EXPLAINING TRENDS IN THE RATE OF CAESAREAN SECTION IN IRELAND 1999-2007

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Abstract: This paper explores levels and trends in the prevalence of Caesarean section delivery in Ireland between 1999 and 2007. Over this period the Caesarean section rate in Ireland increased by almost one quarter. Using data from the Irish National Perinatal Reporting System and the Hospital In-Patient Enquiry scheme we examine the contribution of maternal, birth/infant, hospital and clinical characteristics to the rise in the Caesarean section rate over the period. Analyses show small increases in the clinical indicators of risk for caesarean section driven by significant change in maternal characteristics (mothers age and number of previous deliveries) and changing clinical practice. Grouped logit models of risk of caesarean by hospital and time period account for 63% in the variation the growth trend across hospitals. We discuss the possible contribution of other changes in physician behaviour.

I INTRODUCTION

A Caesarean section (CS) is an operation in which the baby is born through an incision in the woman's abdomen and uterus. In 1997, UNICEF and the World Health Organisation (WHO) stated that CS should account for not less than 5 nor more than 15% of all births (UNICEF et al., 1997). This was a restatement of the WHOs original recommendation published over 10 years earlier (WHO, 1985), in which it was stated that there were no additional health benefits associated with a rate above 10-15% based on an examination of estimates of national CS rates and perinatal and maternal mortality rates from various countries.[2] In a recent publication the WHO *et al.* (2009) have stated that there is no empirical evidence for an optimum percentage or range of percentages. They state that 'the proposed upper limit of 15% is not a target to be achieved but rather a threshold not to be exceeded'. Despite the WHO recommendation and initiatives to curb the trend the CS rate in Ireland increased beyond the threshold in the mid-nineties. In 1993, the Department of Health and Children reported a CS rate of 13% by 1999, the next year for which data was available, the rate had increased to 20.5% of total births (HIPE & NPRS Unit ESRI, 2002). That represents a 57.2% increase over a 7 year period and was even greater than that experienced in England which reported a 37.1% increase in the CS rate over the same period (NHS Information Centre, 2009).

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[2] In setting the acceptable levels it was deemed appropriate to select a conservative lower limit and a maximum that is slightly higher than the level reported in most developed countries, but less than the levels in those countries known to have excessive use of the procedure.

Studies have shown that CS increases risks for both mothers and babies when compared to spontaneous vaginal birth and the consensus tends to be that a lower CS rate is preferable. Research has identified sets of risk factors and many countries including the UK have developed clinical guidelines in an attempt to reduce their CS rate (National Collaborating Centre for Women's and Children's Health, 2004). As well as clinical risks a CS is significantly more expensive than a vaginal delivery which has implications for health service provision.

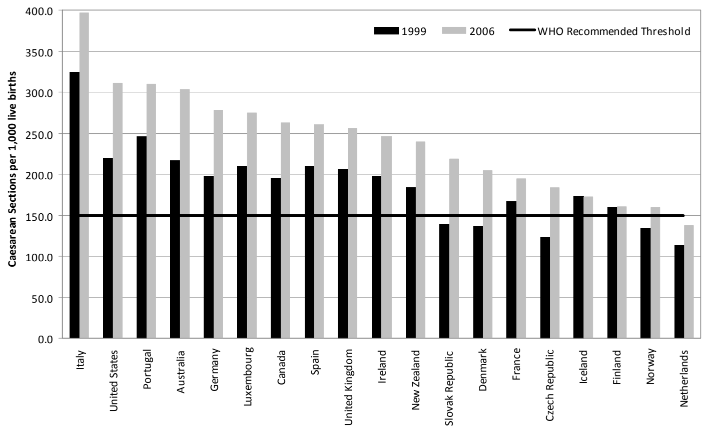
The aim of this paper is to outline and if possible to explain the trend in the CS rate in Ireland using data from the National Perinatal Reporting System (NPRS) and the Hospital In-Patient Enquiry (HIPE) from 1999 to 2007. The paper is laid out as follows. The next section examines the relevant Irish and international literature on CS rates. This is followed by a discussion of the NPRS and HIPE data used for the paper in Section III. Section IV is a descriptive analysis of the CS rate in Ireland between 1999 and 2007 that examines the factors deemed to influence the change in the CS rate by the literature. Using grouped logit models Section V examines the factors leading to the increasing trend in the CS rate. Finally, in Section VI we summarise our findings, draw out some conclusions and outline directions for future research.

