previous Caesarean section, planned trial vaginal delivery can be performed as an alternative of a caesarean delivery

Studies that examined unselected population of mothers, regarding the clinical indications for C-section (DiMaio et al, 2002; Petrou, 2002; Bost, 2003; Kazandjian, 2007; Khan, 2010; Sarowar et al, 2010), as well as population of women with low-risk pregnancies (Allen et al. 2005; Allen et al, 2006; Declerq et al., 2007; Heer et al., 2009) suggested that the estimated mean costs of elective C-sections, as well as total C-sections (both elective and emergency), were higher than those vaginal deliveries. The driving forces of the cost differences between vaginal and elective C-section have been associated with the number of staff that is needed (clinicians and nurses), the hospital resources and the operating room overall costs (Henderson et al., 2001). Moreover, higher pre-natal stay in elective C-section is being observed, compared to vaginal delivery with up to 4-fold variations (Allen et. al., 2005; Khan et al, 2010). In addition, the length of hospital stay that is required after an elective Caesarean delivery is higher, compared to vaginal deliveries. A study in Massachusetts reported that the length of stay after an elective C-section is 1.8% higher compared to planned vaginal deliveries, while a study in the Grampian region of Scotland found that the post-natal length of stay which is associated with total C-sections is 1.61% higher compared to vaginal deliveries (Petrou, 2002). In addition, Petrou (2002) found that the costs associated with follow-up admissions two months after an elective C-section were almost double those associated with vaginal deliveries. Similarly, Liu (2008) showed that hospital outpatient cost was significantly higher 6 months after having a C-section than those associated with vaginal births.

The main finding in studies that examined the costs of elective caesarean deliveries compared with other modes of deliveries was that the mean estimated costs that are associated with the mother and the baby were significantly higher for elective C-section, both in cases where the procedure was performed because of a previous caesarean delivery (DiMaio et. al., 2002; Kamath et. al, 2009; Comas, 2011) or a breech position of the infant (James et al., 2001; Palencia et. al.,2006). Although planned trial vaginal delivery is clearly reported as the most cost-effective method (Grobman et al, 2000; Chung et al, 2001; Fawsitt et al, 2013), it is a subject of controversy in terms of the benefits and risks associated with the procedure, with several studies reporting an increased likelihood of complications for both the mother and the baby (Crowther et. al.,2012;

Azam, 2014). Therefore, studies have found that in the case of a failed planned trial vaginal delivery which is associated with complications the total cost of the birth delivery is higher than performing an elective C-section, mainly due to the need for special neonatal care and hospital resources (DiMaio et al, 2002; Kamath et al,2009).

While concerns about the potential overuse of C-sections and the associated rise in healthcare costs remain valid—particularly in the context of limited medical necessity—policy changes that enhance access to elective procedures may also produce positive outcomes. Central to this is the respect for maternal autonomy; enabling women to choose their preferred mode of delivery can significantly improve the childbirth experience. A growing body of evidence indicates that accommodating maternal preferences is linked to greater satisfaction and more positive perceptions of birth (Badrinath et al., 2004; Byrom et al., 2015). For example, Wiklund et al. (2007) found that women who opted for elective C-sections reported better overall birth experiences than those planning vaginal births. Similarly, Blomquist et al. (2011) demonstrated higher satisfaction among women undergoing planned caesareans compared to those facing unplanned or emergency interventions. Elective caesareans can also offer advantages such as predictable scheduling and reduced anxiety—particularly beneficial for women with prior traumatic deliveries (Karlström et al., 2013). Nonetheless, these potential benefits must be carefully weighed against the increased clinical risks and economic burden associated with surgical deliveries, making it essential to strike a balance when evaluating the broader impact of the NICE guidelines.

All in all, providing the best quality of care for pregnant woman is top priority. Despite the fact that planned trial vaginal deliveries are clearly more cost-effective than elective C-section, the method could be associated with maternal and infant complications. Thus, recommending this mode of delivery over an elective C-section, due to cost-effectiveness reasons, is not what we suggest, as long as evidence about the benefits and the risks is not clear. However, the performance of elective C-section in cases with no clinical indications is questionable due to the complications and the cost that are associated with the procedure.

3.2.1. COST COMPARISON BETWEEN PLANNED C-SECTION AND PLANNED VAGINAL DELIVERY IN THE UK

The average unit costs of a planned C-section versus a planned vaginal section in the UK, as well as the average adverse event cost of these are described in Table II.1.

These costs are based on the weighed average NHS 2020/2021[13] reference costs. The NHS funding is based on 'payment by results', based on a national tariff. The national tariff is applied to all activities for which healthcare resource groups (HRGs) or other appropriate case-mix measures are available.

C-section upon maternal request has no additional tariff and the unit cost is considered to be the same as planned C-section.

Table II.1 Cost comparison of planned C-section vs planned Vaginal Delivery 2019/20

Delivery Mode	**Average Unit Cost (£)**
Planned C-section	2903
Planned Vaginal Delivery	1785
Average Cost Difference	1118

4. THE CASE OF SCOTLAND

In Scotland, the rate of C-sections has increased from 8.7% in 1976 to 32.4% in 2016 (ISD Scotland, 2016). The graph below (Figure II.1) illustrates the increasing trend of C-section usage. Spontaneous vaginal deliveries decrease over the years. Interestingly, elective C-sections show a more extreme increasing trend compared to emergency C-section, especially during the period of 2011-2016, indicating that the new policies of NICE could play a role to these increasing rates of elective C-section.

[13] NHS England & NHS Improvement. (2020). *National Tariff Payment System 2020/21: Annex Dt – Maternity Prices*. Retrieved from https://www.england.nhs.uk/publication/national-tariff-payment-system-documents-and-policies-for-2020-21/

Figure II.1 Rates per mode of delivery over time

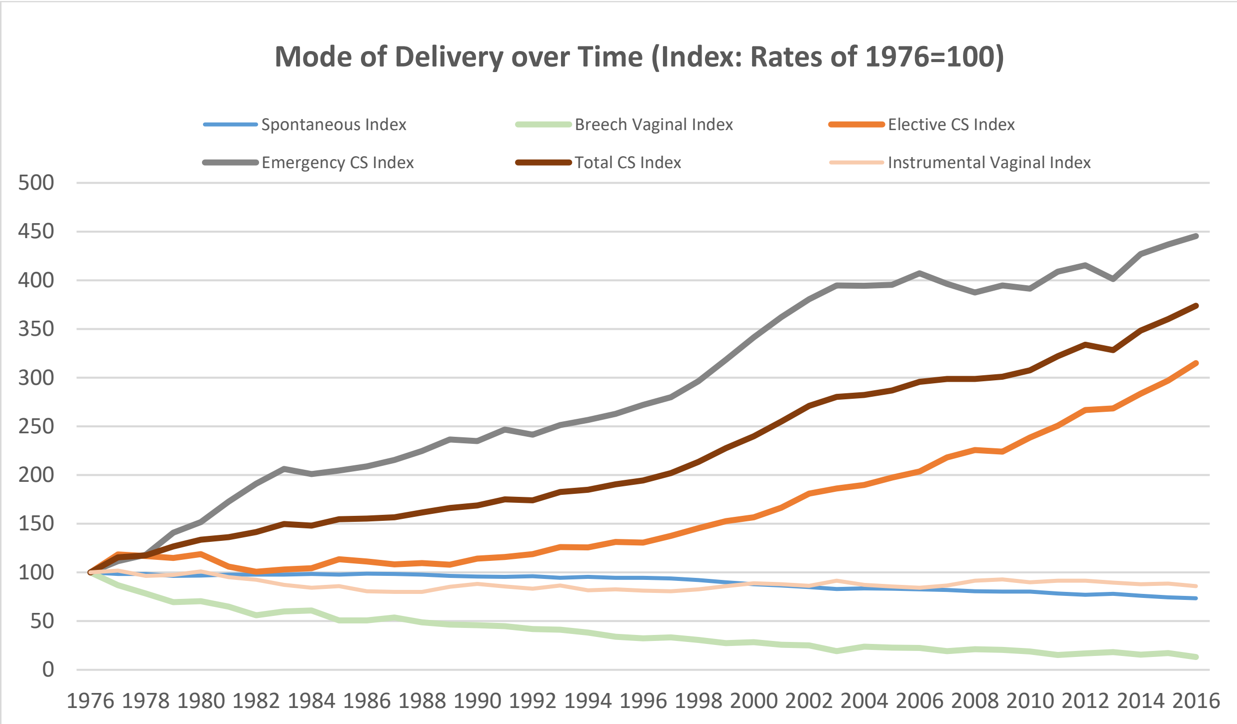


Figure II.2 illustrates the differences in the rates of spontaneous vaginal delivery, instrumental (vacuum and forceps) delivery, as well as the rates of elective, emergency and total C-sections between 1976 and 2016. It is clear that emergency and elective C-section rates have increased dramatically, while the spontaneous, breech and instrumental vaginal deliveries have decreased.

Figure II.3 shows the rates of spontaneous vaginal delivery, instrumental (vacuum and forceps) delivery, as well as the rates of elective, emergency and total C-sections, in 2006, 2011 and 2016. From 2006 to 2011 the rates of elective C-section increased by 2.2%, while from 2011 to 2016 the rates increased by 3.1%, which might reflect the effect of the new guidelines. Moreover, total C-sections increased by 2.3% from 2006 to 2011 and 4.5% from 2011 to 2016. This greater increase after the implementation of the new guidelines, along with the decrease in instrumental vaginal deliveries could suggest that the new policies could have triggered a tendency of clinicians to perform the operation more easily in favor of the convenience that the operation offers or a tendency of women to choose elective C-section as an option that previously was not available.

Figure II.2 Mode of Delivery in 1976 vs 2016

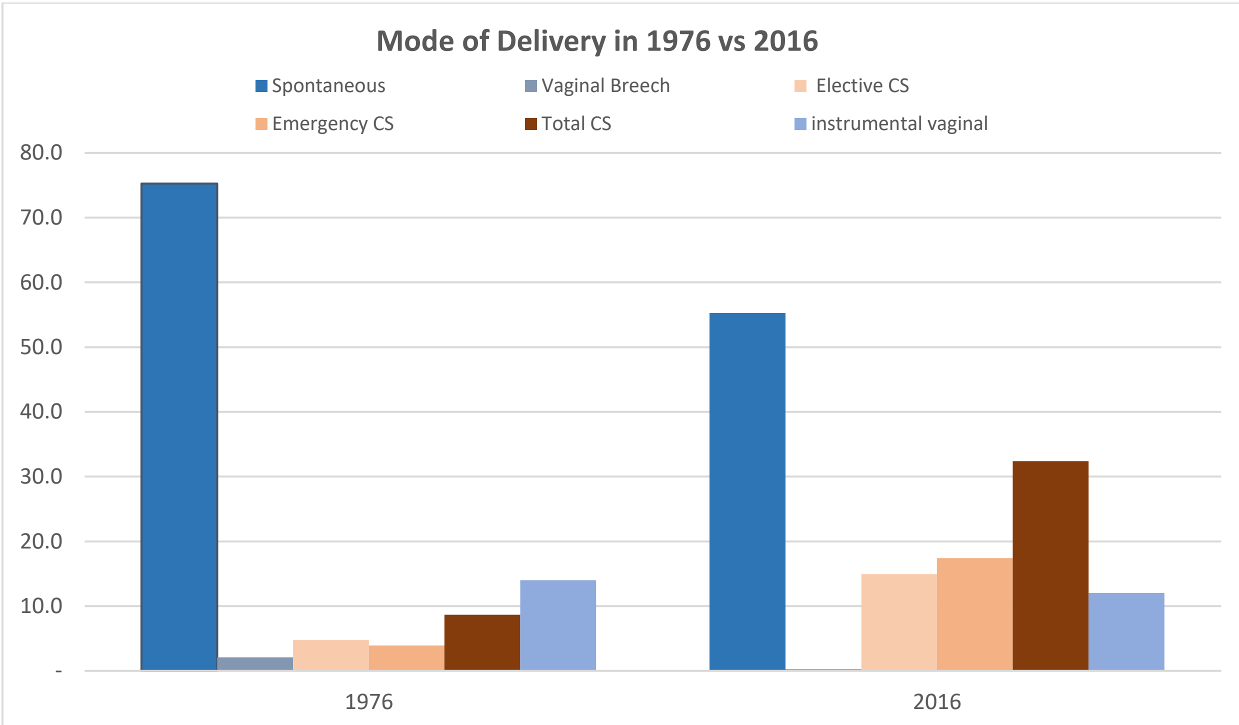


Figure II.3 Mode of delivery in 2006, 2011 (year of policy change) and 2016

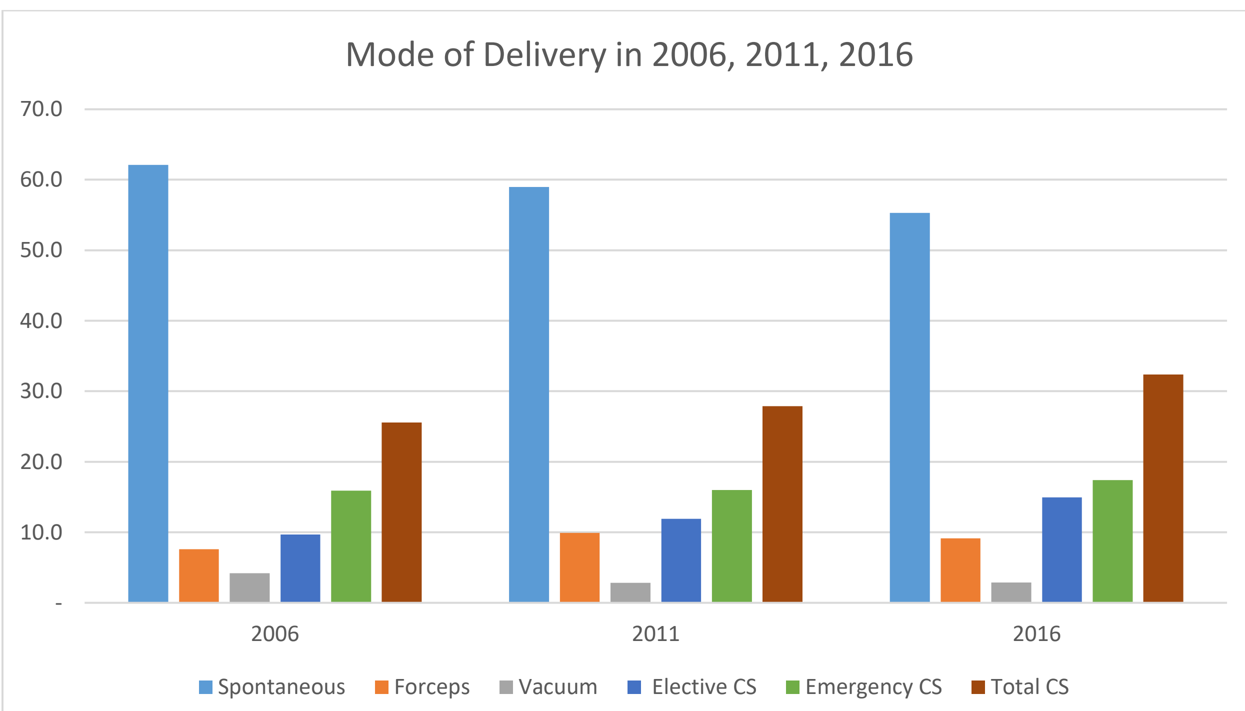
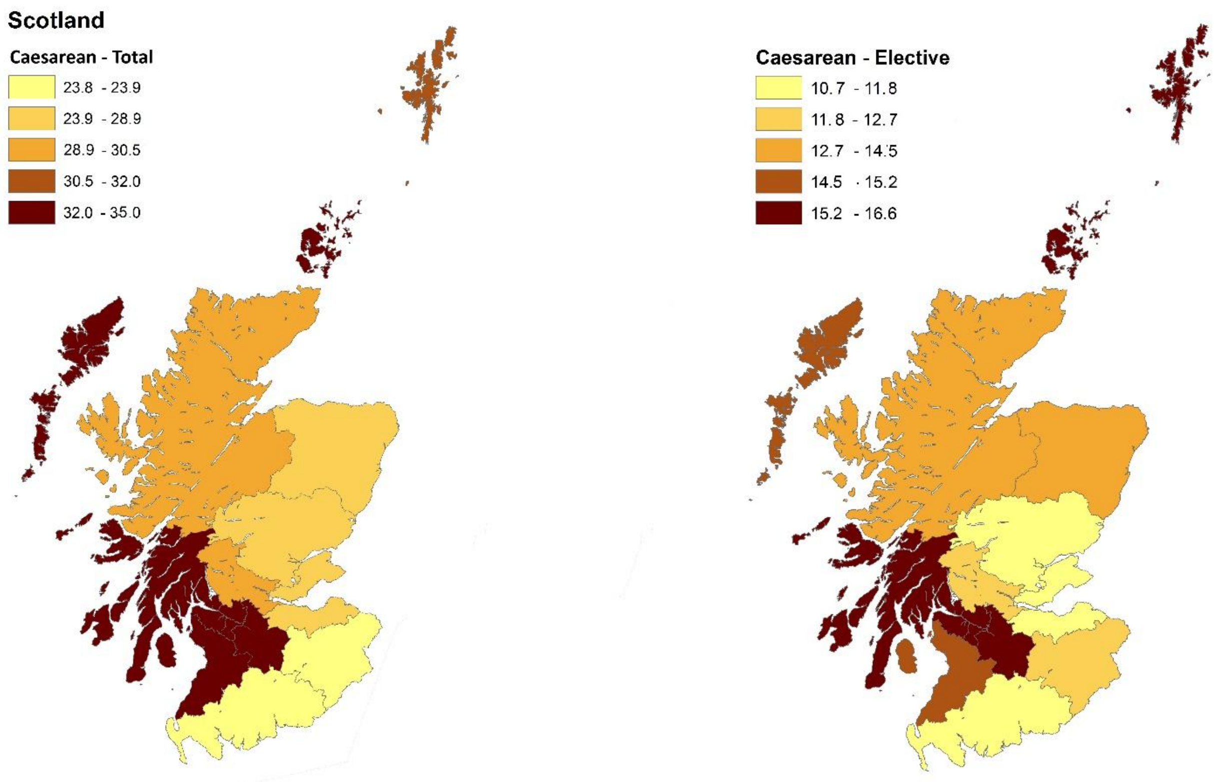


Figure II.4 Variation of C-section rates across Scottish Health Boards



The availability of elective medical procedures covered by insurance has the potential to sway patients towards choosing them, even in the absence of genuine medical requirements. This phenomenon is often labeled as "supplier-induced demand" or "provider-induced demand." When patients are informed that a particular elective treatment is included in their insurance coverage, they may be more inclined to select it, even if their medical circumstances don't truly call for the treatment. This behavior aligns with findings in health economics and behavioral psychology. To be more specific, Folland et al. (2017) delve into how insurance coverage can shape patient and provider behavior, influencing the use of elective procedures. Additionally, Nyman (2004) examines the concept of moral hazard in healthcare, illustrating how insurance coverage can lead to heightened service utilization, including elective treatments, even when medical necessity is limited. In our context, it appears that patients, particularly mothers, might perceive greater value from their insurance by making use of covered services. This perception might drive them to consider elective treatments that they might not otherwise prioritize. Furthermore, they could assume that if a treatment is covered by insurance, it must be both cost-effective and necessary, regardless of their actual medical needs. Lastly, healthcare providers might strongly recommend covered elective treatments, potentially leading patients to view them as indispensable or advantageous. As a result, making C-sections available to women even when there is no medical need could lead increased healthcare utilization, as well as variations due to different individual perspectives (both clinical and maternal). Figure II.4 illustrates the variations in C-section rates in 2015.

5. METHODS AND DATA

5.1. SCOPE AND METHOD

The aim of this research is to examine the effect of NICE guidelines, that were implemented in November 2011, on C-section rates in Scotland by employing a synthetic control method and using German regions as the “donor pool” for the construction of the synthetic control unit. The results of this research could imply the association between the availability of treatment options could increase maternity care utilization when there is no medical necessity for a specific treatment.

5.2. RATIONALE FOR THE USE OF SYNTHETIC CONTROL METHOD

This study uses synthetic control method to evaluate the impact of the 2011 NICE guidelines on elective C-section rates in Scotland. Introduced by Abadie and Gardeazabal (2003) and further developed by Abadie, Diamond, and Hainmueller (2010, 2015), this method is increasingly applied in public health policy evaluation, particularly when traditional experimental designs are not feasible.

Although randomised controlled trials (RCTs) remain the gold standard for causal inference, they are typically impractical in assessing system-wide policy changes (Craig et al., 2012; Jones et al., 2011). A more feasible alternative, the difference-in-differences (DiD) approach, estimates treatment effects by comparing outcome changes between treated and control units across pre- and post-intervention periods (Kreif, 2015). However, DiD relies heavily on the “parallel trends” assumption, which may not hold in policy contexts where regions or countries differ in baseline characteristics or trajectories. Moreover, DiD can be vulnerable to omitted variable bias, mean regression, and reverse causality (Imbens, 2009; Ryan et al., 2014).

The synthetic control method offers a more robust alternative for this study's quasi-experimental setting. It constructs a data-driven counterfactual by optimally weighting donor units—here, German regions—to match Scotland's pre-intervention outcome trends and characteristics (Kreif, 2015). Unlike DiD, it does not assume identical pre-policy trends across groups, and it allows for time-varying confounding, making it especially suitable for evaluating a non-randomised national guideline where limited treatment units and policy heterogeneity exist. By applying the synthetic control approach, the study builds on a growing body of health policy research using quasi-experimental designs (Currie, 2014; Echevin et al., 2014), while improving causal inference over DiD through more precise control group construction and stronger internal validity.

As a result, following the example of Abadie (2003), we employed a synthetic control method for our research. The rationale for this is the lack of a counterfactual control area that can approximate the mode of delivery in Scotland in the absence of new guidelines that NICE implemented. A "donor pool" of German regions was used in order to create a weighted average of the available German regions synthetic control unit. The synthetic control unit was constructed in a way that best matches SES status characteristics of Scotland (e.g. population, GDP per capita, education level) and total births per population, in the pre-intervention period. In that way, we were able to examine how the C-section rates of Scotland should look after 2011 (post-treatment period) and in the absence of the new NICE guidelines.

German regions offer several advantages that make them suitable candidates for the donor pool. First and foremost, no comparable policy change regarding maternal-request C-sections occurred in Germany during the study period (2006–2016). This ensures that any observed changes in Scotland's C-section rates following the policy intervention could be more confidently attributed to the policy itself, rather than to confounding events or systemic shifts in donor units.

There are also meaningful structural and demographic similarities between the two settings. Both the UK and Germany are high-income European countries with well-established, universal healthcare systems that provide broad access to maternity care. Although the UK operates a centralized National Health Service (NHS) model and Germany follows a decentralized insurance-based system, both systems share core features such as public financing, regulated service provision, and comprehensive maternal health coverage. Additionally, both countries have relatively low fertility rates, aging populations, and high standards of obstetric care (The Commonwealth Fund, 2020; Ham, 2021).

Importantly, Germany provides access to high-quality regional-level data on C-section rates and a range of relevant predictors—including maternal age distribution, hospital characteristics, and indicators of socioeconomic status. These covariates are essential for constructing a reliable synthetic control unit that mimics Scotland's characteristics prior to the intervention.

Nonetheless, it is acknowledged that some differences exist between the two countries. These include variations in healthcare system structure, clinical practice norms, and medico-legal environments, which may influence baseline C-section rates (Busse, 2014; The Commonwealth Fund, 2020). However, the synthetic control method does not require perfect institutional equivalence. Rather, its validity rests on the ability to reproduce the outcome trend in the treated unit during the pre-intervention period. In this regard, one of the most critical criteria is that the synthetic control—constructed from a weighted combination of German regions—closely tracks Scotland's C-section rate trajectory prior to the policy change. If a good pre-intervention match is achieved, then the synthetic control serves as a robust counterfactual for evaluating the policy's impact.

In sum, while acknowledging the contextual differences between the UK and Germany, the absence of similar policy changes in Germany, the availability of granular data, and the ability to match pre-intervention outcome trends and key predictors provide a strong rationale for using German regions as the donor pool in this synthetic control analysis.

The core assumption of the method is that the treated unit (Scotland) and its synthetic counterpart would have followed parallel trends in the absence of the intervention. In this case, pre-policy comparability is supported by the close alignment of elective C-section rates in Scotland and the synthetic control unit prior to 2011. Moreover, the timing of the policy (introduced in November 2011) and the availability of consistent, yearly aggregated outcome data support the methodological fit. The method also accommodates policy interventions affecting a single aggregate unit (i.e., Scotland) and is suited to contexts where standard difference-in-differences approaches may be limited due to a small number of treated units and heterogeneous trends across countries.

5.3. CONTRIBUTION OF THE STUDY

Synthetic control methods have been employed in criminology (Saunders et. al., 2014), politics (Abadie et. al., 2015), politics, while most of its applications are in the field of economic policy (Billmeier et. al., 2013). Following the methodological approach of Abadie et al. (2010), recent studies have examined the impact of health finance and health system reforms, using a synthetic control approach. Those health-related studies are summarised in Table II.2.

To our knowledge there only few studies where synthetic control methods have been applied in a UK context and there is no study that has employed the method in Scotland. Moreover, there is not a study yet that attempts to evaluate health policy reform and the effect of the latter to treatment choices by employing a synthetic control method. Therefore, the goal of our research was to examine how the C-section rates were affected after the introduction of the NICE guidelines that were implemented in November 2011. To do so we employed a synthetic control method, following the Abadie et al. (2010) example in order to construct a synthetic control unit based on area-level demographics, using a ‘donor pool’ of German cities. To examine the statistical significance of the NICE guidelines’ effect we observe, we used a “placebo test” (or “falsification test”). As a result, we were able to use the synthetic control method to every control region from the “donor pool”, supposing that each of them was exposed to the NICE guidelines and compare the actual estimated effect with that of each German region. If NICE guidelines have indeed an impact on the treated units under investigation, then the actual estimate has to be larger compared to the distribution of the placebo estimates.

Table II.2 Health Reforms and Health-related studies using synthetic control method

Author, Date	Exposure	Outcome	Treated unit	Donor pool	Result
Studies on Heath Reforms, using synthetic control method					
Roy, 2015	2006 Massachusetts Health care reform	Health insurance sources: • ESI • Medicaid	Insured Massachusetts population	Uninsured Massachusetts population	The reform caused expansion in coverage of over half-a-million which was distributed approximately 60:40 between ESI and Medicaid.
Dunn, 2014	2006 Massachusetts Health care reform	Physician payments under reform	Massachusetts	Untreated US states	Physician payments increased by 11% over the reform period.
Tuzemen, 2014	2006 Massachusetts Health care reform	Uninsured rate	Massachusetts	Untreated US states	Significant reductions in the uninsured rate, particularly among self-employed.
Lo, 2013	Income levels under expansions of 2006 Children's Health Insurance Program	Substitution of public, private health coverage	Illinois	Untreated US states	The Illinois' Sate Children's health insurance program cause an increase in families with income between 400% and 500% FPL
Courtemanche, 2015	2006 Massachusetts Health care reform	Self-assessed health	Massachusetts	Untreated US states	the overall health (based on self-assessments) was significantly higher after the reform introduction
Lepine, 2015	Free primary care in Zambia: user fee removal	Healthcare utilization	Treated Zambian regions	Untreated Zambian regions	The policy didn't change health seeking behaviours among the poorest users
Basu, 2016	1996 Welfare reforms	Health outcomes of low-income US women	Single US mothers	Married and single US mothers	Single mothers experienced worse health outcomes.
Health-related studies on the impact of legislation and guidelines					
Restrepo, 2014	Artificial Trans-fat ban	Cardiovascular disease mortality	Denmark	OECD countries	14.2% decrease in Cardiovascular disease mortality rates after Denmark's food policy

Sampaio, 2014	New York's Handheld cell phone ban	Traffic accidents	New York	Untreated US states	Implementation of the policy led to a decrease of about 9% in fatality rates.
Green, 2014	Alcohol licensing (liberalising bar hours)	Traffic accidents	England and Wales	Scottish regions	A significant decrease in road accidents, especially during the hours directly affected by the liberalisation
Fletcher, 2015	Imposing taxes on soda drinks (sugary drinks	BMI	Arkansas, Ohio	Other US states	The results suggested that there is no impact of the taxes to the BMI
Quast, 2016	Sex work regulation (Registration of sex workers)	Sexually transmitted infections	Tijuana, Mexico	Untreated Mexican cities	A decrease of around 37% of sex transmitted infections after the 2005 introduction of the regulation
Cunningham, 2014	Decreminalisation of indoor prostitution	Sexual violence and public health incidents	Rhode Island, USA	Untreated US states	The results suggest a decline in both sexual offences and sexually transmitted infections
UK Health reforms studies, using a synthetic control method					
Kreif, 2015	Advancing Quality scheme - Pay for performance	Risk adjusted mortality	British hospitals under intervention	Untreated British hospitals	The Pay for performance scheme did not significantly increase the risk adjusted mortality for non-incentivised conditions
Ryan, 2016	QoF - Primary care Pay for performance	Population Mortality	UK	Other high-income countries that were not exposed to P4P	The results suggested no significant changes in mortality

5.4. MODELLING

In this section, we are going to describe the models for the synthetic control method in order to examine the effect of NICE guidelines (2011) in C-section rates in the city of Glasgow, as well as in the NHS Greater Glasgow and Clyde (Scottish Health Board).

Following Abadie's et al. (2010), we consider j areas. Of J+1 units (areas of our analysis) the first unit (City of Glasgow/NHS Greater Glasgow and Clyde) is exposed to the new guidelines of NICE that were implemented in November 2011. The other units (German regions) are not exposed to the treatment (NICE guidelines). These units are the "donor pool" of our analysis.

The outcomes of interest, which are the C-section rates, are observed for T periods and the new NICE guidelines start in T_0+1. We consider 2012 as the implementation point of the NICE guidelines, since the reform was introduced in November of 2011. The observed outcome in our study (C-section rates) is Y_j for each region and the observed outcome vector is $Y_j = (Y_{j1} \cdots Y_{jT_0} \dots Y_{jT})$. It can be expressed as the sum of a treatment-free potential outcome (Y_{jt}^N) and the effect of the treatment (a_{jt}).

$$Y_{jt} = Y_{jt}^N + a_{jt} D_{jt} \tag{1}$$

Where D_{jt} is an indicator variable that takes the value 1 for City of Glasgow or NHS Greater Glasgow and Clyde (the unit which is exposed to the NICE reform) after T_0 or 0 in any other case

$$Y_{jt}^N = \delta_t + \lambda_t \mu_j + \theta_t Z_j + \varepsilon_{jt} \tag{2}$$

Where δ_t is a time-fixed effect and μ_j is a vector of time invariant unobserved predictor variables with time varying coefficients λ_t. Z_j is a (r × 1) vector of observed covariates (not affected by the NICE guidelines) and θ_t is a (1 × r) vector of unknown parameters (time-varying coefficient vector). The error terms ε_{jt} are unobserved transitory shocks with zero mean.

As a result, the outcome of interest can be expressed as:

$$\boldsymbol{Y_{jt} = \delta_t + \lambda_t \mu_j + \theta_t Z_j + a_{jt} D_{jt} + \varepsilon_{jt}} \tag{3}$$

In the pre-intervention period, the treatment-free potential outcome (Y_{jt}^{N}) corresponds to the observed outcome, for both the unit that is exposed to the health reform and the control units. In the post-intervention period, treatment-free counterfactual for the treated region, Y_{jt}^{N}, is not observed. Thus, in order to measure the treatment effect for periods after T_0, we estimate the unobserved Y_{jt}^{N} by constructing a "synthetic control unit", a weighted combination of potential controls that best matches the baseline pre-intervention characteristics of the unit that is exposed to the NICE guidelines.

Consider that the vector of weights is:

$$W = (w_2 \cdots w_{J+1})'$$

where w_j is the contribution of each German area to the weighting of synthetic control unit such that $w_j \geq 0$ and $w_2 + \cdots + w_{J+1} = 1$

The estimator of the counterfactual is constructed as the linear combination of the observed outcomes of the potential control regions:

$$\hat{Y}_{1t}^{N} = \sum_{j=2}^{J+1} w_j \, Y_{jt}$$

Then, the estimated impact of the NICE guidelines for the units that are exposed to the intervention for post-intervention periods can be expressed as:

$$\hat{a}_{1t} = Y_{1t} - \hat{Y}_{1t}^{N}$$

To examine the statistical significance of the NICE guidelines' effect we observe, we are going to use "placebo test" (or "falsification test"), To examine the statistical significance of the NICE guidelines' effect we observe, we are going to use "placebo test" (or "falsification test"), in order to use the synthetic control method to every control region from the "donor pool", supposing that each of them was exposed to the NICE guidelines and compare the actual estimated effect with that of each German region. If NICE guidelines have indeed an impact on the treated units under investigation, then the actual estimate has to be larger compared to the distribution of the placebo estimates.

5.5. DATA

For our analysis, we used data from several sources. We obtain data from ISD Scotland[14] on the rates of each mode of delivery (including spontaneous vaginal delivery, emergency C-section, elective C-section, instrumental delivery, induced). The data about each mode of delivery were available for each Scottish NHS Health Board and for each maternity hospital. In order to obtain data about the rates of C-section at city-level, we combined the rates of hospitals located in each city.

We used area-level demographics data about population, average age, total births per population and GDP per capital from statistics.gov.scot[15], National Records of Scotland[16] and Scotland Census[17]. We examined areas of Scotland based on their population in order to allow statistical methods to produce valid and robust results. For that reason, we examined the four largest cities (Glasgow, Edinburgh, Aberdeen and Dundee) and the four largest NHS Health Boards (NHS Greater Glasgow and Clyde, NHS Lothian, NHS Tayside and NHS Lanarkshire).

In order to construct the synthetic control unit, we used a donor pool of German regions. The data about C-sections were obtained from the Federal Authority of Statistics, Wiesbaden, while data about region-level demographics were obtained from Census, 2011 (Zensus, 2011). Out of 394 German regions, we excluded those with less than 900 total births per year, resulting to a donor pool of 179 German regions. In Germany, the decision making for the performance of a C-section is relied on evidence-based assessment about the validity of the procedure for every mother-to-be and involves discussion of the mother and family with the clinicians and midwives, based on risk assessment and absolute or relative indications for the procedure (Mylonas, 2015).

We used a ten-year window surrounding the NICE guidelines (from 2006 to 2015), as the data for C-sections in Germany were available from 2006.

[14] Data were retrieved from ISD Scotland – available online: http://www.isdscotland.org/Health-Topics/Maternity-and-Births/Births/
[15] Available at http://statistics.gov.scot/
[16] Available at https://www.nrscotland.gov.uk/
[17] Available at http://www.scotlandscensus.gov.uk/

6. RESULTS

6.1. City of Glasgow

In order to obtain data for the C-section rates in city of Glasgow, we used data from the 3 main maternity unit in Glasgow (Princess Royal Maternity Hospital, Southern General Hospital – Queen Elizabeth University Hospital). Table II.3 shows the weights of each German control region in the synthetic Glasgow. The weights suggest that C-section rates are best reproduced by a combination of 6 control regions that are displayed in Table II.3.

Table II.3 Control Region Weights in the synthetic Glasgow

RMSPE: 0.0001829

Region	Unit Weight
Heilbronn, Stadt	0.076
Freiburg im Breisgau, Stadt	0.432
Ingolstadt, Stadt	0.070
München, Landeshauptstadt	0.235
Freising	0.095
Potsdam, Stadt	0.092

Figure II.5 plots the C-section rates for Glasgow and its synthetic counterpart which was constructed by using 179 German regions as control units, during the period 2006-2015. Notice that the pre-intervention trajectory of C-section rates in the synthetic Glasgow matches very closely the trajectory of Glasgow's C-section rates. Combined with the predictor balance (Table II.4), the results suggest that the synthetic Glasgow provides a close approximation of the C-section rates in Glasgow during 2012-2015, in the absence of the new NICE guidelines.

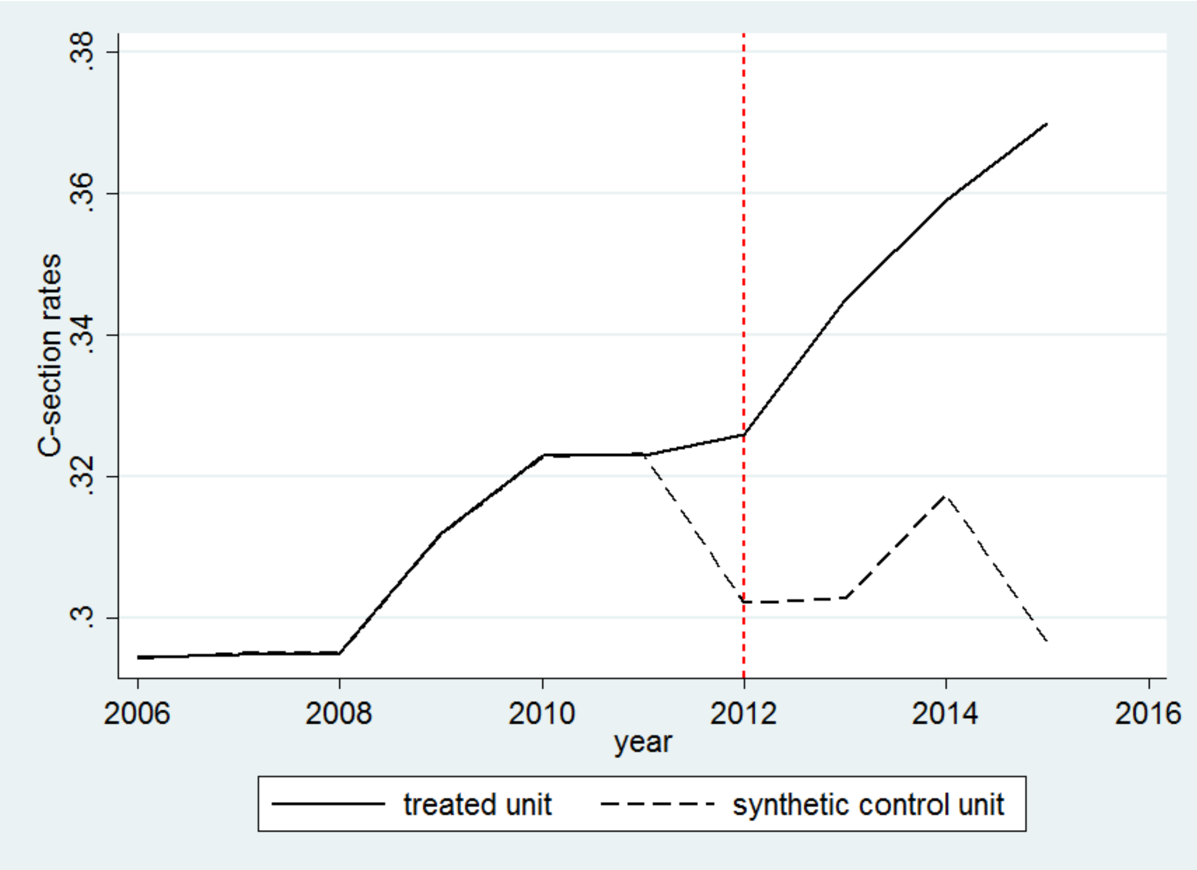
It is worth highlighting that although a substantial difference in GDP per capita is observed between Scotland and the synthetic control regions, this disparity is expected given international economic variation. Nonetheless, GDP per capita was retained as a predictor in the matching process, as it contributes to selecting regions that best approximate the overall socioeconomic context of Scotland prior to the policy intervention.

Table II.4 Predictor Balance: Glasgow vs Synthetic

	Treated	***Synthetic***
Average Age	38	40.7665
Population	593245	454805
No degree	0.107	0.273
Births per population	0.021	0.011
GDP per Capita	38256.54	71945.98
CS rates 2006	0.294	0.294
CS rates 2008	0.295	0.295
CS rates 2010	0.323	0.323
CS rates 2011	0.323	0.323

The estimate of the impact of the NICE guidelines on C-section rates is the difference between C-section rates in Glasgow and in its synthetic control unit after the introduction of the new NICE guidelines (November 2011). Following the introduction of the NICE guidelines, a notable divergence emerges between the observed C-section rates in Glasgow and those predicted by the synthetic control. The initial gap observed between 2011 and 2012 may partially reflect the timing of data collection, as Scottish health data are reported by financial year (ending in March). Thus, this early divergence likely captures the initial four-month impact of the policy change (from November 2011 to March 2012). From that point onward, C-section rates in the synthetic Glasgow exhibit a declining trend, while rates in the actual Glasgow continue to rise, resulting in a difference of approximately 7.5 percentage points by 2015. This differential corresponds to an estimated 319 additional C-sections performed in 2015 alone, and approximately 744 additional procedures across the full post-intervention period (2012–2015), compared to the synthetic control scenario. The difference between those two lines suggests a positive effect of the new NICE guidelines introduction on the C-section rates.