II LITERATURE

We begin by examining CS rates across the EU-27 to see how Ireland compares to other countries and how this has changed between 1999 and 2006, the latest year for which data is available (Figure 1). There has been an increase in the number of CSs per 1,000 live births in all countries. Italy consistently had the highest number of CSs per 1,000 live births with a rate of 397.2 per 1,000 live births in 2006, over two and a half times the WHO recommended threshold. In 2006, only the Netherlands had a CS rate of less than the 15% threshold recommended by the WHO, at 137.8 per 1,000 live births.

It is not only in Europe that CS rates continue to rise. Preliminary data for 2008 for the United States show that the CS rate rose for the twelfth consecutive year reaching 32.3% or almost one third of all births, this was the highest rate ever recorded in the United States. This reflects an increase of over 50% from its level of 20.7% in 1996 (Martin *et al.*, 2009; Hamilton *et al.*, 2010).

Figure 1: *Caesarean sections per 1,000 live births 1999 and 2006*



Source: (OECD, 2009)

CS can and does contribute to better outcomes for some births but it is important to highlight the impact that such an invasive surgical procedure can have on the health outcomes of mothers and babies has and its cost implications for health services.

The National Institute for Clinical Excellence (NICE) in the UK commissioned and published a set of clinical guidelines for CS in 2004. These guidelines are recommendations on the appropriate treatment and care of people with specific diseases and conditions within the NHS, in this case CS. The guidelines are based upon the best available evidence. As part of these guidelines they have summarised the effects of CS compared with vaginal delivery for women (National Collaborating Centre for Women's and Children's Health (2004), p18). They outline several conditions that are more likely to affect the mother after CS compared with vaginal birth. These include abdominal pain, the need for further surgery, increased length of stay, hysterectomy, uterine rupture and maternal death amongst others. These findings have been replicated in other countries (Sakala, 2006; Villar *et al.*, 2006; Knight *et al.*, 2008). Babies born by CS are seven times more likely to have breathing problems just after the birth compared with babies born vaginally (National Collaborating Centre for Women's and Children's Health, 2004).

As well as clinical outcomes for mothers and babies the cost of the increasing number of CSs is an issue that has been highlighted by a number of studies. The UK Audit Commission (1997) examined maternity services in England and Wales and reported that a 1% rise in the CS rate costs the NHS £5 million per year. A study of Scottish data in 2002 examined the economic costs of alternative modes of delivery during the first two months postpartum (Petrou *et al.*, 2002). This found that initial hospitalisation costs for CS delivery were over twice those for spontaneous vaginal delivery. When other costs such as hospital readmissions, midwifery care, general practitioner care and health visitor support were accounted for CS was found to cost 1.8 times as much as spontaneous vaginal deliveries.

What factors might explain the Caesarean section rate and its increase over time?

International research literature suggests three main groups of reasons for the increasing rate of CS over time across different countries. First, the clinical need for CS may have increased, i.e. the clinical indicators may have become more prevalent over time. Across the literature there is significant consensus regarding the clinical indicators for CS. The most frequently cited indicators are previous CS, abnormal labour (dystocia or failure to progress), fetal compromise/distress and breech presentation (Placek *et al.*, 1980; Taffel *et al.*, 1987; Anderson *et al.*, 1989; Henry *et al.*, 1995).[3] In the National Sentinel Caesarean Section Audit in the UK, these four indicators together accounted for almost 70% of the CS rate in England (Thomas *et al.*, 2001).[4] There has been little international research on how changes in these indicators over time are contributing to the increasing trend of CS deliveries. Both Gregory *et al.* (1998) using US data and Liu *et al.* (2004) using Canadian data highlight increases in CSs for dystocia, but other authors have found that the incidence of the main indicators has not increased over time (Shearer, 1993). Declercq *et al.* (2006) raise the point that the increasing rate of primary CS, particularly among young first-time mothers, will itself drive future growth in CS rates by creating a large cohort of women for whom repeat CS will be the norm. They link this assertion to the increased restrictions placed on vaginal birth after CS by the American College of Obstetricians and Gynaecologists guidelines (ACOG, 2006).

Clinical indicators can be seen as the proximate cause of CS but the prevalence of these indicators may change as a result of change in foetal and maternal characteristics. In particular, more multiple births, increasing maternal age, increasing maternal weight both before and during pregnancy and decreasing number of previous births (parity) have been the focus of much research in this area and have been found to be a major contributing factor to trends in the clinical indicators for CS (Joseph et al., 2003). Higher maternal age increases the risk of hypertension, diabetes mellitus and other antenatal complications thus increasing the clinical need for section.

Changing maternal characteristics are of course themselves driven by wider social forces. The increasing age of mothers at birth reflects increasing educational and occupational attainment among women in the latter part of the 20th Century across a large number of countries leading to delayed fertility and smaller families (Blossfeld *et al.*, 2001). Higher

[3] 'Dystocia is defined as abnormal labor that results from what have been categorized classically as abnormalities of the power (uterine contractions or maternal expulsive forces), the passenger (position, size, or presentation of the fetus), or the passage (pelvis or soft tissues).' ACOG (2003) p1446.