Figure II.5 Trends in Caesarean section rates: Glasgow vs. synthetic Glasgow.



While Figures II.5 and II.7 show a slight decline in C-section rates within the synthetic control unit following 2011, this trend should not be overstated. The apparent post-2011 decrease is more accurately interpreted as a return to baseline levels following small peaks observed in 2010 and 2011, rather than a substantive downward trend.

This behaviour reflects the algorithm's selection of donor regions that best matched Glasgow’s pre-policy trend. Importantly, national C-section rates in Germany — from which the synthetic control regions are drawn — remained relatively stable at approximately 30% since mid-2000s (Grote-Westrick, 2024). This is confirmed by our analysis (see Figure II.15, Appendix A), which aggregates data across all German donor regions and shows no systematic policy-driven changes or national initiatives promoting vaginal delivery during the timeframe under study.

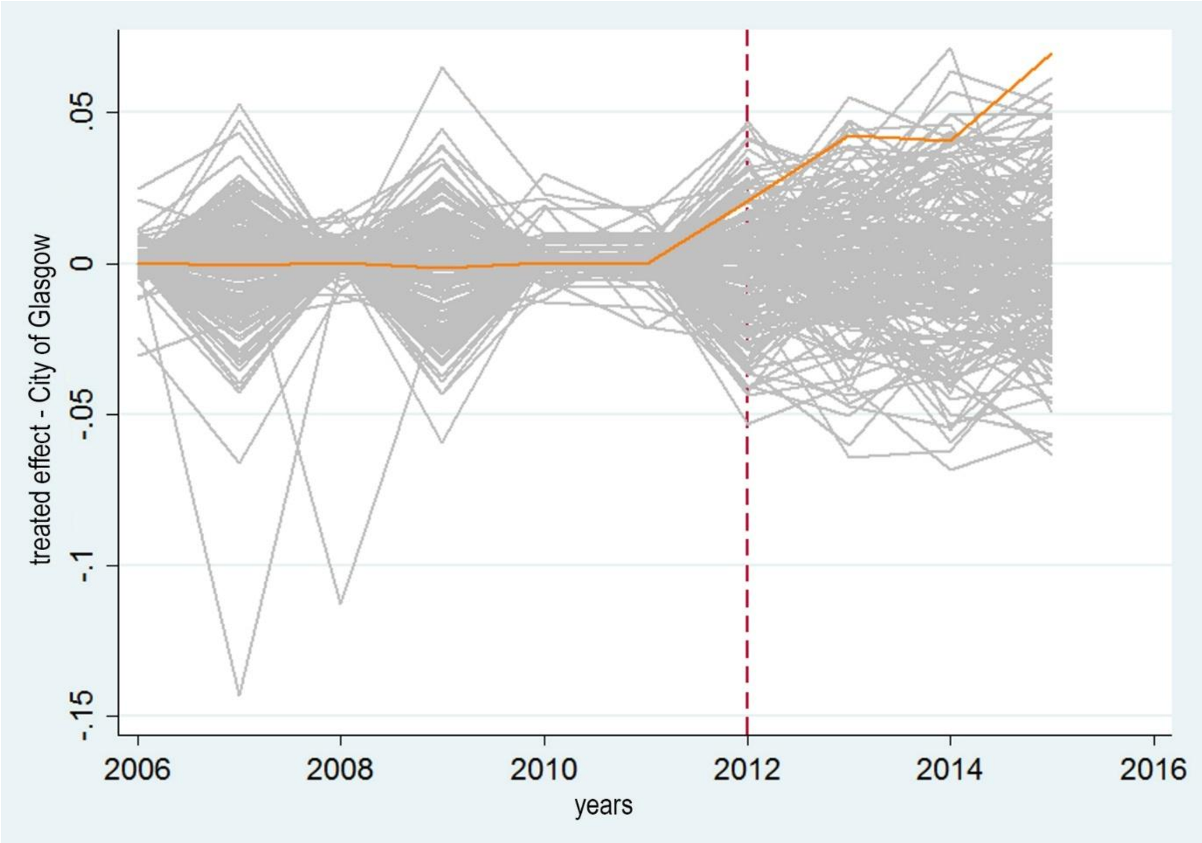
These factors also support the appropriateness of using German regions as a donor pool. Thus, the estimated policy effect is unlikely to be an artefact of declining rates in the control group and instead reflects a genuine divergence following the introduction of the NICE guideline.

We checked the robustness of our estimates and assessed if the results shown in Figure II.5 are significant. Following the example of Abadie and Gardeazabal (2003) and Abadie (2010), we perform a series of placebo tests by repetitively employing the synthetic control method that we used to explore the impact of NICE guidelines in the city of Glasgow to every other German region in the ‘donor pool’. In each iterative placebo test we reassign NICE guidelines intervention to a German region of our ‘donor pool’, treating the latter as the treated unit while shifting Glasgow to the ‘donor pool’. In that way we were able to see what would happen if each of the control units implemented the NICE guidelines instead of Glasgow.

The placebo test can then provide a distribution of estimated gaps for the control units that were used and in reality, NICE guidelines were not implemented (no intervention has taken place). The results of the placebo test are displayed in Figure II.6, where the gray lines show the gap that is linked with each of the 179 runs of the test and represent the difference in C-section rates between each control region and its respective synthetic control, while the orange line shows the gap that is calculated for the city of Glasgow.

Apparently, the estimated gap for Glasgow in the post-intervention period (2012-2016) is much larger compared to the distribution of the gaps for the German regions that were used as control units, suggesting that the synthetic control method can be a very good fit for C-section rates in Glasgow before the introduction of the NICE guidelines in November 2011.

Figure II.6 Caesarean section gaps in Glasgow and placebo gaps in all 179 German control regions.



6.2. NHS Greater Glasgow and Clyde

Table II.5 shows the weights of each German control region in the synthetic NHS Greater Glasgow and Clyde (NHS GCC) health board. The weights suggest that C-section rates are best reproduced by a combination of 5 control regions that are displayed in Table II.5. Figure II.7 shows the C-section rates for NHS Greater Glasgow and Clyde and its synthetic counterpart which was constructed by using 179 German regions as control units, during the period 2006-2015. The pre-intervention trajectory of C-section rates in the synthetic NHS GGC matches the trajectory of NHS GGC' C-section rates, with a slight difference in 2007 and 2009. Combined with the predictor balance (Table II.6), the results suggest that the synthetic NHS GGC provides a fairly close approximation of the C-section rates in NHS GGC during 2012-2015, in the absence of the new NICE guidelines.

Table II.5 Control Region Weights in the synthetic NHS Greater Glasgow and Clyde

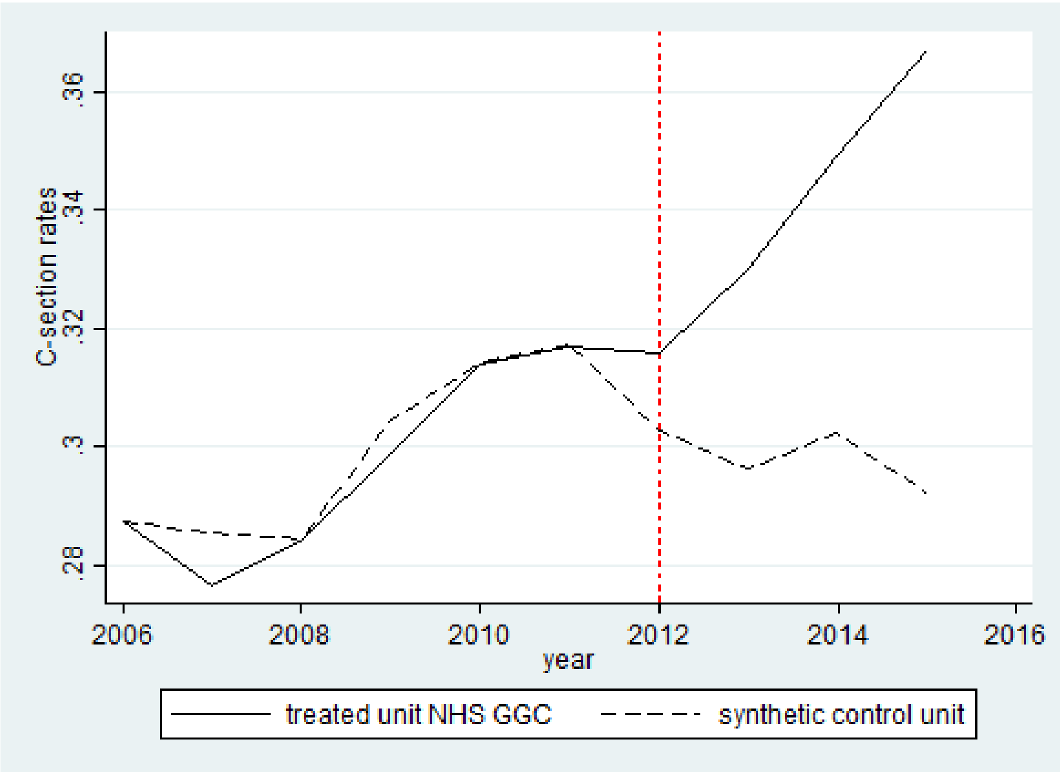
RMSPE: 0.0041284

Region	Unit Weight
Paderborn	0.291
Rastatt	0.096
Freiburg im Breisgau, Stadt	0.382
Ingolstadt, Stadt	0.035
Freising	0.197

Table II.6 Predictor Balance NHS Greater Glasgow&Clyde vs Synthetic

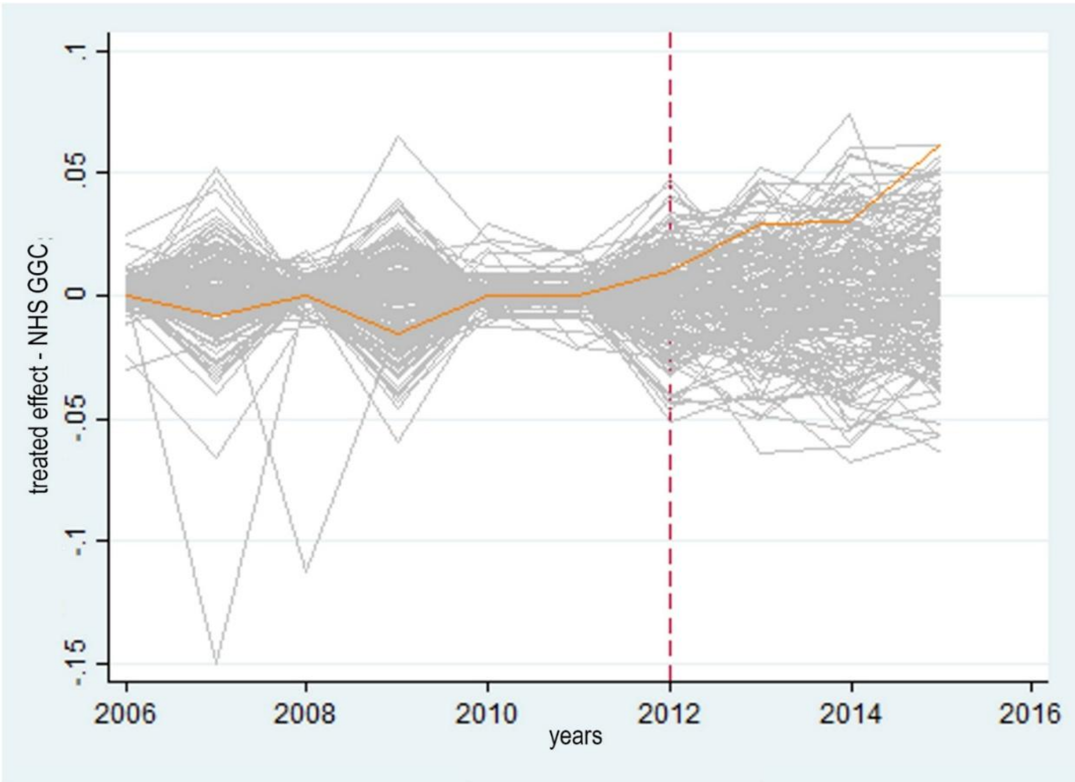
	Treated	***Synthetic***
Average Age	39.5	40.2
Population	1135090	216342.8
No degree	0.143	0.294
Births per population	0.0115	0.010
CS rates 2006	0.2874	0.2876
CS rates 2008	0.284	0.285
CS rates 2010	0.314	0.314
CS rates 2011	0.317	0.317

Figure II.7 Trends in Caesarean section rates: NHS Greater Glasgow and Clyde vs. the synthetic one.



The estimate of the impact of the NICE guidelines on C-section rates is the difference between C-section rates in NHS Greater Glasgow & Clyde and in its synthetic control unit after the introduction of the new NICE guidelines (November 2011). Right after the introduction of NICE guidelines, the two lines start to diverge significantly. Similarly to the Glasgow case, the gap between the lines in the period 2011-2012 can be explained by the fact that the year ending for Scottish data is end of March, as a result this gap could represent the 4 months effect of the implementation of NICE guidelines (November to March), while C-section rates in the synthetic NHS GGC show a downward trend, the real NHS GGC show a sharp increase of the C-section rates, with a gap of about 8 % between the synthetic NHS GGC and the real NHS GGC in 2015. The difference between those two lines suggests a positive effect of the new NICE guidelines introduction on the C-section rates.

Figure II.8 Caesarean section gaps in NHS Greater Glasgow & Clyde and placebo gaps in all 179 German control regions.



We checked the robustness of our estimates and assessed if the results shown in Figure II.7 are significant. Following the example of Abadie and Gardeazabal (2003) and Abadie (2010), we perform a series of placebo tests by repetitively employing the synthetic control method that we used to explore the impact of NICE guidelines in the NHS GGC to every other German region in the 'donor pool'. In each iterative placebo test we reassign NICE guidelines intervention to a German region of our 'donor pool', treating the latter as the treated unit while shifting NHS GGC to the 'donor pool'. In that way we were able to see what would happen if each of the control units implemented the NICE guidelines instead of NHS GGC. The placebo test can then provide a distribution of estimated gaps for the control units that were used and in reality, NICE guidelines were not implemented (no intervention has taken place). The results of the placebo test are displayed in Figure II.8, where the gray lines show the gap that is linked with each of the 179 runs of the test and represent the difference in C-section rates between each control region and its respective synthetic control, while the orange line shows the gap that is calculated for the NHS GGC. Apparently, the estimated gap for NHS GGC in the post-intervention period (2012-2016) is much larger compared to the distribution of the gaps for the German regions that were used as control units, suggesting that the synthetic control method can be a very good fit for C-section rates in NHS GGC before the introduction of the NICE guidelines in November 2011.

Results from the synthetic control method and the placebo tests for Edinburgh, Dundee and Aberdeen, as well NHS Lothian, NHS Tayside and NHS Lanarkshire were also obtained but none of these cases showed significantly close matches between the treated areas and the synthetic controls. The results can be found in Appendices A and B.

7. DISCUSSION

7.1. Overview

After employing a synthetic control method and using German regions as the “donor pool” for the construction of the synthetic control unit, we examined the effect of the NICE guidelines, implemented in November 2011, on Caesarean section (C-section) rates in Scotland. The results showed a gap of about 7.5% between the synthetic Glasgow and real Glasgow in 2015, and a gap of about 8% between the synthetic NHS Greater Glasgow and Clyde (NHS GGC) and the real NHS GGC in the same year, in terms of C-section rates.

The total births taking place in hospitals located within the city of Glasgow represent approximately 22% of all births in Scotland, while births in the wider NHS GGC health board account for 23% of total Scottish births. Therefore, both Glasgow and NHS GGC serve as meaningful and representative examples of the wider potential effect of the NICE guidelines on C-section rates across Scotland.

These results should be understood in the context of a longstanding upward trend in C-section rates, both globally and within Scotland. (Betrán et al., 2016; ISD Scotland, 2016). Despite international efforts to curb this rise (Chaillet et al., 2007; Kozhimannil et al., 2013), the UK took a different direction in 2011 when NICE released updated guidelines. These replaced the earlier 2004 recommendations and introduced the right for women to request a C-section even in the absence of medical indications, provided the procedure was planned and informed (NICE, 2011). This policy change expanded the eligibility for elective C-sections and potentially influenced both patient preferences and clinical decision-making across maternity care in the UK.

In this context, the observed divergence in C-section rates between real and synthetic controls suggests that the 2011 NICE guidelines may have played a substantial role in reinforcing the upward trajectory of C-section utilisation in Scotland, particularly in Glasgow and NHS GGC.

7.2. Contribution

This study offers several contributions to the literature on health policy evaluation and caesarean section (C-section) utilisation. Conceptually, it extends the understanding of how national policy reforms — such as the 2011 NICE guidelines that made elective C-sections available without medical indication — can influence clinical practice on a regional level. By focusing on C-section rates in Glasgow and the NHS Greater Glasgow and Clyde health board, the analysis provides insights into how centrally issued guidelines may translate into observable changes in healthcare utilisation within a devolved healthcare system.

Methodologically, this study contributes to the growing body of literature that applies the synthetic control method to evaluate the effects of health interventions. While this technique has been increasingly used in public policy evaluation, its application to healthcare reforms in the UK — and particularly in Scotland — remains limited. This study demonstrates how the method can be adapted to regional administrative health data to construct valid counterfactual scenarios in the absence of randomized control trials.

From a policy perspective, the findings highlight the potential implications of policies that expand access to elective procedures without medical necessity. The analysis shows a significant increase in C-section rates following the policy change, raising important questions about the balance between respecting patient autonomy and ensuring cost-effective, evidence-based care. The results can inform future evaluations of similar reforms in other jurisdictions and contribute to debates on variation in maternity care practices

7.3. Strengths and Limitations of the study

This chapter contributes to the existing literature on health policy evaluation and maternal healthcare. One of its strengths is that it provides the first empirical analysis of the impact of the 2011 NICE guidelines—which extended the option of elective C-section to women without medical indication—using robust quasi-experimental methods. To our knowledge, this is also the first study in Scotland to employ the synthetic control method to evaluate a national policy reform, and one of the very few studies applying this method within the UK context. The findings are particularly policy-relevant, offering insights on how the implemented policy change could potentially lead to increased healthcare utilization, with important implications for healthcare planning, resource allocation, and quality of care.

Moreover, by comparing Glasgow to a carefully constructed synthetic control group derived from German regions, the study also brings a valuable international comparative perspective. This cross-national approach helps situate local trends within wider European healthcare dynamics and highlights how different systems and patient preferences can shape outcomes. Nevertheless, the study is not without limitations. One of the key constraints is that, due to a lack of information on elective C-section rates for the German regions, we were not able to explore the effect of the NICE guidelines explicitly on elective C-sections. Moreover, since the reform occurred only four years prior to the latest available data, the time window surrounding the reform was limited to ten years. Finally, due to the absence of city-level data on C-section rates, we explored the effect of the reform in Glasgow using hospital-level data from maternity units located within the city. For this reason, we also assessed the impact of the reform on C-section rates in the wider NHS Greater Glasgow and Clyde health board.

7.4. Conclusion and Policy Implications

The results of our analysis showed a clear increasing effect of the new NICE guidelines introduction on the C-section rates in Glasgow, as well as in NHS Greater Glasgow and Clyde health board, suggesting that in the absence of the NICE guidelines, which made the caesarean procedure available even to women with no medical indication for the operation, the C-section rates would have followed a completely different trajectory, with significantly decreased rates.

The offer of elective treatments that are covered by insurance could influence patients to choose them, even when there is no medical necessity. This phenomenon is often referred to as "supplier-induced demand" or "provider-induced demand." When patients are aware that a particular elective treatment is covered by their insurance, they might be more inclined to opt for it, even if their medical condition might not warrant the treatment. This phenomenon is supported by research in health economics and behavioral psychology. More specifically, Folland et al. (2017) discuss how insurance coverage can lead to changes in patient behavior and provider practices, including the utilization of elective treatments. Furthermore, Nyman

(2004) explores the concept of moral hazard in healthcare and how insurance coverage can lead to increased utilization of services, including elective treatments, even in cases where medical need is limited. It seems that patients (in our case mothers) might perceive that they are getting more value from their insurance by utilizing covered services, leading them to consider elective treatments they might not otherwise prioritize. Moreover, they may believe that if the treatment is covered by insurance, it must be cost-effective or essential, even if their medical condition doesn't necessitate it. Finally, healthcare providers may recommend covered elective treatments more strongly, leading patients to perceive them as necessary or beneficial.

However, while concerns about potential overuse and rising healthcare costs are valid, it is equally important to consider the possible positive implications of such policy changes. Respecting a woman’s autonomy and enabling her to choose her preferred mode of delivery can significantly enhance the overall childbirth experience. Several studies support the notion that accommodating maternal preferences can lead to improved satisfaction and more positive birth outcomes (Badrinath et al., 2004; Byrom et al., 2015). For instance, Wiklund et al. (2007) found that women who opted for elective C-sections reported more positive birth experiences than those who planned a vaginal delivery. Similarly, Blomquist et al. (2011) observed that planned caesarean births were associated with higher satisfaction than unplanned caesareans or emergency vaginal deliveries. Moreover, elective caesareans are scheduled and may help reduce the anxiety associated with emergency procedures or unpredictable labour, particularly among women with a history of traumatic birth experiences (Karlström et al., 2013). This dual perspective—acknowledging both risks and benefits—is essential in evaluating the broader implications of the NICE policy.

Nonetheless, the rising rates of C-sections following the implementation of the NICE guidelines raise important public health concerns. C-section procedures carry potential maternal and neonatal risks, including higher rates of infection, delayed recovery, and complications in future pregnancies. These medical implications, in turn, affect healthcare systems, contributing to increased hospital stays, greater use of resources, and elevated costs. The financial burden includes both the immediate cost of surgery and the associated increase in postnatal care requirements.

As a result, the establishment of strategies to mitigate these implications is crucial. One such way is through evidence-based clinical guidelines for elective C-section. By aligning treatment decisions with established medical criteria, patients and providers can make more informed choices, reducing the influence of insurance coverage on decisions Graham, 2011; Qaseem, 2012). Moreover, shared decision-making can allow mothers to make more informed and conscious decisions, through discussing treatment options, potential benefits, risks, and costs. Finally, ways of standardizing the procedure (C-sections) are also very important. Enhanced recovery pilots (ERPs) are programmes that aim to standardize surgical procedures by implementing evidence-based practices to optimize patient outcomes. ERPs can enhance patient safety and satisfaction, provide faster recovery, as well as they can reduce healthcare costs through optimization of resources, fewer complications and reduced length of hospital stay (Pędziwiatr et al., 2015).

What is known about the topic

- Since the 1970s, there is a significant increase in the rate of caesarean sections across many developed countries (Althabe, 2006), including the UK (Information Centre, 2009; Betrán, 2016; OECD, 2017; NHS, 2017)
- In 2011, new NICE guidelines were introduced which made elective C-sections available to women even when there is no medical need
- In Scotland there are significant variations in the rates of C-sections across time and an increasing trend in the utilisation of the procedure.
- In Scotland, the rate of Caesarean-sections has increased from 8.7% in 1976 to 32.4% in 2016 (ISD Scotland, 2016).

What this research adds

- This is one of the few studies where synthetic control method has been applied in a UK context, examining the effect of health-related policy changes and the first one in Scotland.
- This is the first study yet that evaluates the health policy reform that was introduced by NICE and implemented in November 2011, regarding the availability of elective C-sections to women with no medical indication for the procedure.

Initiatives for Further Research

- Given the rising rates of C-sections worldwide, and in Scotland, establishing ways to mitigate the health and cost implications are necessary. One such way is through standardising the procedure through Enhanced Recovery Pilots (ERPs). ERPs could enhance patient safety, satisfaction and recovery, as well as they can reduce healthcare cost though reducing the length of stay post C-section.
    - Evaluate an Enhanced Recovery Pilot that was implemented at the Princess Royal Maternity Unit in 2015 and examine the effect of the pilot on the maternal length of stay post elective C-section.

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9. APPENDIX A

Results for City of Edinburgh

Table II.7 *Control Region Weights in the synthetic City of Edinburgh*

RMSPE: 0.0014429

Region	Unit Weight
Paderborn	0.357
Ulm, Universitätsstadt	0.285
Ingolstadt, Stadt	0.081
München, Landeshauptstadt	0.176
Freising	0.100
Potsdam, Stadt	0.001

Table II.8 Predictor Balance for City of Edinburgh

	Treated	*Synthetic*
Average Age	39.5	40.2
Population	476626	216342.8
No degree	0.085	0.287948
Births per population	0.0144893	0.0099898
GDP per capita	60235.53	74757.19
CS rates 2006	0.262	0.2601836
CS rates 2008	0.248	0.2485803
CS rates 2010	0.272	0.2732058
CS rates 2011	0.276	0.2763031

Figure II.9 Trends in C-section rates: City of Edinburgh vs. the synthetic one.

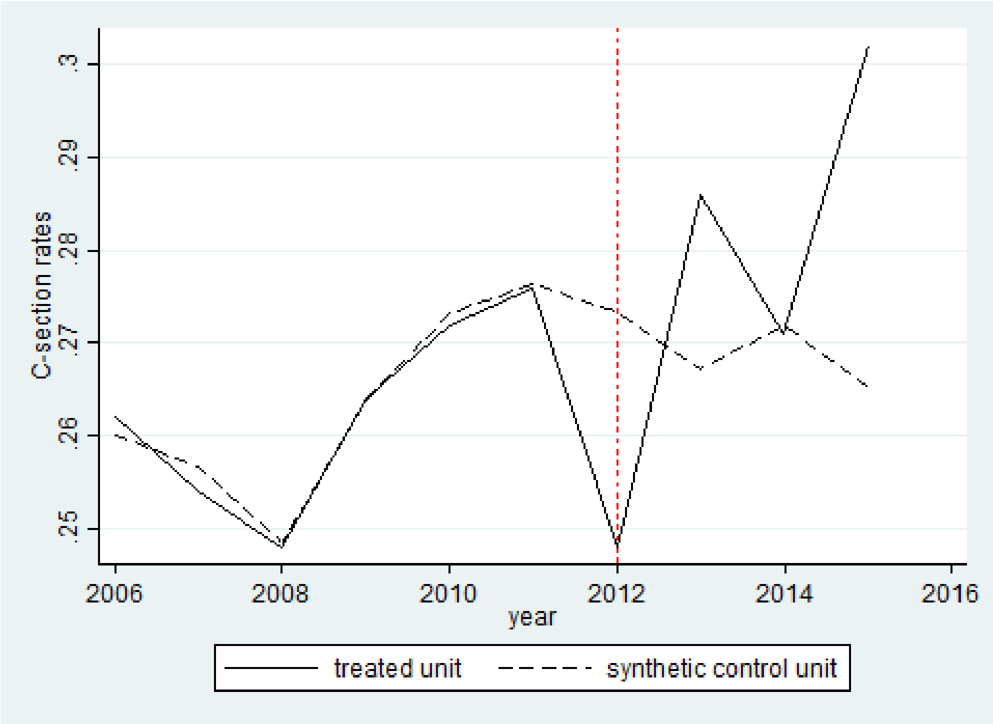


Figure II.10 C-section gaps in City of Edinburg and placebo gaps in all 179 German control regions.

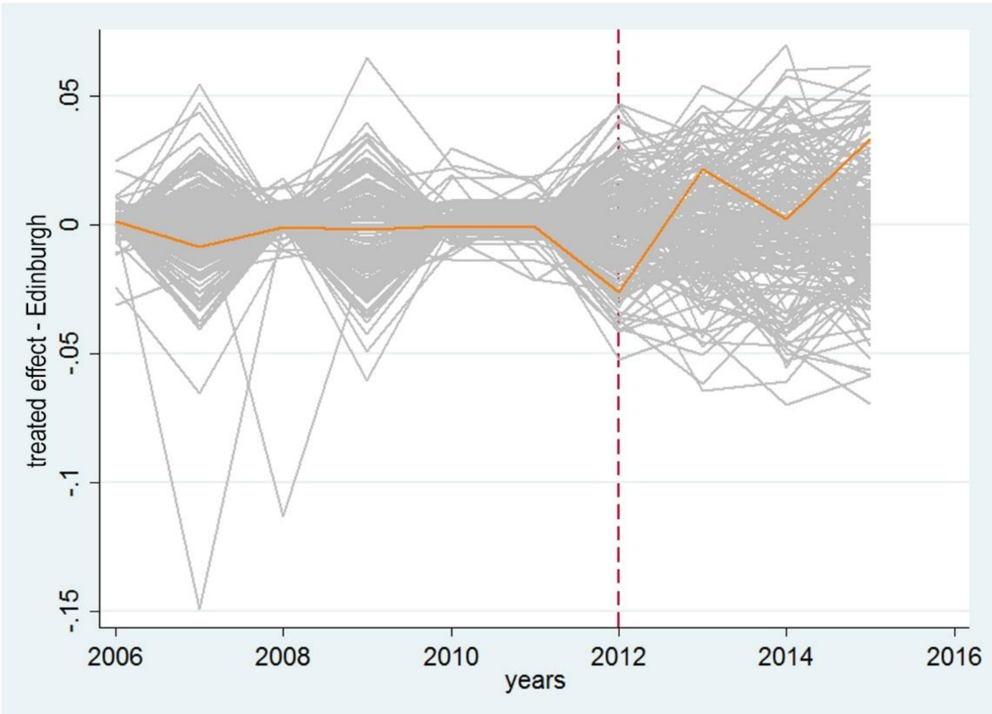


Table II.9 Control Region Weights in the synthetic City of Aberdeen

RMSPE: 0.001491

Region	Unit Weight
Borken	0.215
Offenbach am Main, Stadt	0.029
Ulm, Universitätsstadt	0.079
Erding	0.180
Fürth, Stadt	0.336
Unterallgäu	0.161

Table II.10 Predictor Balance for City of Aberdeen

	Treated	***Synthetic***
Average Age	38.7	41.4983
Population	22460	173955
No degree	0.095	0.2778708
Births per population	0.0225074	0.0091799
CS rates 2006	0.306	0.3042498
CS rates 2008	0.305	0.3047686
CS rates 2010	0.281	0.282868
CS rates 2011	0.287	0.2874027

Figure II.11 Trends in C-section rates: City of Aberdeen vs. the synthetic

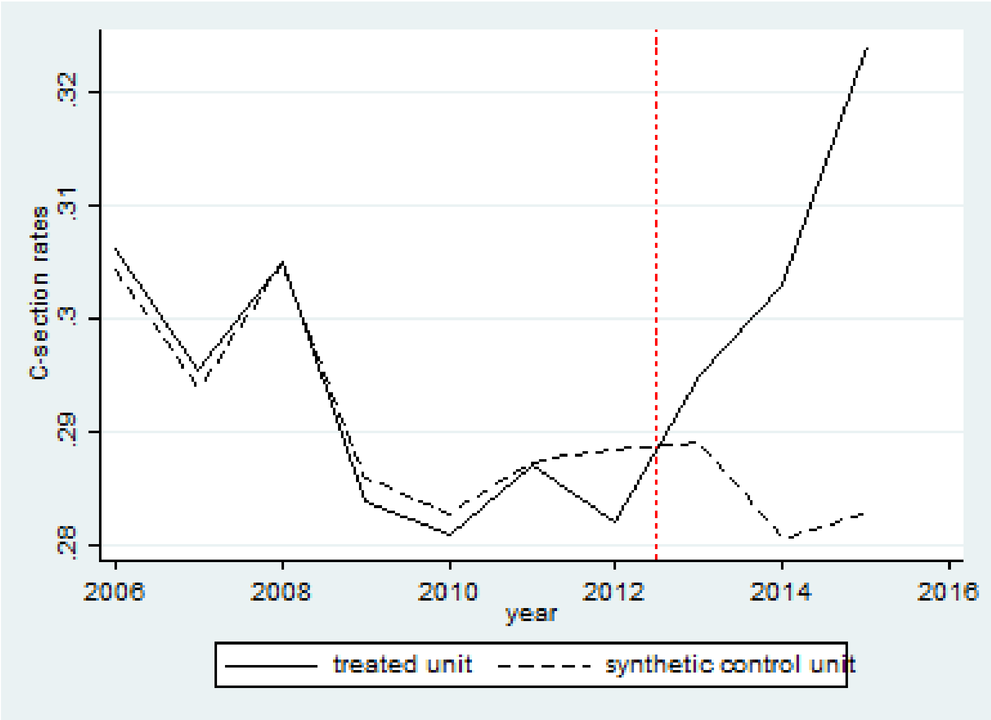


Figure II.12 C-section gaps in Aberdeen and placebo gaps in all 179 German control regions.

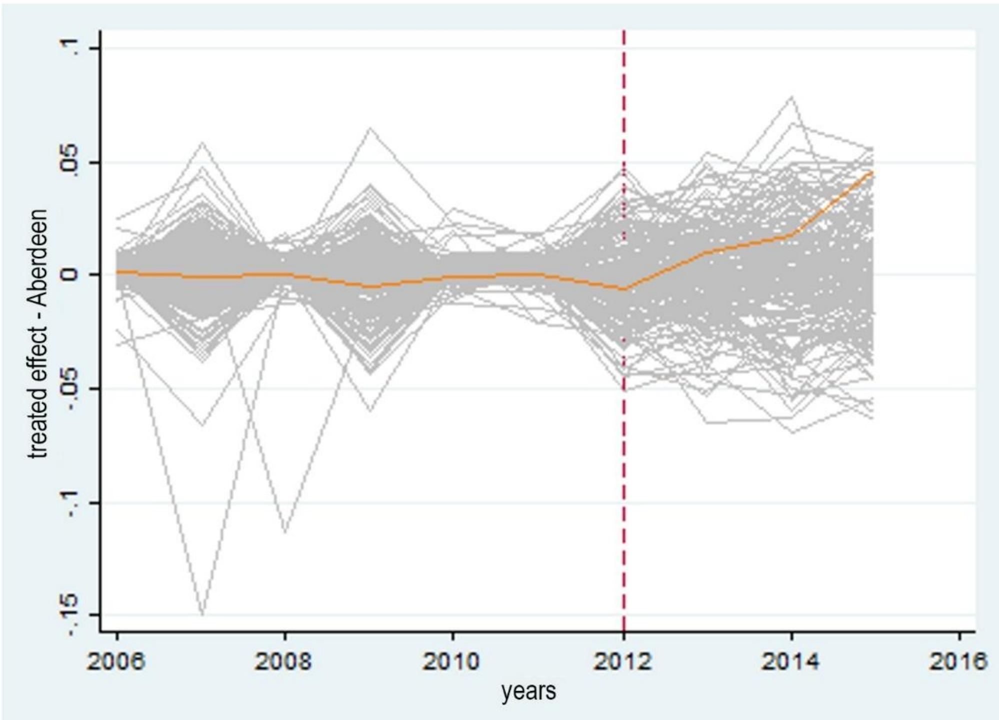


Table II.11 Control Region Weights for the synthetic City of Dundee

RMSPE: 0.0055697	
Region	**Unit Weight**
Freiburg im Breisgau, Stadt	0.498
Potsdam, Stadt	0.502

Table II.12 Predictor Balance for City of Dundee

	Treated	***Synthetic***
Average Age	39.3	40.904
Population	147200	182717.3
No degree	0.128	0.2355746
Births per population	0.0278193	0.0106136
CS rates 2006	0.238	0.2412496
CS rates 2008	0.265	0.2668659
CS rates 2010	0.275	0.2737669
CS rates 2011	0.296	0.2862415

Figure II.13 C-section gaps in Dundee and placebo gaps in all 179 German control regions

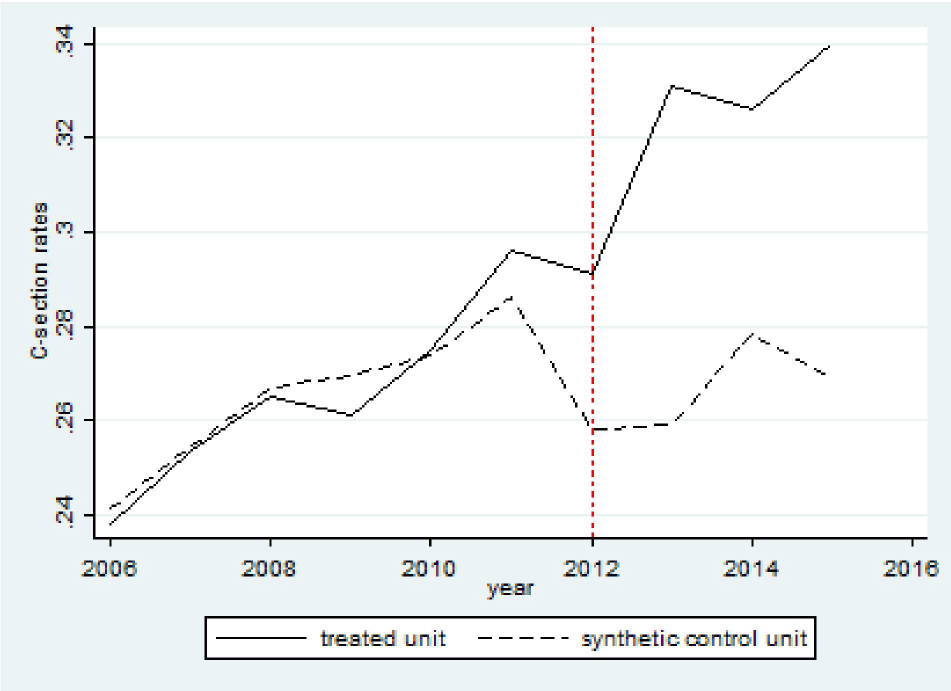
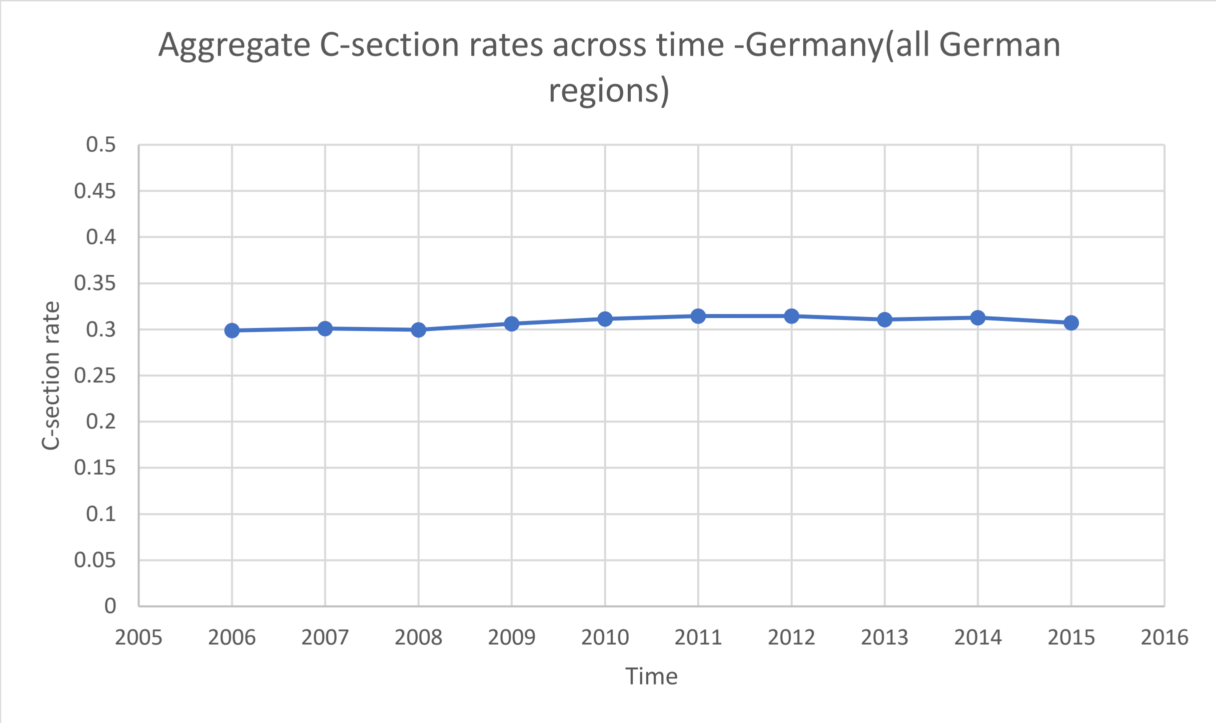


Figure II.14 C-section gaps in Dundee and placebo gaps in all 179 German control regions

Figure II.15 Aggregate C-section rates in Germany 2006-2015 (all German donor regions)



The figure above aggregates data across all German donor regions and shows no systematic policy-driven changes or national initiatives promoting vaginal delivery during the timeframe under study.