[4] 'These data may need to be treated with caution because: there may be more than one indication to the decision to perform a Caesarean section, and there may not be consistency in deciding the primary indication.' Thomas and Paranjothy (2001), p20.

maternal weight reflects trends in diet and exercise across western industrial nations and increasing levels of obesity (International Obesity Taskforce, 2005).

A third source of variation in CS rate may be physician practices. If physicians change the way they treat a given clinical situation this may influence CS rates even if the prevalence of that condition remains stable. The choice of CS over vaginal birth always requires an assessment of the clinical costs of benefits of each in any given situation and changing medical technology and practice has meant that CS has become less clinically problematic over time. *Ceteris paribus*, this will have made CS more attractive as an option. For example in previous decades obstetricians and mid-wives would have been more likely to deliver breech births vaginally but changing clinical practice has made CS the dominant form of delivery (Placek *et al.*, 1980; Joseph *et al.*, 2003; Devane *et al.*, 2007).

Other changes in clinical practice may also impact on the prevalence of CS, though not necessarily intentionally. An example of this is the increase in the prevalence of induction of labour and augmentation of a labour in process which many authors feel have had an impact on the CS rate.[5] Induction has been reported as one of the fastest growing procedures in the United States; the rate more than doubled between 1990 and 2006 to 22.5% of live births (MacDorman *et al.*, 2002; ACOG, 2009). The goal of labor induction is to artificially, by medication or other methods, stimulate uterine contractions so that pregnant women can deliver vaginally (ACOG, 2009). Induction of labour has been associated with an increased risk of a diagnosis of dystocia and CS (Boulvain *et al.*, 2001; Lowe, 2007). In particular, the CS rate is found to be higher in cases of elective (no evident complications) induction in first-time mothers (Seyb *et al.*, 1999; Dublin *et al.*, 2000; Cammu *et al.*, 2002; Lowe, 2007).

Using Canadian data on primary CS rates, Joseph *et al.* (2003) found that the recent increases in the primary CS rates can be attributed in part to changes in obstetric practice. Changes in obstetric practice included reductions in mid-pelvic forceps use, increases in the use of CS for breech presentation, labour induction, epidural anaesthesia, and obstetrician delivery. The authors point out that the changes in obstetric practice could be a response to changing maternal characteristics.

Non-clinical factors could also have a role in changing physician behaviour. In a survey of obstetricians which asked for the three main causes of the rise in CS rate, Weaver *et al.* (2007) found that litigation and defensive practice was the second most cited reason. The first most cited reason was maternal request, although the majority of respondents pointed

[5] The goal of labor induction is to artificially, by medication or other methods, stimulate uterine contractions so that pregnant women can deliver vaginally (ACOG, 2009).

out that they did not personally receive many requests for them. On the other hand, the national CS audit in the UK, Thomas and Paranjothy (2001) found that maternal request as reported by clinicians was a primary indication for only 7% of CSs. Reviews of the literature by McCourt *et al.* (2007) and Gamble *et al.* (2007) found little evidence that women are requesting CSs and concluded that maternal request is not a significant factor influencing CS rates.

Economic incentives may also influence the physician's choice of delivery method. Recent data has shown that there is variation between the CS rates for public and private patients in public hospitals in Ireland.[6] This raises the issue of possible supplier induced demand, that is, if physicians are compensated at a higher level for CSs. Tussing and Wojtowycz (1992) used the ratio of obstetricians to fertile females, the per capita output of gynecologic procedures and the ratio of the estimated area cesarean section fee to the vaginal delivery fee to investigate the hypothesis of SID using data from the United States. The authors fail to find support in the data for the hypothesis that "obstetricians perform cesarean (sic) sections to enrich themselves from the additional fee income" (Tussing and Wojtowycz 1992: p538).

A more recent study from the United States has argued that an observed 13.5% fall in fertility over the 1970-1982 period led physicians to substitute from normal childbirth toward a more highly reimbursed alternative, CS. Using a nationally representative microdata set for this period, they show that there is a strong correlation between within-state declines in fertility and within-state increases in Caesarean utilization (Gruber *et al.*, 1996).

In the next section we detail the data and methods that we will use for the analyses in the paper before moving on to a description of trends in CS and CS predictors over the period from 1999 to 2007. In the fifth section we then test some of these predictors more formally.

III DATA AND METHODS

These analyses use nine years of data from two different Irish sources that cannot be linked at the individual level at present due to data protection legislation: the National Perinatal Reporting System (NPRS) and the Hospital In-Patient Enquiry (HIPE) scheme.