10. APPENDIX B

NHS Lothian

Table II.13 Control Region Weights for synthetic NHS Lothian

RMSPE: 0.0015274

Region	Unit Weight
Rhein-Sieg-Kreis	0.187
Paderborn	0.142
Hohenlohekreis	0.101
Ulm, Universitätsstadt	0.271
Ingolstadt, Stadt	0.008
München, Landeshauptstadt	0.259

Table II.14 Predictor Balance for NHS Lothian

	Treated	***Synthetic***
Average Age	38.9	41.5436
Population	836610	546986.5
No degree	0.0935542	0.2838167
Births per population	0.0113673	0.009696
CS rates 2006	0.260425	0.2591847
CS rates 2008	0.2487930	0.2500161
CS rates 2010	0.2715316	0.2719150
CS rates 2011	0.2815983	0.281545

Figure II.16 Trends in C-section rates: NHS Lothian vs. the synthetic

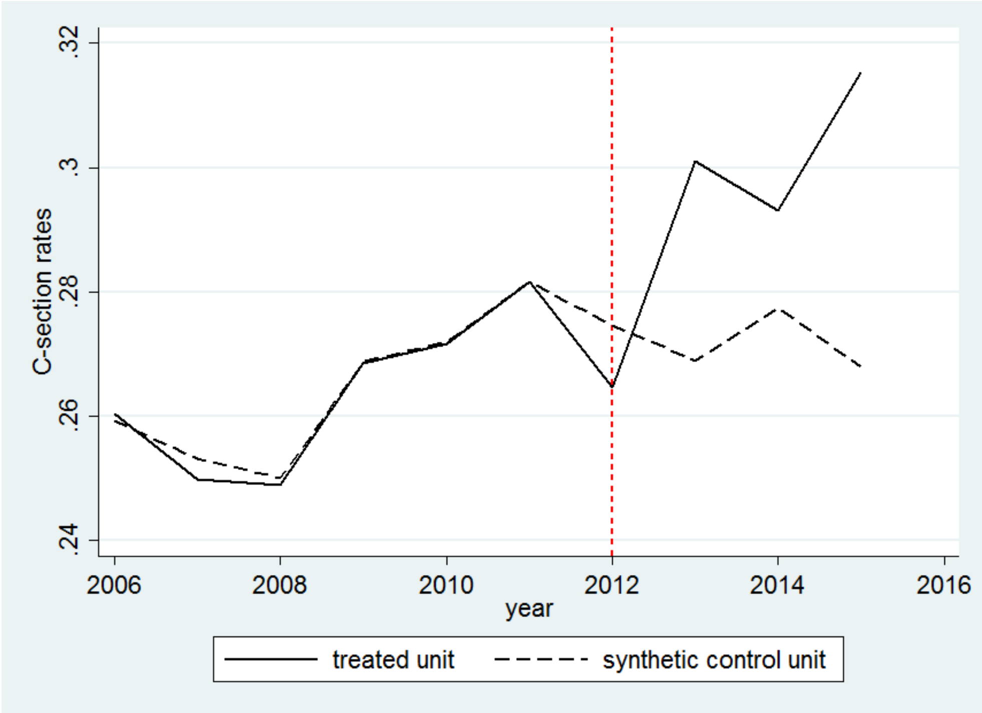


Figure II.17 C-section gaps in NHS Lothian and placebo gaps in all 179 German control regions.

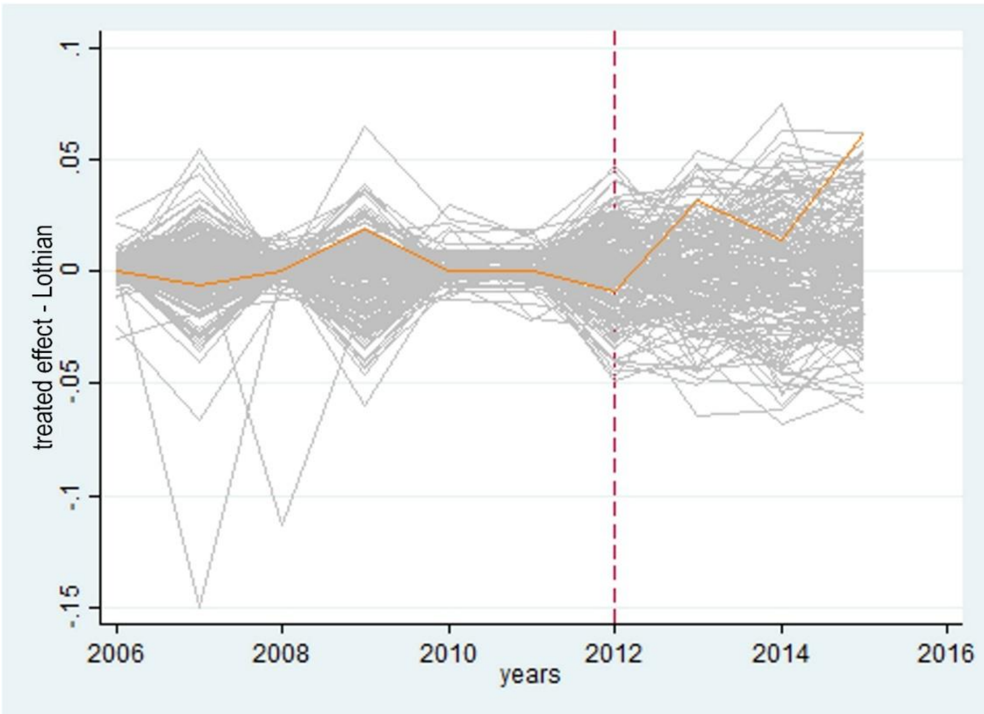


Table II.15 Control Region Weights for synthetic NHS Lanarkshire

RMSPE: 0.0076573

Region	Unit Weight
Frankfurt am Main, Stadt	0.147
Heidelberg, Stadt	0.056
Freiburg im Breisgau, Stadt	0.496
Ingolstadt, Stadt	0.035
Potsdam, Stadt	0.266

Table II.16 Predictor Balance for NHS Lanarkshire

	Treated	*Synthetic*
Average Age	39.8	40.6273
Population	651620	256252.5
No degree	0.1584153	0.2704568
Births per population	0.0111184	0.0105674
CS rates 2006	0.2664533	0.2677741
CS rates 2008	0.2806826	0.2818661
CS rates 2010	0.3048181	0.3025686
CS rates 2011	0.3112491	0.3116341

Figure II.18 Trends in C-section rates: NHS Lanarkshire vs. the synthetic

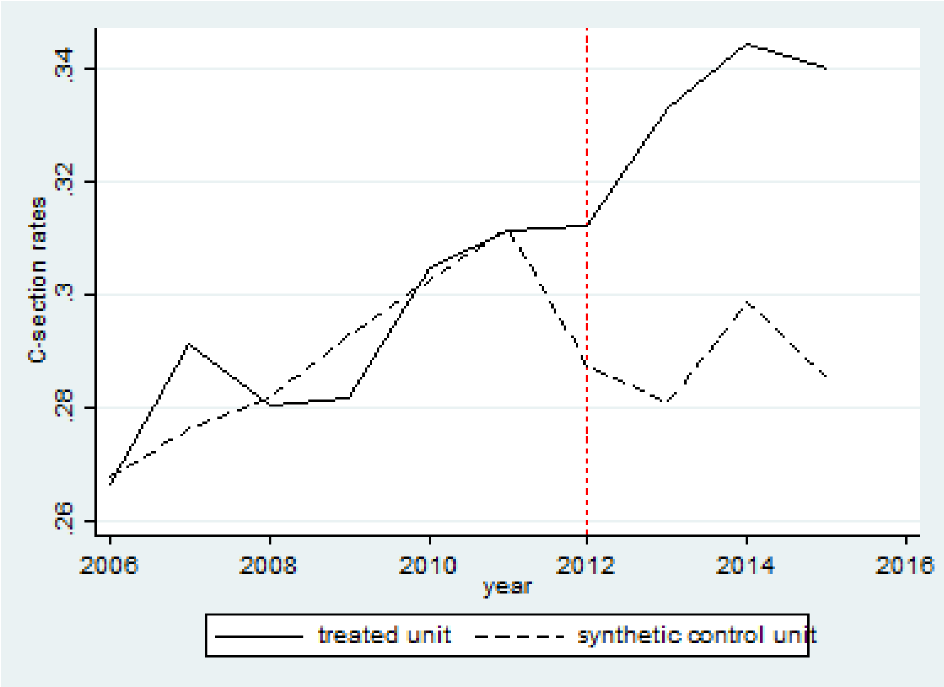


Figure II.19 C-section gaps in NHS Lanarkshire and placebo gaps in all 179 German control regions.

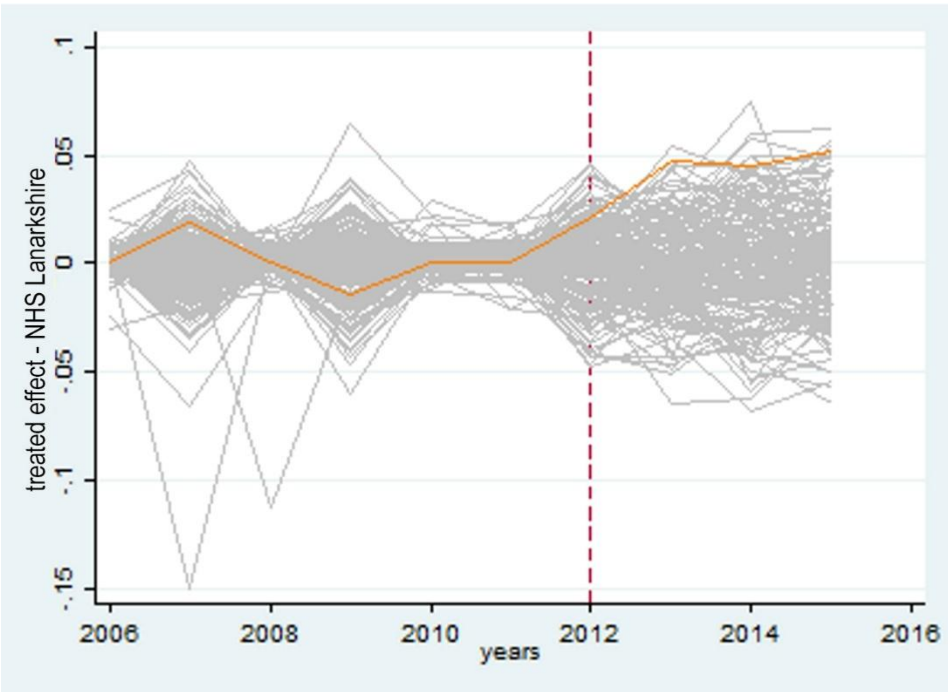


Table II.17 Control Region Weights for synthetic NHS Tayside

RMSPE: 0.0047883

Region	Unit Weight
Reutlingen	0.345
Potsdam, Stadt	0.296
Oberhavel	0.145
Gotha	0.214

Table II.18 Predictor Balance for NHS Tayside

	Treated	***Synthetic***
Average Age	41.4	43.5023
Population	410250	195498.9
No degree	0.1200755	0.202493
Births per population	0.010674	0.0086472
CS rates 2006	0.2009804	0.2048297
CS rates 2008	0.2269767	0.2270089
CS rates 2010	0.2340973	0.2346027
CS rates 2011	0.2614752	0.2554601

Figure II.20 Trends in C-section rates: NHS Tayside vs. the synthetic

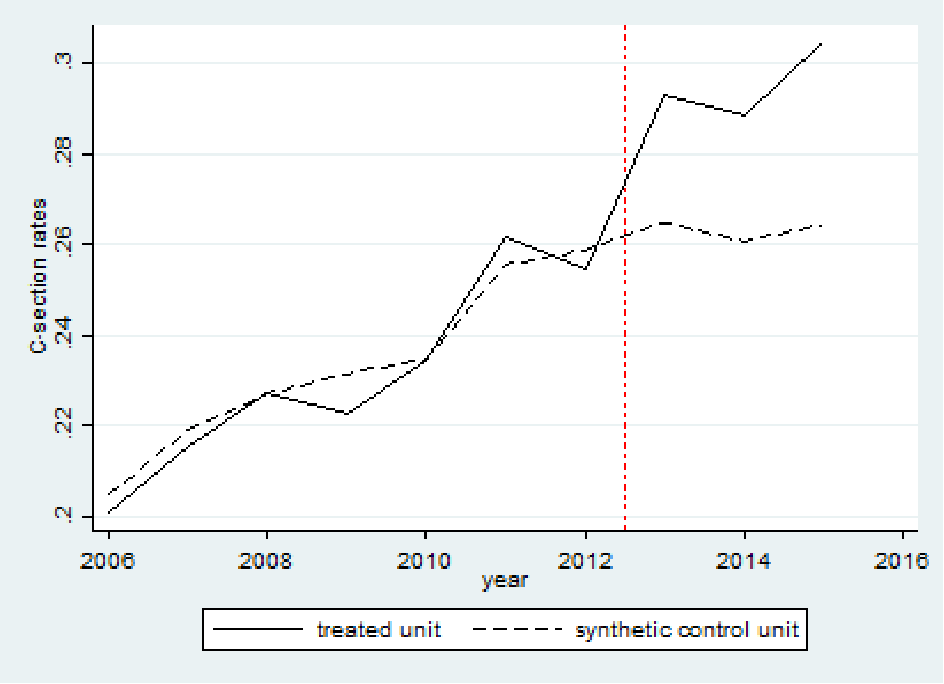
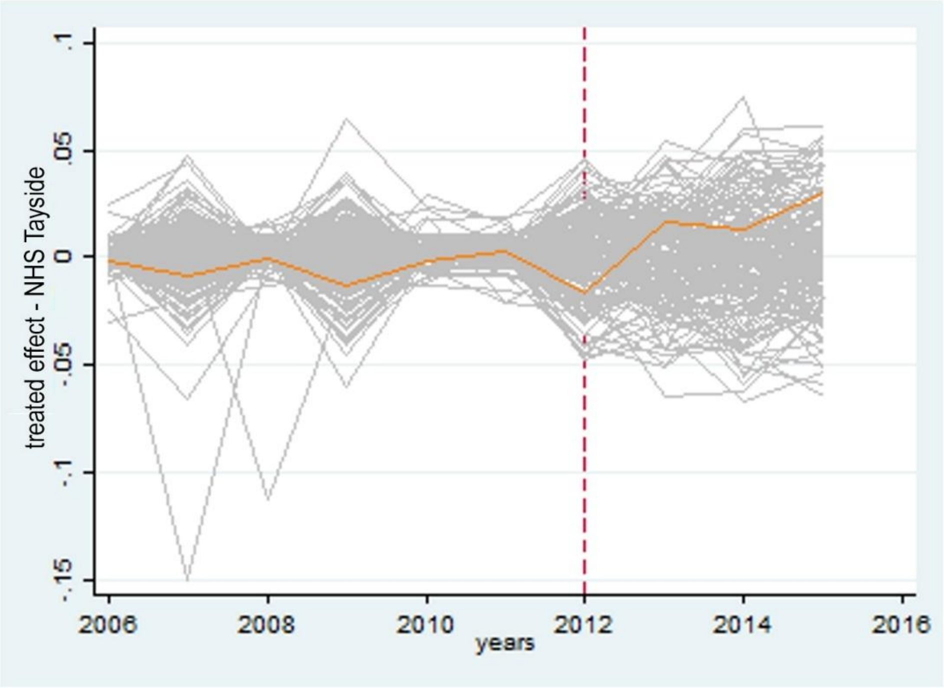


Figure II.21 C-section gaps in NHS Tayside and placebo gaps in all 179 German control regions.



III. Chapter III: **EVALUATION OF ENHANCED RECOVERY PILOT FOR CAESAREAN SECTION**

1. BACKGROUND: Enhanced Recovery Pilots/Programs

Enhanced recovery protocols or Pilots (ERPs), also known as fast-track surgery or multimodal perioperative care, have revolutionized the field of surgical care by implementing evidence-based practices to optimize patient outcomes. ERPs focus on reducing surgical stress, maintaining physiological function, and enhancing recovery through a coordinated and multidisciplinary approach.

More specifically, ERPs emphasize the importance of pre-operative optimization to enhance patient readiness for surgery. This includes prehabilitation, nutritional optimization, and smoking cessation. Prehabilitation, which involves physical exercise, has been shown to improve functional capacity, reduce complications, and enhance recovery (Santa Mina et al., 2017). Nutritional optimization ensures adequate nutritional status, which is crucial for wound healing and immune function (Gillis et al., 2018). Smoking cessation significantly reduces postoperative complications, including wound infections and pulmonary complications (Møller et al., 2014).

Furthermore, ERPs can optimize pain by focusing on multimodal analgesia and combining various analgesic techniques to improve pain control and minimize opioid use (Ljungqvist et al., 2014), as well as promote early mobilisation and oral nutrition to expedite recovery (Gustafsson et al., 2012). They also aim to educate patients and enhance their engagement throughout the perioperative period, which can improve adherence and empower patients to actively participate in their recovery (Zhuang et al., 2019). Engaging patients in shared decision-making promotes a patient-centred approach, leading to improved satisfaction and better outcomes (Gustafsson et al., 2013).

Moreover, ERPs employ strategies to minimize surgical stress, such as minimally invasive surgery, regional anesthesia, and fluid management. Minimally invasive surgery reduces tissue trauma, leading to reduced postoperative pain, shorter hospital stays, and faster recovery (Pędziwiatr et al., 2015). Regional anesthesia techniques, such as epidurals and nerve blocks, reduce the need for opioid analgesics, minimize side effects, and improve postoperative pain control (Kehlet et al., 2018). Goal-directed fluid therapy helps maintain optimal intravascular volume, reducing complications and facilitating recovery (Thacker et al., 2016).

Enhanced Recovery Protocols (ERPs) have predominantly been implemented in surgical specialties such as colorectal or orthopedic surgery. However, there is increasing recognition of the potential benefits of applying ERPs to obstetric care, specifically in caesarean section (C-section) deliveries. (Kumar et al., 2019; Charlton et al., 2020).

2. INTRODUCTION

Caesarean section (C-section) is one of the most common surgical procedures performed in the world. In 2012, it was estimated that 22.9 million C-Sections were performed each year, approximately 19% of all deliveries (Molina, 2015). The rate of C-sections has been increasing globally, as is reflected in the previous chapters. More specifically, the global rate of C-section has increased from 7% in 1990 to 21% in 2021 (WHO, 2021). In Scotland, the trend over the past 40 years has been of a steady rise in the percentage of C-Section being performed. In 1976 approximately 9% of all deliveries were undertaken by C-Section, and this has risen to nearly 32% by 2017 (ISD Scotland).

Compared with vaginal delivery, C-section is associated with increased length of stay (LoS) in the hospital, which is reported to be longer in C-section than vaginal delivery (Campbell, 2015; Kumar, 2021). As a result, the length of hospital stay is becoming an area of interest and a critical outcome measure for researchers worldwide since it reflects the duration of patient hospitalization and can be an important health indicator. The reason for that is that length of stay can imply the hospital's activity and efficiency, as well it can reflect its implications for resource utilization and consumption, patient outcomes, and healthcare costs (Bowers, 2016; Ghaffari, 2021).

The type and complexity of surgical procedures can significantly impact the length of stay. Surgeries or procedures requiring extensive postoperative care, such as organ transplantation or cardiac surgery, typically result in longer hospital stays (Gerard et al., 2019). Furthermore, postoperative complications, such as infections or wound healing issues, can prolong hospitalization (Nguyen et al., 2016). Variations in LOS have significant implications for patient outcomes, healthcare resource utilization, and healthcare costs. Obstetrics and gynecology is no exception to this, where wide variations in the length of stay are being observed worldwide (Federspiel et al, 2020).

As mentioned above, prolonged length of stay after C-section and variations in the length of stay, similarly to other procedures, can affect resource utilization and healthcare costs. Variations in LOS after a C-section have direct implications for resource utilization and healthcare costs. Prolonged hospital stays result in increased consumption of hospital resources such as bed occupancy, nursing care, medications, and diagnostic tests (Bick et al., 2019). Moreover, the length of hospital stay can indirectly reflect the quality of care and patient safety, indicating postoperative complications or suboptimal recovery processes, which can affect patient outcomes and satisfaction (Cunningham et al., 2018). Finally, longer stays can lead to increased bed occupancy and potential bottlenecks in the maternity ward or surgical units, affecting the ability to accommodate other patients in need of care (Bick et al., 2019).

This transition from a small minority to a significant proportion of mothers undergoing C-Section has implications for both the maternal population and health care providers. Enhanced recovery is an intervention which aims to limit the stress of surgery and promote a return to normality following surgery. Following a C-Section, mothers are expected to bond with and care for their baby, therefore, limiting the stress of surgery and optimising recovery at this time seems particularly pertinent. Multiple centres have introduced enhanced recovery programs in a variety of formats and common themes between units were observed (Coates, 2016). However, Corso et al. (2017) in a review of enhanced recovery after elective C-section concludes that there is a paucity of existing evidence to support structured interventions in C-section, and that the individual effect of enhanced recovery elements has not been studied and further highlights a lack of controlled studies.

Hospital protocols and care pathways are a way of standardizing care and addressing prolonged length of hospital stays, while ensuring high quality health services. The implementation of standardized care protocols, such as enhanced recovery pilots after surgery (ERPs), can reduce LOS, as well as variations in LOS, after procedures such as a C-section. ERPs programs incorporate evidence-based interventions, optimized pain management, early mobilization, and enhanced patient education to promote faster recovery and reduce hospital stays (Ljungqvist et al., 2017). A study by Spanjersberg et al. (2016) demonstrated the effectiveness of an ERP in reducing the length of stay after colorectal surgery.

2.1. Aim of the Study

In this chapter we evaluate the effect of implementing an enhanced recovery pilot programme after elective caesarean section (C-Section). The pilot targeted at reducing the length of stay in hospital post-delivery for elective C-section patients at the Princess Royal Maternity (PRM) in Glasgow.

In this study, we will utilise the Scottish Morbidity Record (SMR) data, in combination with locally collected data. Our aim is to conduct a comparison of the length of stay (measured in days) between mother who underwent treatment within the pilot program and mothers who did not. We will achieve this by establishing a matched group of mothers, sharing similar observable characteristics, who were treated at different maternity units across Scotland during the same pilot timeframe.

2.2. The Pilot: An Enhanced Recovery Pilot after Caesarean section

The Princess Royal Maternity is a city centre tertiary maternity unit with approximately 5,200 deliveries per annum and a C-Section rate of approximately 35%. It has a dedicated elective theatre which runs alongside two emergency theatres. The Princess Royal Maternity (PRM) is a tertiary referral centre for invasive placental disease and these elective C-section are also accommodated in the elective theatre.

An enhanced recovery protocol was introduced at the Princess Royal Maternity unit in June 2015, and was fully embedded by August 2015. This comprised a bundle of care with five elements: a multidisciplinary (anaesthetic, midwifery and physiotherapy) pre-operative preparation class held the week prior to surgery which educated mothers and their birthing partners about their expected clinical course and recovery; return to oral diet within one hour of leaving theatre; discontinuation of intravenous fluids within one hour of leaving theatre; mobilisation (defined as stood out of bed) within eight hours of the onset of anaesthesia; and, removal of urinary catheter by seven o'clock the morning following surgery (see flow chart below).

Figure III.1 Flow chart of enhanced recovery intervention at the Princess Royal Maternity Unit

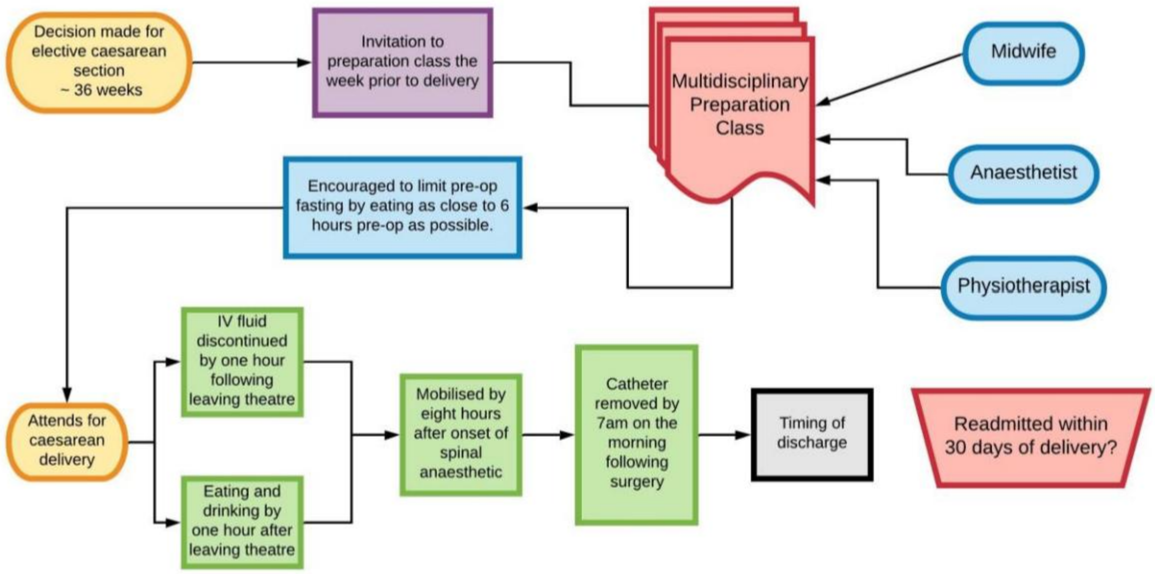


Figure III.1 illustrates the structured care pathway followed as part of the Enhanced Recovery (ER) protocol. The flowchart outlines the sequence of intervention elements, beginning with the decision for elective C-section around 36 weeks gestation, followed by multidisciplinary preparation and specific perioperative milestones.

2.3. Research Objectives

Our study will primarily focus on mothers who underwent elective C-section with the main goal to evaluate the effect of the pilot on maternal length of stay post operation.

To investigate the hypothesis that mothers treated under the pilot, with shorter hospital stays post-delivery, are more prone to subsequent readmissions, we will conduct a parallel analysis to determine whether those with lower average post-birth hospital stays had differing probabilities of being readmitted.

While the primary emphasis of the pilot centres on mothers who underwent elective C-sections, an exploration will also be undertaken to assess the impact of the pilot on mothers who underwent emergency C-sections.

Lastly, leveraging local audit data, we will compare the compliance with enhanced recovery elements to the length of hospital stay (measured in hours) following delivery.

Table III.1 Research Objectives

Research Objective	Outcome variable	Methods
1.Investigate the effect of the pilot on maternal length of stay post elective C-section	LOS	Matching methods
2.Investigate the effect of the pilot on the probability of readmission post elective C-section	Readmission to hospital for reasons related to childbirth	Matching methods
3.Investigate the effect of the pilot on maternal length of stay post emergency C-section	LOS	Matching methods
4.Investigate if compliance with the pilot can influence maternal length of stay	Length of stay in hours versus number of pilot elements delivered	Descriptive analysis/visualisation

3. MOTIVATIONAL INCENTIVES OF THIS STUDY

Since the 1970s, there is a significant increase in the rates of C-sections across many developed countries (Althabe, 2006; Information Centre, 2009; Betrán, 2016; OECD, 2017; NHS, 2017). More specifically, in Scotland, the rates of C-section increased from 20.7% in 2000 to 32.4 in 2015 (ISD Scotland, 2016).

C-sections are a vital surgical intervention that ensures the safe delivery of infants when vaginal birth poses risks to the mother and baby. However, the rising rates of C-sections worldwide have led to an increased focus on the length of postoperative hospitalization following these procedures. Prolonged hospital stays after C-sections not only impact healthcare costs but also influence maternal and neonatal outcomes.

The duration of hospitalization after C-sections varies widely and is influenced by a multitude of factors. One key determinant is the type of C-section performed, with emergency C-sections often resulting in longer hospital stays due to potential complications and need for additional monitoring (Maraqa et al., 2019). Maternal health plays a significant role, as the presence of complications such as infections, hemorrhage, or thromboembolic events can necessitate prolonged stays (Dyrbye et al., 2019). Additionally, neonatal health, particularly the need for specialized care, influences maternal hospitalization length (Huang et al., 2014).

The variation in length of stay after C-sections has far-reaching implications for both patients and healthcare systems. Prolonged hospitalization can impact patient satisfaction, increase healthcare costs, and potentially disrupt family dynamics. Longer stays may also delay maternal-infant bonding, hinder breastfeeding initiation, and contribute to psychological stress for both the mother and her support system (Beiranvand et al., 2021).

More specifically, longer stays strain resources, increase bed occupancy rates, and elevate healthcare expenditures, including charges for hospital accommodations, medical procedures, medications, and staff services. This places an additional burden on both patients and the healthcare system (Zhan et al, 2003), which can impact the care provided to other patients and potentially lead to overcrowding in healthcare facilities. Moreover, it can increase the risk of healthcare-associated infections, including surgical site infections. The longer a person remains in a healthcare facility, the higher the exposure to potential pathogens. Additionally, prolonged hospitalization may lead to decreased maternal satisfaction due to the inconvenience, discomfort, and separation from family members. This can negatively impact the overall childbirth experience (Declercq E et al., 2015). Listening to Mothers III: Pregnancy and Birth. New York: Childbirth Connection. A significant implication of extended hospital stays is that they might delay the mother's physical recovery from the C-section surgery. Early mobilization and proper postoperative care are crucial for optimal recovery. Prolonged bed rest can lead to complications such as blood clots, muscle atrophy, and joint stiffness. Finally, they can disrupt family routines, particularly if the mother is the primary caregiver for other children or dependent family members which also can affect the bonding between the mother and her newborn, as well as influence the mental and emotional stability of the mother, contributing to feelings of isolation, anxiety, and depression (Gausia et al, 2010). It's important to note that the specific implications mentioned above may vary based on individual circumstances, healthcare practices, and policies.

Consequently, efforts to minimize the length of postoperative hospitalization after C-sections can improve maternal and neonatal care and enhance the overall experience of the mother, the newborn and the caregiver. One effective approach is the implementation of Enhanced Recovery Pilots or protocols (ERPs) after surgery. ERPs pathways focus on optimizing perioperative care to enhance postoperative recovery and reduce hospital stays (Carvalho et al., 2017) as mentioned in previous sections. These programs aim to reduce postoperative complications, shorten hospital stays, accelerate recovery, and enhance patient satisfaction, following a multidisciplinary approach to patient care (see section 1, section 2.1, Figure III.1). Encouraging early ambulation and mobilization after C-sections has been shown to promote faster recovery and shorten hospital stays (Thöni et al., 2019). Multidisciplinary care involving close collaboration between obstetricians, midwives, and nurses can ensure comprehensive postoperative management, enabling timely discharge and reducing unnecessary delays (Dinsmoor et al., 2020).

It is worth noting that the importance of evaluating Enhanced Recovery Programs cannot be overstated. Comprehensive evaluation empowers healthcare providers, administrators, and policymakers with evidence to make informed decisions, optimize patient outcomes, and streamline healthcare delivery processes. By addressing challenges and embracing evolving methodologies, the healthcare community can harness the full potential of ERPs to revolutionize perioperative care and drive healthcare system improvements.

The evaluation of ERPs ensures that interventions are not only effective but also safe for patients and in our case mothers. Rigorous assessment provides evidence of reduced postoperative complications, lowered morbidity rates, and improved quality of life for patients undergoing various surgical procedures (Greco et al., 2017; Gustafsson et al., 2017). Effective evaluation can also provide healthcare administrators and policymakers with data-driven insights to allocate resources more efficiently (Pędziwiatr et al., 2015). Furthermore, rigorous evaluation aids in identifying the most effective components of ERPs and helps refine protocols based on empirical evidence. This iterative process ensures that ERPs evolve to meet the evolving needs of patients and the healthcare landscape (Nygren et al., 2012). Finaly, the evaluation of this pilots can enable healthcare providers to identify areas for enhancement within ERPs, fostering a culture of evidence-based care delivery (Husted et al., 2012) and develop clinical guidelines, policies, and best practice recommendations, promoting standardized care across healthcare institutions (Ljungqvist & Scott, 2017).

However, the evaluation of ERPs is not without challenges. Heterogeneity in program implementation, variability in outcome measures, and the need for long-term follow-up data pose methodological complexities that require careful consideration. Thus, appropriate quantitative methods are needed in order to effectively evaluate the effectiveness of these pilot programmes. Matching methods offer a powerful means to enhance the validity and reliability of evaluating Enhanced Recovery pilots. More specifically, ERPs often face challenges due to non-random treatment assignment, leading to confounding variables that can distort treatment effect estimates. Matching methods help control for these confounders, making it easier to isolate the true impact of the intervention (Austin, 2011). Furthermore, matching methods can facilitate causal inference by creating more balanced groups, allowing for a cleaner comparison between treatment and control subjects (Stuart, 2010). The application of matching methods also increases the validity of results, enhancing the reliability of conclusions drawn from the evaluation of ER pilots (Rosenbaum & Rubin, 1983).

While matching methods offer several benefits, their successful application requires careful consideration of methodological aspects such as: the choice of covariates for matching, as including irrelevant variables can reduce the quality of matches; the assessment of covariate balance between groups to ensure that the method has achieved its goal of creating comparable groups; the conduction sensitivity analyses helps gauge the robustness of findings to potential hidden biases (Rosenbaum, 1983; Stuart, 2010; Austin, 2011).

Several studies have evaluated the effects and outcomes of enhanced recovery pilots by employing matching methods. Smith et al (2019) evaluated the Impact of Enhanced Recovery Programs on Postoperative Outcomes. This study employs propensity score matching to assess the effects of enhanced recovery programs on postoperative outcomes. The research finds that patients participating in enhanced recovery programs experienced significantly shorter hospital stays and lower complication rates compared to the non-participant group. Johnson (2018) used nearest neighbour matching to evaluate the impact of an enhanced recovery program on gastrointestinal surgery patients. The study reveals that participants in the program had reduced pain medication usage and faster return to functional status compared to non-participants. Similarly to Smith et al (2018), Miler (2020) employed propensity score matching to compare outcomes of patients undergoing cardiac surgery with and without an enhanced recovery protocol. The results indicate that patients following the enhanced recovery pathway experienced shorter lengths of stay and decreased rates of postoperative complications. Propensity score matching has also been used to assess the effects of an enhanced recovery program on gynecologic cancer patients (Chen et al, 2017) . The research finds that patients enrolled in the program had decreased hospital stays and improved postoperative recovery compared to the control group. Finally, Jackson (2019) employed a series of matching methods to evaluate the impact of an enhanced recovery pathway on uro-oncology surgery patients. The findings suggest that patients in the enhanced recovery group exhibited shorter lengths of stay and a reduced need for postoperative interventions compared to the matched control group.

As a result, the continued application and development of matching methods can undoubtedly contribute to advancing the field of healthcare evaluation and improving patient care through guiding clinical decision making and the optimasation of enhanced recovery protocols and informing the refinement of these protocols by enduring they remain relevant and effective in evolving healthcare landscapes.

4. DATA AND METHODS

4.1. Data

After the implementation of the enhanced recovery pilot in August 2015, at Princess Royal Maternity unit, a project board (consisting of Hospital Management, Consultant Obstetrician, Consultant Anaesthetist, Lead Midwife, Enhanced Recovery midwife, and Physiotherapist) was established with assistance from the Scottish Government Whole System Patient Flow Team. The board met on a monthly basis in order to discuss protocol implementation aspects and address barriers to change. An Enhanced Recovery Implementation Midwife was appointed to educate staff, promote enhanced recovery principles, collect data and establish the preparation class. Contemporaneous distribution of audit data to staff was undertaken monthly to inform and motivate staff.

This research conducts an analysis using information from two distinct sources. The first source consisted of national health record data, held by ISD Scotland. The second source comprised data specific to individual hospitals, and it was directly supplied to ISD Scotland.

The research was undertaken in collaboration with ISD Scotland, which granted approval for the study and facilitated the provision of all necessary data. In adherence to this collaboration, the research underwent thorough scrutiny and was granted approval by the Public Benefit and Privacy Panel of ISD Scotland. This approval was secured under the application titled '1617-0023/McIntyre: Evaluating the enhanced recovery pilot in Obstetrics, and the related analysis of C- Section variation in Scotland.' Additionally, the requirement for local Research Ethics Committee approval was waived by the Scientific Officer for NHS Greater Glasgow and Clyde. This exemption was granted based on the determination that the project constitutes a service evaluation.

To conduct this analysis, the primary data source employed was the 'Scottish Morbidity Record Maternity Inpatient and Day Case' (SMR02), maintained by ISD Scotland. These data were utilized to examine the duration of length of stay post-delivery and patient characteristics for all elective C-sections occurring between the 1st of August 2015 and 31st of December 2016. The pilot group from PRM was paired with a comparable cohort of mothers who delivered during the same timeframe at different maternity units across Scotland.

The matching process was based on available observable traits such as age, height, BMI exceeding 35, diabetes, previous C-Section history, prematurity during this C-Section (defined as birth before 35 weeks), delivery month, and the Scottish Index of Multiple Deprivation decile for 2016. The Scottish Index of Multiple Deprivation is a statistical metric established by the Scottish Government to gauge and monitor deprivation across diverse dimensions in Scotland. For additional details and data access, visit: http://simd.scot.

The selection of covariates for the matching process was driven both by clinical relevance and data availability. These variables are widely recognised in the obstetric and health services literature as influential determinants of maternal recovery outcomes, particularly length of stay (Campbell et al., 2015; Molina et al., 2015). For example, BMI, diabetes, and prematurity are closely associated with increased risk of post-operative complications and prolonged hospital stays, while prior C-sections may influence surgical complexity and recovery trajectories. Delivery month was included to account for seasonal or staffing-related effects, and SIMD decile served as a proxy for socioeconomic status, which can influence both health outcomes and healthcare-seeking behaviour.

Moreover, these variables were the most consistently available across both datasets used in this study. The second dataset—derived from the hospital-level enhanced recovery pilot and supplied directly to ISD Scotland—had more limited variable capture compared to the national maternity dataset. As such, the analysis was constrained to observable and harmonised covariates across both sources. While additional confounders such as post-operative complications, neonatal care needs, or maternal preferences would have strengthened the adjustment process, these were not recorded uniformly in the available data. Therefore, variable selection reflects a balance between clinical relevance and the pragmatic limitations of the data infrastructure.

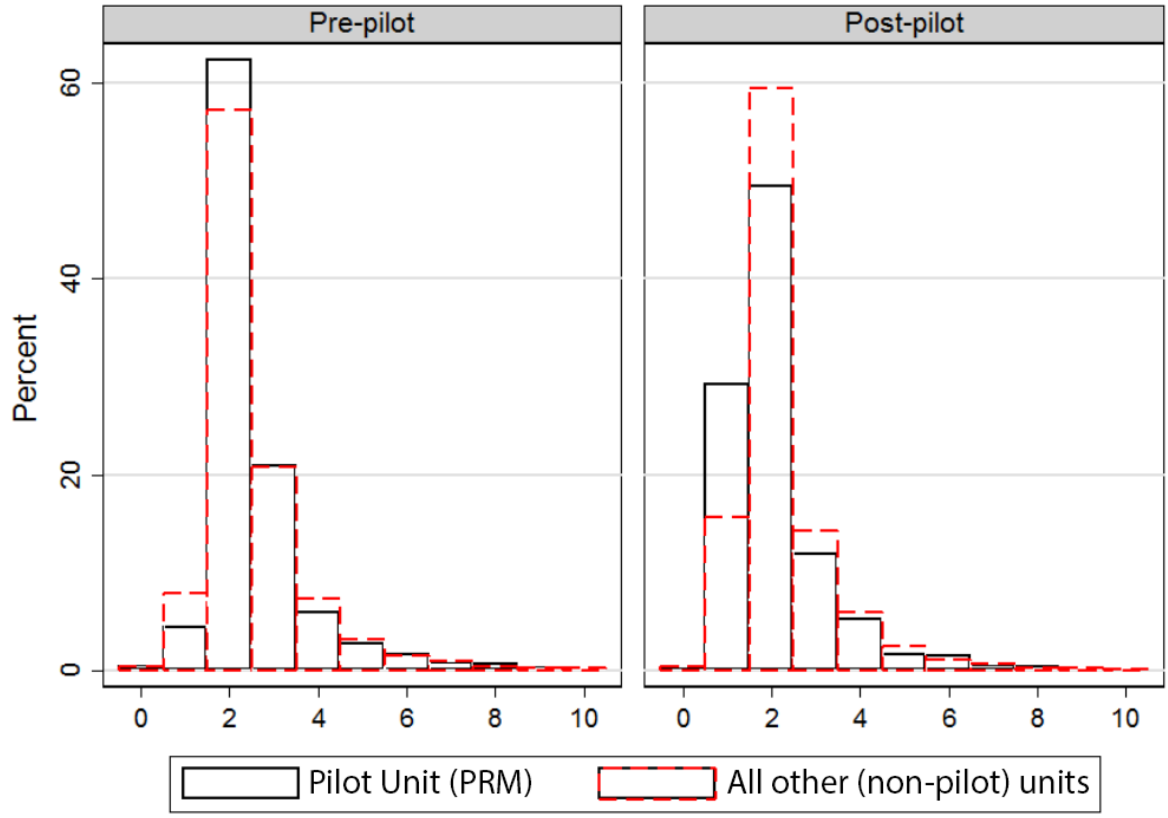
The table below (Table III.1) shows descriptive statistics of the sample that we used for our analysis after undergoing data cleaning (for more information regarding the data cleaning see Appendix).