The main source of data on perinatal events in Ireland is the NPRS which contains information on all births in the Republic of Ireland and has been collected and processed by

[6] In the Coombe in 2008, 32.2 per cent of births to private patients were Caesarean sections compared with 21.7 per cent for public and semi-private patients (Cullen, 2009).

the Economic and Social Research Institute (ESRI) since 1999.[7] Births are registered and notified on a standard Birth Notification Form (BNF) which is completed where the birth takes place, either at the hospital or by the attending midwife. The sample employed for these analyses consists of all hospital births in Ireland between 01 January 1999 and 31 December 2007 and totals 549,071 births.[8] Of the 549,071 births over this period CSs accounted for 131,301 or 23.9%.

Unfortunately clinical data on births is not available in the NPRS which means that it is not possible to identify the clinical indicators for CSs using this data. The necessary morbidity data is however contained in HIPE. Between 1999 and 2007 there were 503,977 discharges from HIPE hospitals with a diagnosis of 'outcome of delivery'.[9,10]

HIPE contains administrative data (for example, admission and discharge dates, and medical card and public/private status), demographic data (sex, age) and clinical data on discharges from, and deaths in, acute hospitals in Ireland. The clinical data on discharges in 2007 were recorded in HIPE using *The International Statistical Classification of Diseases and Related Health Problems*, Tenth Revision, Australian Modification (ICD-10-AM).[11] In total, 20 diagnosis (one principal and up to 19 additional) codes and, where applicable, 20 procedure (one principal and up to 19 additional) codes could be recorded for these discharges.[12]

Neither of the data sets alone contains all of the variables desirable for an examination of increasing CS rates nor is it currently possible to cross match the data in order to do an individual level analysis using the necessary variables from each data set. To circumvent these issues we model trends in the probability of CS at the level of the hospital. Data from

7 The NPRS data set excludes all births where weight is under 500 grams. In the case of a multiple birth where one or more births from the set weighs under 500 grams, the birth/s weighing under 500 grams is/are removed from the national data set. Any birth/s weighing over 500 grams in the multiple birth set is/are retained in the national data set as a multiple birth/s.

8 For these analyses, only births that took place within a hospital are included, that is, cases where 'place of birth' is recorded as 'domiciliary', 'born before arrival' and 'unknown' are excluded. Domiciliary births are planned home births. The vast majority of these are attended by an independent midwife and are not associated with a hospital. Born before arrival indicates that an infant was delivered before arrival at hospital. Together these account for 0.6% of total births.

9 i.e. V27 – ICD-9-CM or Z37 – ICD-10-AM.

10 There are two main differences between the HIPE and NPRS datasets when looking at births. The unit of measurement in NPRS is the birth, that is, there is one record for each baby born. In HIPE the unit of measurement is the discharge, that is, there is one record for each mother who delivered at least one baby. In addition, HIPE does not collect data from private maternity hospitals. For these reasons there are fewer records in HIPE than NPRS.

11 This coding classification scheme applied to discharges from 01 January 2005. Prior to the move to ICD-10-AM, The International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) was used. The move from ICD-9-CM to ICD-10-AM also entailed changes to coding guidelines (such as the definition of additional diagnoses). Consequently, the ICD-9-CM and ICD-10-AM coding schemes are not directly comparable. For a detailed discussion of updating the clinical coding classification in Ireland, see Murphy *et al.* (2004).

12 The potential number of additional diagnosis and procedure codes captured by HIPE has increased from five (diagnoses) and three (procedures) prior to 2002 to nine (for both diagnoses and procedures) until 2005 when the number increased to 19 diagnosis and procedure codes.

HIPE and NPRS are used to construct hospital level data for our variables of interest. To model trends these variables are constructing for each quarter from January 1999 to December 2007 yielding 36 quarters per hospital.

A number of hospitals are excluded from the hospital level analysis. As the private hospitals reporting to NPRS do not report to HIPE only public hospitals are included in the analysis (27,484 births). In addition, 25 hospitals that reported very small numbers of births over the nine year period were excluded from the analysis (1,905 births). Finally, due to the reconfiguration of maternity services in Cork in 2007 (HRID ESRI (2009); p207), births from Cork hospitals have been excluded from the analysis for the final four of the 36 periods (7,987 births). This reduces the total number of births used in the hospital level analysis from 549,071 to 511,695.