Table III.2 Descriptive Statistics for raw sample

	Elective C-section non-pilot			Elective C-section pilot		
	Obs	**Mean**	**SD**	**Obs**	**Mean**	**SD**
ln(age)	5,825	3.444	0.176	1,262	3.439	0.177
Height	5,825	163.793	6.578	1,262	163.027	6.562
Previous C-Section	5,825	0.604	0.489	1,262	0.557	0.497
Diabetic	5,825	0.077	0.266	1,262	0.047	0.211
Premature	5,825	0.031	0.173	1,262	0.027	0.162
Obese	5,825	0.334	0.472	1,262	0.450	0.498
Month of delivery	5,825	7.631	3.316	1,262	7.709	3.338
SIMD2	5,825	0.117	0.322	1,262	0.124	0.330
SIMD3	5,825	0.111	0.314	1,262	0.105	0.307
SIMD4	5,825	0.105	0.306	1,262	0.077	0.266
SIMD5	5,825	0.093	0.290	1,262	0.061	0.239
SIMD6	5,825	0.096	0.294	1,262	0.066	0.248
SIMD7	5,825	0.092	0.290	1,262	0.071	0.257

SIMD8	5,825	0.096	0.295	1,262	0.078	0.268
SIMD9	5,825	0.093	0.290	1,262	0.074	0.261
SIMD10	5,825	0.072	0.258	1,262	0.044	0.204

Figure III.2 Distribution of maternal length of stay post elective C-Section (unmatched)



The histogram presented in figure III.2 illustrates the length of post-birth hospital stays for mothers who underwent elective caesarean deliveries. This includes both those at the pilot unit and those at all other maternity units across Scotland. The similarity between the distributions is evident prior to the implementation of the pilot project. However, following the initiation of the pilot program, the two distributions seem to diverge, notably with a higher percentage of mothers at the pilot unit staying in the hospital for just one day compared to the other maternity units. Investigating the reason behind this difference and determining its statistical significance necessitates the matching analysis that will follow in section 5.

4.2. Methods

This study evaluates the impact of the enhanced recovery pilot by comparing outcomes for those patients treated under the pilot with a matched sample of patients. Unlike in a full randomised control trial where patients are randomly allocated to a treatment or a control group, in this case all elective C-section patients at the pilot maternity unit received the enhanced recovery protocol. However, comparing this cohort of mothers to all those giving birth at other Scottish hospitals by elective C-section may not provide a robust comparison. The sample of mothers who give birth at the pilot hospital (one of two main units in the city of Glasgow) may differ from those giving birth elsewhere in Scotland. Therefore, a matching approach was used to construct a control group of mothers who match as closely as possible – on the basis of their observable characteristics - to mothers treated under the pilot.

The principal matching approach was undertaken using propensity score matching (*teffects psmatch* in Stata). However, the robustness of these headline estimates to different matching approaches– including 'doubly robust' methods – is explored. Six different approaches (including the principal approach and robustness methods) were used to estimate the effect of the intervention; propensity score matching (PSM), regression adjustment (RA), inverse probability weighting (IPW), augmented inverse probability weighting (AIPW), inverse probability weighted regression adjustment (IPWRA), and nearest neighbour (NN) matching. These methods are outlined in more detail later in the following section, with indicative references for further discussion of these methods. All estimation used Stata MP 14.1.

In the following sections we will provide a more detailed description of the methods used, justifying the choice of the particular methods mentioned above.

4.2.1. Justification of the choice of methods

4.2.1.1. Principal Matching Approach: Propensity score matching

The simplest matching model matches those individuals in the pilot with individuals in the non-pilot sample based on their predicted probabilities of treatment, this is propensity score matching (Rosenbaum, 1983; Abadie, 2012). It has been used extensively in the literature and will be familiar to most readers.

Propensity Score Matching (PSM) is a statistical technique utilised to address selection bias and confounding in observational studies, enhancing their internal validity. It involves creating balanced comparison groups by estimating the probability of receiving a treatment (propensity score) based on observed covariates (Austin, 2011). Subsequently, treated and untreated individuals are matched based on their propensity scores, reducing the impact of confounding variables and allowing for more accurate causal inference (Stuart, 2010).

PSM leverages the propensity scores to create matched groups for comparison. By pairing treated and untreated individuals with similar or identical propensity scores, the method balances covariate distributions and reduces potential bias. This enhanced comparability aids in isolating the treatment effect and strengthens causal inference (Guo and Fraser, 2010).

In the context of enhanced recovery programs, as the pilot we are evaluating, the latter aim is to optimize patient recovery outcomes through evidence-based interventions. Evaluating the effect of the pilot on the length of maternal stay post C-section is essential to improving surgical practices and patient care. However, inherent challenges like selection bias can introduce biases and affect the credibility of results. PSM mitigates this bias by forming matched groups that are comparable in terms of covariates, ensuring fair comparisons between treated and untreated individuals (Guo and Fraser, 2010). Moreover, PSM allows the creation of control groups that closely resemble the treated group in terms of observed characteristics. This similarity reduces the likelihood of confounding variables influencing outcomes and facilitates the isolation of the effects of pilot intervention (Austin, 2011). By reducing selection bias and confounding, PSM strengthens the ability to draw causal inferences, and we can more confidently attribute observed outcomes to the pilot, yielding more reliable insights (Thorell, 2017).

While PSM is a widely used technique to reduce selection bias in observational studies by balancing observed covariates between treatment and control groups, the method has several limitations — both general and specific to this study. First, and most critically, PSM cannot account for unobserved confounding. The assumption of ignorability (i.e. that all variables influencing both treatment assignment and outcomes are observed and included in the model) is often difficult to verify in practice (Austin, 2011). In this study, factors such as maternal preferences, staff availability, or intraoperative complications were not captured in the dataset and could not be included in the matching process, potentially biasing the treatment effect estimates.

Moreover, PSM results are highly sensitive to the choice and specification of covariates. The inclusion or exclusion of certain variables — or incorrectly modelling their relationship with the treatment assignment — can lead to poor balance and misleading results(Stuart, 2010). Moreover, the functional form of the propensity score model (e.g. linear vs. non-linear effects, interactions) can substantially affect the quality of matches and should be chosen carefully. Furthermore, PSM may lead to loss of data and external validity. Matching can result in dropping unmatched treated or control individuals, reducing the effective sample size and, in some cases, the generalisability of the findings to the full population (Austin, 2009). This issue is particularly problematic in healthcare evaluations with limited sample sizes or rare outcomes.

Propensity Score Matching (PSM) was selected as the principal method for this study due to its intuitive framework for reducing selection bias in observational data—particularly important given the non-random rollout of the Enhanced Recovery (ER) pilot across hospitals. However, given the limitations mentioned above, it is important to perform robustness analyses to assess the robustness of findings after employing propensity score matching. This involves testing the stability of results under different matching techniques, reinforcing the validity of conclusions (Austin, 2011). As a result, the study complemented PSM with a range of alternative matching methods (RA, IPW, AIPW, IPWRA, NN) to ensure robustness of the results and mitigate method-specific weaknesses. These methods are described in the following sections (sections 4.2.1.2 – 4.2.1.5).

4.2.1.2. Nearest Neighbour matching

Similarly to the PSM approach, the nearest neighbour matching (NN) approach is non-parametric in that it does not require the specification of an outcome (in our case, days in hospital post-delivery) or treatment model, instead it identifies a nearest neighbour in the non-treated sample for each treated individual using a weighted average of each of the covariates (Abadie, 2006; Abadie, 2011). NN involves pairing treated mothers with non-treated mothers who have similar covariate profiles. This approach seeks to minimize the distance between individual characteristics, thus creating matched pairs. In the context of evaluating the pilot, NN can help balance patient characteristics and confounding variables between the treated and non-treated groups. Although NN's simplicity suits scenarios where covariate information is limited, it may lack the precision of PSM in achieving covariate balance (Thoemmes, 2011). PSM, on the other hand, explicitly targets balance and addresses interactions, potentially producing more reliable results (Stuart, 2010; Austin, 2011).

4.2.1.3. Regression Adjustment

Regression adjustment (RA), in contrast to these two approaches that were discussed above, estimates a regression model for each treatment level to generate predicted outcomes for each observation, and then averages over these to produce predicted outcome means between the different treatment levels. As a result, it allows us to isolate the effect of the treatment, while accounting for potential biases. (Wooldridge, 2010). This is done without assuming any functional form for the treatment model.

Evaluating the effectiveness of the pilot requires accounting for cofounding variable and ensuring accurate estimations of the treatment effects. Regression adjustment can effectively address the control for the influence of confounding variables when estimating the relationship between an independent variable (the pilot) and a dependent variable (length of stay). Regression adjustment involves building a regression model that includes both the treatment variable and the confounding variables, allowing researchers to isolate the effect of the treatment while accounting for potential biases (Austin, 2011).

4.2.1.4. Inverse probability weighting

The inverse probability weighting (IPW) approach models the probability of treatment without assuming any functional form for the outcome model. Methodologically, it has emerged as a potent technique in observational studies, offering a systematic approach to adjust for confounding factors and derive unbiased treatment effect estimates. In the context of evaluating the pilot under study, IPW holds promise for providing reliable insights into the effect of the pilot on maternal length of stay post C-section (Wooldridge 2010; Wooldridge 2006).

IPW aims to mitigate the effects of confounding variables in observational studies by assigning appropriate weights to observations. It is particularly useful when randomized controlled trials are not feasible or ethical, and observational data is used to assess treatment effects (Feldman, 2011). IPW involves assigning larger weights to observations in underrepresented groups and smaller weights to overrepresented groups, thus reweighting the data to mimic a balanced distribution of confounding variables between treated and non-treated mothers. Overall, Inverse Probability Weighting presents a robust approach for evaluating Enhanced Recovery pilots in healthcare contexts, effectively addressing confounding variables and yielding more accurate treatment effect estimates. By leveraging the propensity score to reweight observations, researchers can draw meaningful conclusions from observational data, enhancing the evidence-based decision-making process in healthcare interventions (Austin 2011; Stuart, 2010).

4.2.1.5. Augmented inverse probability weighting and Inverse probability weighted regression adjustment

Both the augmented inverse probability weighting (AIPW) and inverse probability weighted regression adjustment (IPWRA models are ‘doubly robust’ in that they are robust to either the treatment or outcome model being mis-specified (Wooldridge, 2010).

More specifically, AIPW combines the strengths of Inverse Probability Weighting (IPW) and enhances the precision and validity of the treatment effect estimation by augmenting the IPW technique with targeted maximum likelihood estimation (Wooldridge, 2010; Schuler, 2017). While IPW involves assigning weights to observations to balance the distribution of covariates between treatment and control groups, AIPW introduces a second step where a model is built to predict the treatment outcome, and the weights are further adjusted based on this model's predictions. This augmentation helps achieve doubly robust estimates that remain unbiased even if either the propensity score model or the outcome model is mis specified (Wooldridge, 2010; van der Laan, 2010; Schuler, 2017). In the context of evaluating our pilot, AIPW can be useful for estimating the treatment effects while mitigating the influence of confounders. As a result, AIPW renders the estimates robust to potential model misspecifications, given that it combines information from both the propensity score model and the outcome model. Moreover, by incorporating the outcome model, AIPW can lead to more efficient and precise treatment effect estimates, yielding narrower confidence intervals (Gruber, 2010; Schuler, 2017.

Similarly to AIPW, Inverse Probability Weighted Regression Adjustment (IPWRA) combines the strengths of Inverse Probability Weighting (IPW) and regression adjustment. IPWRA seeks to address confounding by simultaneously incorporating the concepts of IPW and regression adjustment (Wooldridge 2010; Wooldridge, 2015). The method involves assigning weights to observations based on the inverse of their estimated propensity scores, balancing covariate distributions between treated and non-treated groups (in our case mothers). Regression adjustment utilizes these propensity score weights in a regression model, allowing for both the treatment variable and confounding variables to be considered in the analysis (Austin 2011, Wooldridge 2015).

Within the context of this pilot evaluation, IPWRA offers a comprehensive approach to account for confounding, providing more accurate insights into the impact of the intervention on the maternal length of stay post C-section (Robin, 2000; Lumley, 2002). More specifically, IPWRA offers improved covariate balance, as propensity score weights ensure that confounding variables are equally distributed between treatment and control groups, as well as it helps to reduce potential bias in treatment effect estimates, by addressing both the confounding variables and the treatment effect within a single analysis (Wooldridge, 2015).

4.2.2. Methodological Assumptions

The methods used in our analysis our analysis rest upon several fundamental assumptions:

i) Once we've accounted for covariates, there are no unmeasured cofounders influencing the allocation of the treatment (i.e., being treated at the pilot unit).
ii) ii) that each individual has the potential to receive any treatment level
iii) iii) the observations are both independent and identically distributed.

Each of these assumptions is met in our study.

As far as the first assumption is concerned, the pilot program examined in this study was conducted at a single maternity unit and encompassed all mothers who underwent elective (planned) C-sections at that particular unit. It is improbable that patients deciding on their birth-delivery location were aware of this pilot program or that it influenced their choice of maternity unit. Hence, the prospect of patients actively selecting treatment based on this program appears to be highly unlikely. However, even if this was the case, we can still reliably calculate the difference in means between the treated and non-treated groups, provided that the outcome in the absence of treatment is statistically unrelated to the treatment itself. In fact, we can consistently estimate this difference even under a milder assumption: that given a set of covariates, the outcomes of both treated and control groups are unrelated (Colhoon, 2017).

In terms of the second assumption, any mother who were not subjected to this pilot treatment could have received treatment if they had they chosen this pilot maternity unit (Princess Royal Maternity Unit).

Finally, the third assumption is also met, given that the treatment of one patient within the pilot did not exert any influence on the outcomes of other patients, thereby confirming the validity of this assumption as well.

5. RESULTS

Between August 2015 and December 2016, a hospital in Scotland witnessed a total of 63,889 childbirths as part of the pilot phase. Among these, 5,914 births occurred specifically at the pilot unit, constituting approximately 9.3% of all childbirths in Scotland during that time frame. Within the pilot phase, 29.7% of mothers who gave birth at the pilot unit underwent C-sections, with 21.5% being elective C-section and 8.3% being emergency C-section. In comparison, 24.6% of mothers delivering at other hospitals across the same period had C-section deliveries (10.0% elective and 14.6% emergency). Our main sample includes 7,087 women who underwent elective C-section after undergoing data cleaning.

5.1. Elective C-sections

5.1.1. The effect of the pilot on the length of stay

The results (Table III.3) after undertaking propensity score matching to examine the effect of the Enhanced Recovery pilot on maternal length of stay following elective C-section, show a statistically significant reduction in length of stay post elective C-section.

Table III.3 Propensity Score matching results for elective C-section

Type of Test	Coefficient	SE	Z	N
Propensity Score Match	-0.181	0.047	-3.850	7,087

The estimated average pilot effect on the treated sample, after the employment of propensity score matching, indicates a statistically significant reduction in length of stay of 0.181 days. Given that the baseline mean length of stay among control patients was approximately 2.35 days, this equates to a relative reduction of about 7.7%.

Although modest in absolute terms, this effect is meaningful in a high-volume maternity setting. Based on the 2024 average cost of inpatient hospital stay in Scotland—£262 per day (Public Health Scotland, 2021)—this reduction translates to potential cost savings of approximately £0.34 million[18] if all 7,087 patients in the analysis had undergone the ER protocol.

These findings highlight the financial value of even small reductions in postnatal length of stay when applied across a large patient population. Beyond cost implications, the reduction also reflects improved efficiency in postoperative care without apparent clinical compromise. Enhanced recovery protocols aim to promote earlier mobilisation and discharge while supporting patient recovery through standardised, evidence-based practices.

The table presented below (Table III.4) displays the standardized mean and variance for each of the matched variables following the execution of propensity score matching. A standardized mean closer to 0 and a standardized variance closer to 1 indicate a more successful matching outcome.

Table III.4 Comparison of matched and treated cohort

	Standardised differences		Variance ratio	
	Raw	Matched	Raw	Matched
ln(age)	-0.024	0.028	1.020	0.984
Height	-0.117	-0.007	0.995	0.961
Previous C-section	-0.096	-0.010	1.033	1.004
Diabetic	-0.125	0.024	0.629	1.079
Premature	-0.023	0.008	0.881	1.045
Obese	0.240	-0.005	1.114	0.997
Month of delivery	0.024	0.016	1.013	0.997
SIMD2	0.022	-0.037	1.054	0.914
SIMD3	-0.017	0.008	0.958	1.019
SIMD4	-0.096	-0.023	0.758	0.938
SIMD5	-0.119	0.044	0.682	1.130
SIMD6	-0.110	0.015	0.711	1.044
SIMD7	-0.077	-0.006	0.791	0.983

[18] Public Health Scotland (2021) *Delayed discharges in NHSScotland annual: Annual summary of occupied bed days and census* figures data to March 2021 (planned revision). Available at: https://www.publichealthscotland.scot/publications/delayed-discharges-in-nhsscotland-annual/delayed-discharges-in-nhsscotland-annual-annual-summary-of-occupied-bed-days-and-census-figures-data-to-march-2021-planned-revision/

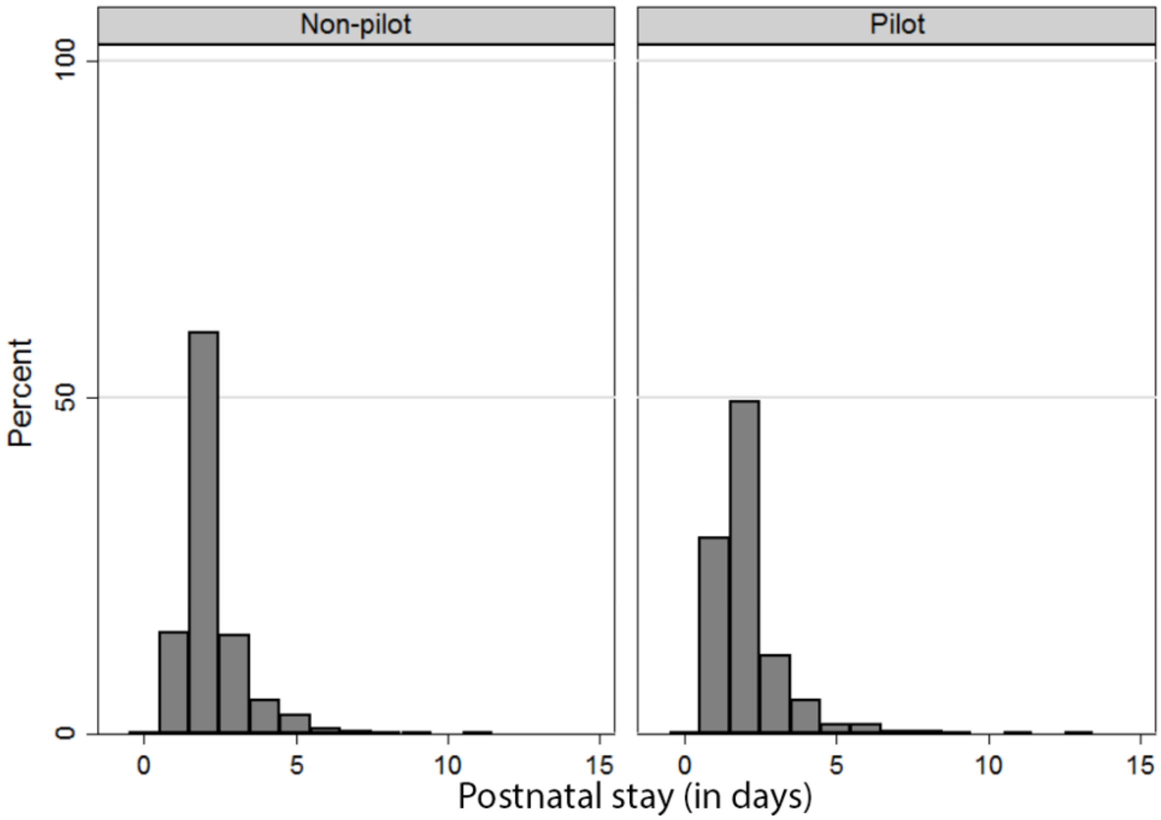
SIMD8	-0.065	0.032	0.826	1.091
SIMD9	-0.069	-0.019	0.811	0.946
SIMD10	-0.120	-0.030	0.628	0.899

Number of obs	=	7,087
Treated obs	=	1,262
Control obs	=	5,825

Based on this assessment, it is evident that our matched and treated groups exhibit significant similarity.

Figure III.3 presents a comparison between the distributions of maternal length of stay after elective C-section for both the treated and control groups.

Figure III.3 Distribution of maternal length of stay matched and pilot sample



The impact of the pilot initiative is evident in Figure III.3, depicting the length of stay distribution for mothers who underwent elective C-section at the Princess Royal Maternity unit (pilot group) in contrast to those who gave birth at other maternity units across Scotland.

Within the pilot group, a higher proportion of mothers (29.3%) are observed to be discharged from the hospital on the first day compared to the matched group (14.4%).

In order to further examine the robustness and consistency of our findings after applying propensity score matching (PSM), we conducted a comprehensive robustness analysis using a variety of alternative matching and estimation techniques. Specifically, we employed regression adjustment (RA), inverse probability weighting (IPW), augmented inverse probability weighting (AIPW), inverse probability weighted regression adjustment (IPWRA), and nearest neighbour (NN) matching using two neighbours. These methods offer complementary approaches to estimating treatment effects and are particularly useful for assessing the sensitivity of results to different modelling assumptions and specifications.

Table III.5 Robustness analysis results for elective C-section

Type of Test	Coefficient	SE	Z	N
RA	-0.172	0.041	-4.170	7,087
IPW	-0.150	0.046	-3.280	7,087
AIPW	-0.164	0.042	-3.880	7,087
IPWRA	-0.167	0.041	-4.020	7,087
NN(1) BA	-0.209	0.042	-4.950	7,087
NN(2) BA	-0.202	0.042	-4.860	7,087

The results presented in Table III.5 confirm the robustness of the initial estimates derived using PSM. Across all alternative matching methods, the estimated effect of the enhanced recovery pilot on the average length of stay (LOS) following elective Caesarean section remained statistically significant and consistent in direction and magnitude. This reinforces the conclusion that the observed reduction in LOS is not an artefact of a specific modelling choice, but rather a robust finding that holds under a range of estimation strategies. Moreover, the treatment effect visualised in Figure III.3 is supported by the statistical significance demonstrated through these alternative approaches, suggesting that the observed differences in LOS are unlikely to be due to random variation or sampling error.

The estimated treatment effects across all five methods range between 0.15 and 0.21 days, indicating that participation in the enhanced recovery programme is associated with a meaningful reduction in LOS. While the absolute reduction in LOS may appear modest at first glance, this effect is clinically relevant and operationally significant in high-volume maternity settings. Such a reduction, when scaled to a large number of patients, translates into a substantial improvement in resource utilisation, hospital efficiency, and potentially patient outcomes. The consistency of these estimates across different methodological frameworks enhances the credibility of the results and provides strong empirical support for the effectiveness of the enhanced recovery pilot in reducing post-operative hospital stays following elective C-sections.

These findings further highlight the value of using multiple estimation strategies in observational studies, particularly when estimating treatment effects in healthcare settings where unmeasured confounding and selection bias can pose challenges. By demonstrating that the core finding—reduced LOS associated with the pilot—is stable across a diverse set of analytical approaches, we strengthen the internal validity of our study and provide more compelling evidence to inform clinical and policy decisions

5.1.2. The effect of the Pilot on readmissions

In order to examine the effect of the enhanced recovery pilot on the likelihood of hospital readmission following an elective C-section, we applied propensity score matching to compare outcomes between mothers who participated in the pilot and a matched cohort who did not. This analysis aimed to assess whether the observed reduction in hospital stay was associated with any unintended increase in post-discharge complications that might require hospital readmission.

The result from the primary analysis using propensity score matching (Table III.6) showed that mothers treated under the enhanced recovery protocol had no statistically significant difference in their likelihood of being readmitted to hospital compared to mothers in the matched control group. The coefficient for the treatment effect was −0.004 with a standard error of 0.011 and a Z-value of −0.370, indicating a small and statistically insignificant effect.

Table III.6 Propensity score matching results for readmissions post elective C-section

Type of Test	Coefficient	SE	Z	N
PS Match	-0.004	0.011	-0.370	7,087

As with the previous length of stay analysis, we tested the robustness of our results using a range of alternative estimation methods, including regression adjustment (RA), inverse probability weighting (IPW), augmented inverse probability weighting (AIPW), inverse probability weighted regression adjustment (IPWRA), and nearest neighbour (NN) matching using one and two neighbours, respectively. The primary finding of this analysis (as shown in Table III.6), remained consistent across all alternative estimation strategies, as reported in Table III.7. Across methods, effect estimates ranged from −0.007 to 0.000, with none of the Z-values approaching the conventional threshold of ±1.96 required for statistical significance.

Table III.7 Sensitivity analysis results for readmissions post elective C-section

Type of Test	Coefficient	SE	Z	N
RA	-0.007	0.008	-0.860	7,087
IPW	-0.005	0.008	-0.620	7,087
AIPW	-0.006	0.008	-0.710	7,087
IPWRA	-0.006	0.008	-0.750	7,087
NN(1) BA	0.000	0.009	-0.050	7,087
NN(2) BA	-0.005	0.008	-0.610	7,087

5.2. Emergency C-sections

Table III.8 presents the results from propensity score matching for mothers who underwent emergency Caesarean sections. The estimated effect of the enhanced recovery pilot on maternal length of stay for this group was not statistically significant, and thus there is no evidence to suggest that the pilot influenced hospital stay duration for women who experienced an emergency C-section.

Table III.8 Propensity score matching results for emergency C-sections

Type of Test	Coefficient	SE	Z	N
PS Match	0.116	0.165	0.700	8,950

This finding was consistent across all additional matching approaches, as shown in Table III.9. The alternative estimators—including regression adjustment (RA), inverse probability weighting (IPW), augmented IPW (AIPW), inverse probability weighted regression adjustment (IPWRA), and nearest neighbour matching (NN)—all yielded small, non-significant effects, with Z-values ranging from −0.860

Table III.9 Sensitivity analysis results for emergency C-sections

Type of Test	Coefficient	SE	Z	N
RA	-0.067	0.082	-0.820	8,950
IPW	-0.040	0.090	-0.450	8,950
AIPW	-0.073	0.085	-0.860	8,950
IPWRA	-0.071	0.085	-0.840	8,950
NN(1) BA	-0.059	0.091	-0.650	8,950
NN(2) BA	-0.050	0.089	-0.560	8,950

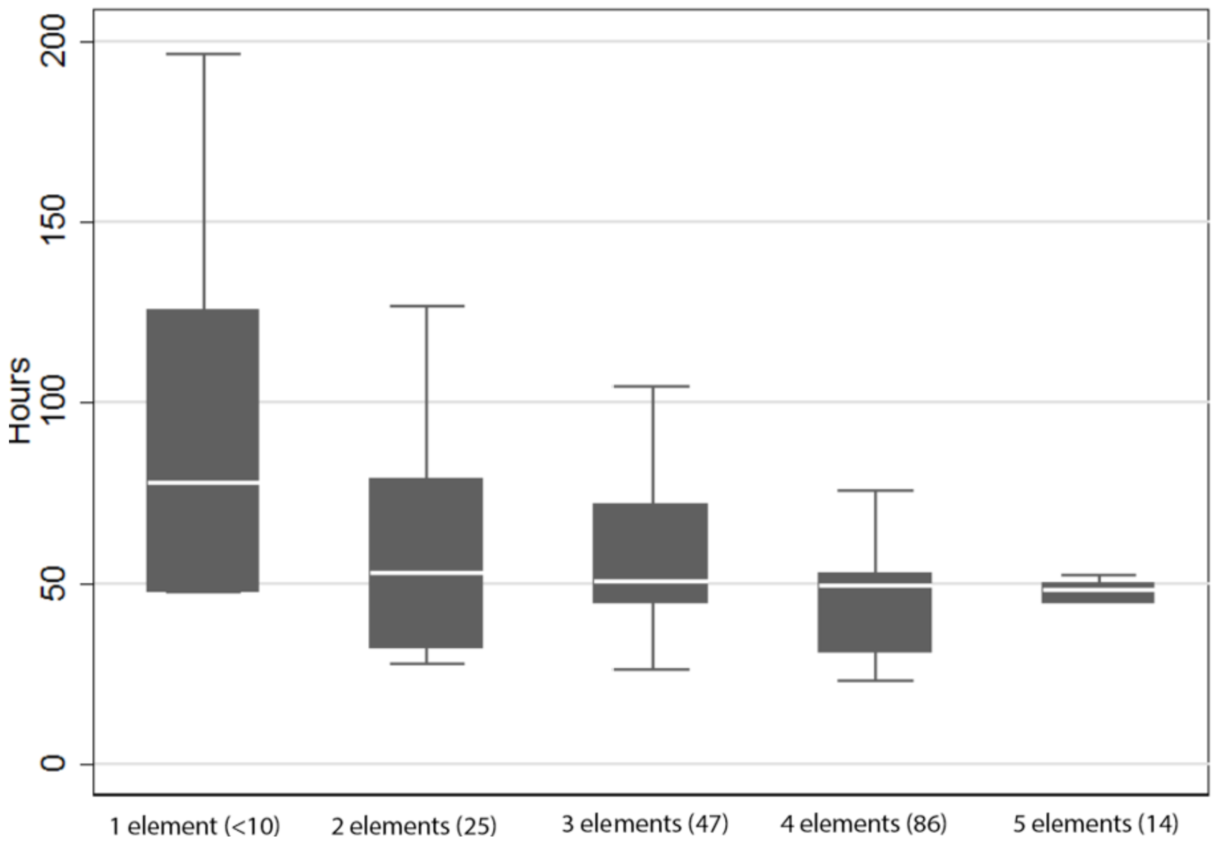
The consistency of the null results across methods suggests that the enhanced recovery protocol had no measurable impact on postnatal length of stay among women undergoing emergency C-sections. This is perhaps explained by the fact that the ER pilot (in its currently applied form) was primarily designed for and targeted at elective Caesarean deliveries, where the clinical pathway is predictable and can be standardised in advance. In contrast, emergency C-sections are typically performed in urgent or unplanned circumstances, often involving greater clinical complexity, more severe maternal or fetal risk factors, and a higher likelihood of post-operative complications. These factors may limit the feasibility or effectiveness of applying ER elements—such as early mobilisation or oral intake protocols—in a consistent and timely manner.

Moreover, patients undergoing emergency C-sections may require more intensive monitoring and longer recovery regardless of postoperative protocols, thereby attenuating any potential benefit from the ER model. Additionally, since the ER programme includes pre-operative education and multidisciplinary preparation—which is not feasible in emergency contexts—key components of the intervention are inherently absent for this patient group. As such, it is reasonable to expect that the ER pilot would not significantly affect outcomes for emergency cases, and the results here provide empirical support for that distinction.

5.3. Additional Analysis – variation in the length of stay based on the number of pilot elements received

As mentioned in section 4.1, local audit data was collected from mothers included in the pilot programme. Whilst the sample of treated mothers was not randomly sampled, the local audit data was collected from every fourth mother on a rolling basis. The key feature that we examine here is whether mothers included in the pilot programme varied in their length of stay post—delivery depending upon how many elements of the protocol they received. This is show in Figure below.

Figure III.4 Distribution of maternal length of stay in hours by number of pilot elements received



The figure above (Figure III.4) suggests that the more pilot elements a mother to be receives, the more decreased the maternal length of stay is post C-section. As a result, greater compliance with the enhanced recovery protocol, as measured by the number of elements of the protocol the mother received, seems to be associated with a decreased length of stay. It is worth mentioning that causation cannot be inferred given the structure of the pilot and the fact that data was collected locally.

6. DISCUSSION

6.1. Overview

The main finding of this study is that the implementation of the Enhanced Recovery (ER) pilot was associated with a significant reduction in maternal length of stay following elective Caesarean sections. The primary results, derived using propensity score matching, showed a reduction of 0.181 days in average length of stay among treated mothers. This translates to an estimated cost saving of approximately £0.34 million during the pilot period alone, based on Public Health Scotland estimates regarding the average cost of daily hospital stay. To test the robustness of this result, a series of alternative matching methods were applied. These methods consistently reported reductions in length of stay ranging from 0.15 to 0.21 days, corresponding to estimated cost savings between £0.29 and £0.39 million[19] during the pilot period. These findings support the effectiveness of the ER pilot in reducing postoperative recovery time without compromising patient outcomes, as readmission rates remained unchanged.

Notably, the pilot's impact on the length of stay for mothers undergoing emergency C-sections at the pilot unit was not established. While an anticipation of decreased length of stay in both elective and emergency cases might have been anticipated, this wasn't observed. Colhoun et al. (2017) noted an increase in day one discharges in emergency cases post their elective enhanced recovery protocol introduction, suggesting multidisciplinary adoption and cultural changes.

Moreover, no rise in readmissions, a reassuring control measure, was detected. Nonetheless, readmission rates are coarse measures indicating significant complications post-discharge. Discharge timing is intricate, influenced by diverse factors beyond patient fitness. Furthermore, no rise in readmissions for treated mothers under the pilot who had an elective C-section was detected. Nonetheless, readmission rates are coarse measures indicating significant complications post-discharge. Discharge timing is intricate, influenced by diverse

[19] Based on Public Health Scotland estimates, the average cost of bed is 262£.
Public Health Scotland (2021) *Delayed discharges in NHSScotland annual: Annual summary of occupied bed days and census* figures data to March 2021 (planned revision). Available at: https://www.publichealthscotland.scot/publications/delayed-discharges-in-nhsscotland-annual/delayed-discharges-in-nhsscotland-annual-annual-summary-of-occupied-bed-days-and-census-figures-data-to-march-2021-planned-revision/

factors beyond patient fitness. That said, readmission is a relatively crude outcome indicator and does not fully capture the complexity of discharge decisions, which may be influenced by social support, staffing, ward policy, or maternal preferences.

6.2. Contribution

This study contributes to the growing body of literature on enhanced recovery protocols by providing quantitative evidence on their impact within the context of elective C-sections in Scotland. Specifically, it evaluates how such protocols influence maternal length of hospital stay and the likelihood of readmission, using robust quasi-experimental methods such as propensity score matching and alternative estimators.

In addition to assessing overall effectiveness, this study also explores the role of adherence to specific elements of the enhanced recovery bundle, offering new insights into how partial versus full compliance influences outcomes. This granularity in analysis enriches current understanding of implementation fidelity and its importance in clinical effectiveness evaluations.

While enhanced recovery protocols have been studied in other surgical contexts and health systems, their application to maternity care—particularly in elective caesarean deliveries—remains relatively underexplored. This study, therefore, adds valuable evidence to a limited but emerging field and provides policy-relevant findings that can inform service design, resource allocation, and patient care strategies in maternity services.

6.3. Strengths and Limitations of the study

This study has several notable strengths. First, it employs a rigorous quasi-experimental design using propensity score matching (PSM) to reduce bias from confounding variables, thereby improving the internal validity of the findings. The inclusion of multiple alternative matching estimators—such as regression adjustment, inverse probability weighting, augmented IPW, IPW regression adjustment, and nearest neighbour matching—strengthens the robustness of the results and increases confidence in the reported treatment effects. Second, the study benefits from a rich administrative dataset covering a comprehensive set of pre-treatment covariates, enabling detailed adjustment for observable differences between treatment and control groups. Third, the research provides practical insights into the real-world implementation of enhanced recovery protocols within a large urban maternity unit and considers both effectiveness (in reducing length of stay) and safety (through hospital readmission rates). Finally, this study adds an important dimension by investigating the role of compliance with individual components of the intervention bundle, offering further implications for implementation science and maternity service design.

Nonetheless, the study does not come without limitations. One limitation of our study is that the matching process was constrained by the quantity of variables stored within the national database and the locally collected hospital-level dataset. While it's probable that additional co-factors are present and it would have been preferable to include them in the matching, it's important to note that we are confident that all factors influencing treatment allocation have been accounted for. Other potential variables that could impact the duration of stay after a C-section might encompass factors such as medical treatment provided to the newborn, complications arising from surgery, and maternal health conditions.

In terms of the analysis of the possibility of readmission, interactions with general practitioners and community midwives were not included in the study but could offer a more meaningful measure of appropriateness for early discharge, since the timing of discharge is a complex outcome and influenced by many factors not just patient fitness (Brasel, 2007; Colhoon, 2017).

As far as the correlation between pilot bundle adherence and the length of stay is concerned, the non-random allocation of care bundles limits causal inference. While the observed association is informative, the possibility of residual confounding cannot be entirely ruled out.

6.4. Policy implications and Recommendations

From a policy perspective, one clear recommendation is to scale up enhanced recovery protocols for elective C-sections nationally, while ensuring that such programs are implemented with fidelity to the core bundle elements. However, caution should be exercised in assuming automatic replication of these results. A key limitation in implementation is that this pilot was conducted in a tertiary urban maternity unit with relatively consistent clinical leadership and engagement. Therefore, contextual adaptation and continuous monitoring of outcomes are crucial to ensure effectiveness and safety in varied hospital settings (Colhoun et al., 2017; Pędziwiatr et al., 2015).

Furthermore, this study highlights the importance of integrating ERP initiatives into wider maternity care planning, especially as elective C-sections become increasingly common—both due to maternal request and clinical complexity (Betrán et al., 2016; WHO, 2021). Yet, enhanced recovery should not be viewed simply as a cost-containment measure. There is a risk that focusing solely on reducing length of stay may inadvertently pressure early discharge, especially in resource-constrained settings. Therefore, patient-centred metrics, including maternal satisfaction, perceived readiness for discharge, and post-discharge support, should be embedded in the evaluation of ERP outcomes (Wiklund et al., 2007; Blomquist et al., 2011).

Another key recommendation is to improve the capture and use of routine maternity care data, particularly regarding ERP compliance, maternal morbidity, and patient-reported outcomes. For policy to be genuinely data-driven, investment is needed in better electronic health record infrastructure and data linkage between secondary care and community services (Brasel et al., 2007; Campbell et al., 2015).

Finally, as health systems confront growing demand, interventions that promote clinical efficiency without compromising care quality should be a strategic priority. Enhanced recovery protocols, when embedded within multidisciplinary teams and supported by quality improvement methods, present a viable avenue to achieve this. However, further research—particularly pragmatic trials and implementation studies—is necessary to assess long-term clinical and economic outcomes, and to ensure equitable delivery of benefits across all population groups.

6.5. Conclusion

This study provides clear evidence of the effect of Enhance Recovery Pilot on the length of stay post elective C-section. At present, there is a lack of randomized controlled trials (RCTs) that examine how enhanced recovery protocols influence the duration of hospital stays for elective (planned) caesarean deliveries. Consequently, conducting a broader and more thorough examination of enhanced recovery protocols could provide greater insight into how individual and combined factors affect recovery times. As our medical record databases advance in quality, especially in the context of big data, it is probable that enhanced matching techniques can be achieved, leading to more dependable and conclusive outcomes.

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Appendix

The cleaning of the initial raw sample included the following steps:

Table III.10 Cleaning of the data

We removed observations from the initial raw sample if:	Post-natal stay was longer than 30 days
	Maternal Height was less than 100 (cm)
	Estimated gestation was over 45 (weeks)
	Baby weight was over 5500 (grams)
	Maternal weight was over 999
	There were inconsistencies in the duration of labour
	Inconsistencies in the clinical risk factors (diabetes)
	There were inconsistencies in the deprivation index
	There were inconsistencies in the year or month
	There were any duplicates