Given the nature of the data and our interest in modelling the factors which affect the probability of CS we use a grouped logit model. This estimates the (log) probability of CS (p/1-p) for the $_j$th observation as a function of a set of variables using maximum likelihood:

$$Y_j = \beta_0 + \beta_1 Q_j + \beta_2 h_j + \beta_3 m_j + \beta_4 b_j + \beta_5 ci_j + \varepsilon_j$$

Where Q: quarter (i.e. time trend); h: hospital; m: mother's characteristics; b: birth characteristics; ci: clinical indicators; ε_j is a normally distributed error term. A full list of the variables and their construction used in the models is given in Table 1. The inclusion of the variable representing the time period (q) means that we control for the increasing trend in CS over the period of observation. To control for variation in this trend over hospitals, interactions between hospital and quarter are estimated.

Table 1: *Variables definitions and summary statistics*

Hospital and Time	
Hospital	Dummy variable representing 19 hospitals in analysis
Quarter	Integer from 1 to 36 representing yearly quarters 1999 to 2007
Hospital * Quarter	Interaction of hospital and quarter
Maternal Characteristics	
Age 35-39	% aged 35 to 39
Age 40+	% of mothers aged 40+
First Time Mothers	% parity=0
First Time Mothers*35+	% parity=0 and age 35+
Private	% births private insurance
Birth/Infant characteristics	
Multiple	%multiple births
Induction	% births medically or surgically induced
Augmentation	% births medically or surgically augmented
Clinical Indicators	
Previous CS	% CS births where mother has uterine scare from previous CS (dummy)
Breech	% CS births with breech presentation (dummy)
Dystocia*	% CS births dystocia (excluding high head at term and breech) (dummy)
Distress	% CS births fetal distress (including cord prolapse) (dummy)
Other˜	% CS births other causes (dummy)
Remainder	% CS births remaining causes (dummy)

Notes: Dystocia includes 'disproportion', 'obstructed labour', 'abnormality of forces of labour', 'long labour', 'malpresentation' and 'failed induction of labour'.
Other includes 'Antepartum haemorrhage, abruptio placenta and previa placenta', 'insufficient or excessive fetal growth', 'genital herpes', 'diabetes mellitus in pregnancy, 'hypertensive disorders', 'oligohydramnios', 'chorioamnionitis', 'malformation of fetal central nervous system', and 'congenital/acquired abnormality of cervix or vagina'.

The adoption of the grouped logit model has a number of implications for the analysis. First, this is an analysis where the units of analysis are hospitals and time periods. Hospitals differ substantially in size and births are not spread evenly across the year but each hospital/quarter is given equal weighting in the estimate of the impact of the predictors. If the data were available, analysis at the individual level may produce different estimates if the effect of a predictor is strongly correlated with hospital size. We include a dummy variable for each hospital in the analysis which will control for hospital specific effects but do not interact this variable with each other predictor or a variable representing hospital size for reasons of brevity.

Second, because we are using aggregated data our predictors are the proportion of births with a particular characteristic rather than a discrete (i.e. dummy) indicator (except in the case of the hospital dummies). This complicates interpretation, particularly in terms of the interaction between variables. Our model expresses the effect of a unit increase in the predictor on the odds of each birth being a CS per hospital time period.

IV RECENT TRENDS IN CAESAREAN DELIVERY IN IRELAND

The following section profiles births in Ireland from 1999 to 2007. We investigate factors that have been suggested in the literature to have led to an increase in the CS rate: multiple births, maternal age, parity, birthweight, occupation/social class, day of week of birth, hospital type and clinical indicators. The NPRS data is used to examine all but the clinical indicators and the public/private status of mothers upon their discharge from hospital, both of which are analysed using HIPE data.[13]

The CS rate is defined here as the proportion of total births delivered by CS.[14] Figure 2 shows how the CS rate increased from 20.5% in 1999 to 26.3% or over one quarter of total births in 2007. This represents an increase of 28.3% in nine years.

Figure 2: *Caesarean Sections as percentage of total births, 1999-2007*

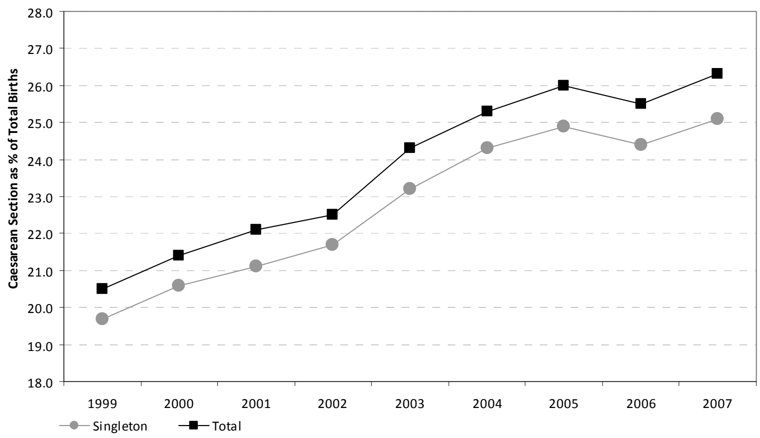
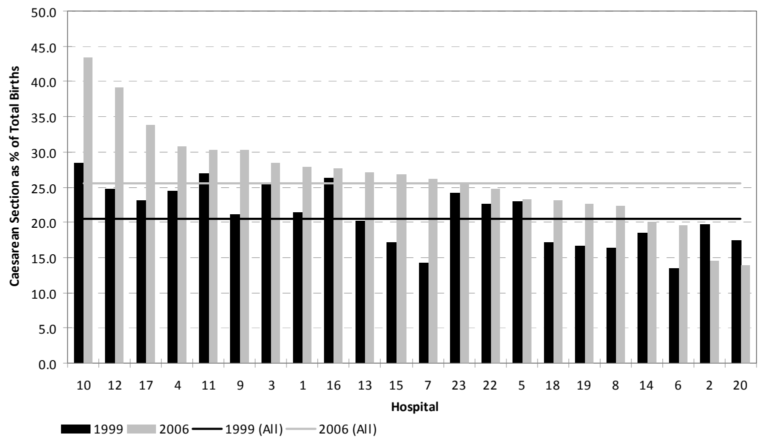


Figure 3 shows how the CS rates for 1999 and 2006 varied widely by hospital.[15] Between 1999 and 2006 the CS rates for all but two of the hospitals increased, albeit at different rates. Hospital 7 experienced the highest growth in CSs over the period, increasing from 14.2% to 26.2%.

Figure 3: *Caesarean Section rate by hospital, 1999-2006*



[13] Refers to the public/private status of the patient on discharge and not to the type of bed occupied.

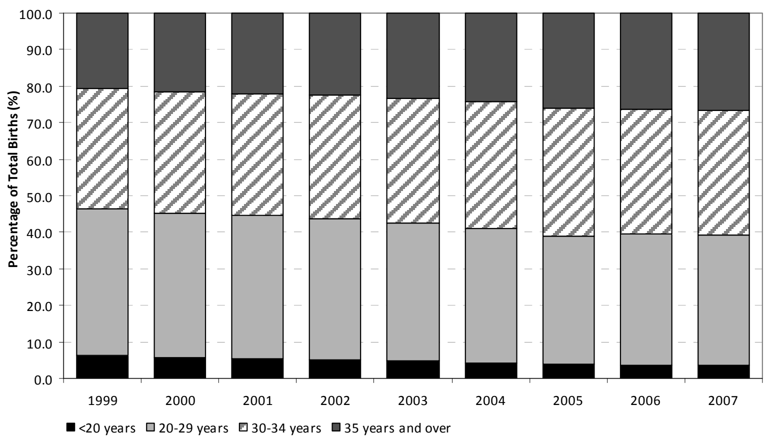
[14] Total births = ((live births + stillbirths) – (domiciliary + born before arrival (BBA) + unknown)).

[15] Due to the reconfiguration of maternity services in Cork in 2007 we use 2006 data here to avoid identifying individual hospitals.

Changing Maternal Characteristics and CS

As previously discussed, a changing pattern of maternal characteristics could be one driver of changing CS rates in Ireland. Maternal age has been found to have a significant effect on the probability of having a CS in several international studies. It is clear from Figure 4 below that the age profile of women giving birth in Irish hospitals has changed significantly over the eight year period. There were a higher proportion of births to women in the older age groups in 2007 than there were in 1999. The proportion of births to women aged less than 20 years and 20 to 29 years decreased by 43.5% and 10.7% respectively. The proportion of births to women aged 30 to 34 years increased by 3.6%, and for women in the 35 years and over age group it increased by 28.0% over the nine years. The average age of women giving birth in Ireland increased from 30.1 years to 31.1 years between 1999 and 2007.

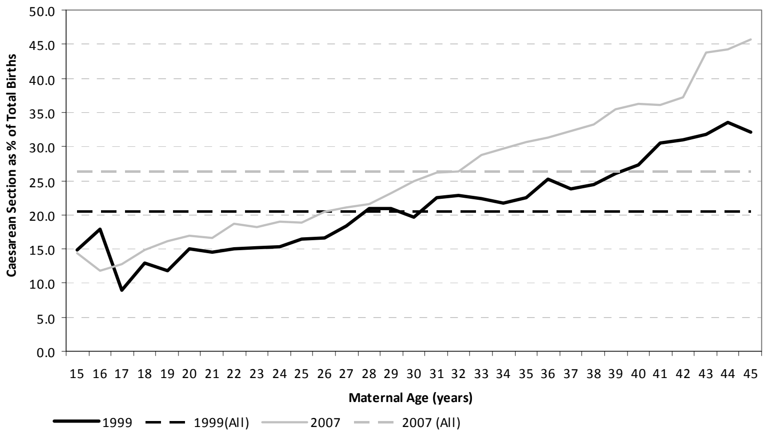
Figure 4: *Total births by mother's age group, 1999-2007*



The CS rate in 2007 was 26.3%, however this varied widely by maternal age as can be seen in Figure 5. It is clear that the CS rate, in general, increases with age and has increased over time. From 17 years of age onwards the CS rates in 2007 are consistently higher than those in 1999. In 2007 the CS rate surpassed 30% for births to women aged 35 years and over, this represented a significant shift from 1999 when the CS rate did not reach this level until women reached 41 years and over.

Growth in the CS rate between 1999 and 2007 was lowest for births to mothers aged 20-29 years at 13.0% and highest for births to mothers aged 35 years and over at 28.9%.

Figure 5: *Maternal age (years) by Caesarean section rate (%), 1999 and 2007*

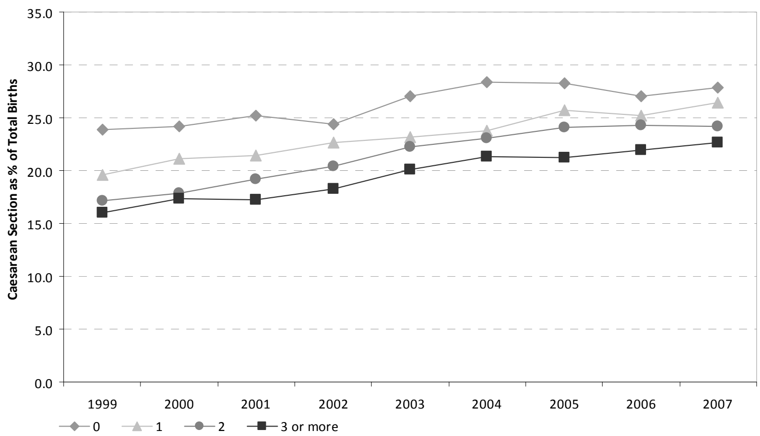


Note: Only mothers aged between 15 and 45 are included in this chart.

Maternal parity is defined as a woman's total number of previous live births and stillbirths. Falling maternal parity has been linked in the literature to an increasing CS rate. In 2007, approximately 42% of births in Ireland were to first-time mothers, 32% to women with one previous birth, 16% to women with two previous births and the remainder to women with three or more previous births. The most significant change over the period was the 21.5% fall in the three or more category between 1999 and 2007. Average maternal parity fell from 1.12 to 0.99 between 1999 and 2007.

The CS rate in Ireland varies by maternal parity group, as illustrated in Figure 6. The CS rate is highest for first-time mothers and decreases with each subsequent parity group presented. In 2007, first-time mothers had a CS rate of 27.9% compared to 22.7% for women with a parity of 3 or more.

Figure 6: *Caesarean section rate by maternal parity group, 1999-2007*



Changing Patterns of Birth Complications and CS

If the changing pattern of maternal characteristics examined above impacts on CS rates this is most likely through its impact on the prevalence of specific birth complications or the expectation of these complications. To examine whether the clinical progenitors of CS have increased over time we use the method outlined in (Anderson *et al.*, 1984; Henry *et al.*, 1995), where one broad indication for the CS is assigned to each relevant case, with each indication taking precedence over all succeeding ones (previous caesarean, breech, dystocia, fetal distress, other), regardless of the order in which they were recorded in the dataset.[16] Discharges with two or more of the relevant indication codes were assigned to one or other category according to this hierarchy.

Table 2 shows that having a prior CS accounted for almost 27% of cases in 1999 rising to almost 35% in 2007. Table 2 also shows that this 3.5 percentage point increase between the periods can explain over 60% of the rise in total CSs. The influence of prior CS means that increases due to other clinical reasons are amplified in later years although medical practice is moving away from assuming a CS at subsequent births. Of those women who recorded a previous caesarean in 1999, 85% had a CS; this decreased to 83.4% in 2007.

After previous CS, Table 2 shows that increases in the prevalence of dystocia (failure of the labour to progress) and 'breech' are the second and third most common clinical indicators 'explaining' the increase in the CS rate between 1999 and 2007. As stated above, trends in the prevalence of these clinical indicators may be driven by changes in the characteristics of mothers and pregnancies.

When Table 2 is disaggregated by the age of the mother it is evident that indicators for CS vary by age group. As would be expected the proportion of CS accounted for by 'previous CS' increases with age while the proportion for all other indicators decreases with age. For example, in 2007 'previous CS' accounted for 3.4% of CSs in those aged <20 years and for 45.7% in those aged 35 years and over.

[16] The clinical coding for the conditions outlined in Henry *et al.* (1995) are in ICD-9 format. For the purpose of this paper these codes have been mapped to ICD-9-CM and ICD-10-AM. For this reason it has been necessary to make some minor adjustments to the codes presented in Henry *et al.* (1995) to make the codes in ICD-9-CM as comparable as possible to those in ICD-10-AM. See HRID ESRI (HRID ESRI, 2008); and (Murphy *et al.*, 2004) for a discussion of the changes to clinical coding in Ireland in 2005.

Table 2: *Obstetric risk factors. Hierarchical classification of indications for caesarean 1999 and 2007*

	1999			***2007***			***Change from 1999 to 2007***	
	ICD-9-CM	*Rate*	*Per Cent Distribution*	*ICD-10-AM*	*Rate*	*Per Cent Distribution*	*Rate*	*Per Cent Distribution*
Previous CS	654.2	5.3	26.9	O34.2, O75.7	8.8	34.6	3.5	60.8
Breech	652.1^, 652.2	2.6	13.1	O32.1, O64.1	3.2	12.6	0.6	11.2
Dystocia	653, 652 (ex. 652.5)^, 660, 659.0, 659.1, 661 (ex. 661.3), 662	5.0	25.3	O32, O33, O61, O62 (ex. O62.3), O63, O64, O66	6.1	23.8	1.1	18.8
Fetal distress and cord prolapse	656.3, 659.7^, 656.8^, 656.9^, 663.0	3.7	18.9	O68, O690	4.0	15.6	0.3	4.7
Other~	641, 656.5, 656.6, 647.6, 054, 648.0, 648.8, 642, 658.0, 658.4, 655.0, 654.6, 654.7, 665.0, 665.1	1.8	9.0	O44, O45, O46, O365, O366, O98.3, A60, O24, O10, O11, O13, O14, O15, O16, O41.0, O41.1, O35.0, O34.4, O34.6, O71.0, O71.1	1.8	7.2	0.1	1.1
Remainder	All else	1.4	6.9	All else	1.6	6.1	0.2	3.5
Total		19.7	100.0		25.5	100.0	5.8	100.0

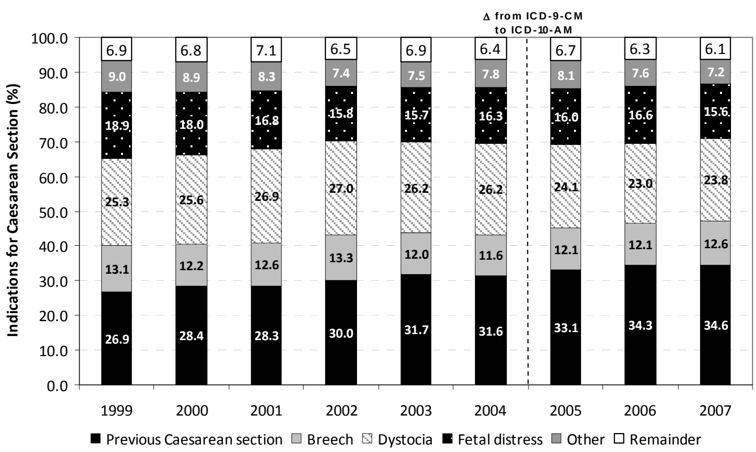
Notes: * Dystocia includes 'disproportion', 'obstructed labour', 'abnormality of forces of labour', 'long labour', 'malpresentation' and 'failed induction of labour'.

^ These are minor changes from coding outlined in Henry *et al.* (1995) in order to make ICD-9-CM as comparable to ICD-10-AM as possible.

~ Other includes 'Antepartum haemorrhage, abruptio placenta and previa placenta', 'insufficient or excessive fetal growth', 'genital herpes', 'diabetes mellitus in pregnancy, 'hypertensive disorders', 'oligohydramnios', 'chorioamnionitis', 'malformation of fetal central nervous system', and 'congenital/acquired abnormality of cervix or vagina'. In addition, Henry *et al.* (1995) 'rhesus isoimmunization' included in 'remainder' rather than 'other' due to difficulties with coding comparisons.

Figure 7 below illustrates how the indications for CS have changed between 1999 and 2007. The change in the clinical coding scheme between 2004 and 2005 does appear to have had an impact on the proportions in the various categories. Dystocia experienced the largest change between 2004 and 2005, decreasing by 8.0%. However, a fluctuation of the magnitude recorded between these two years is not unusual, for example the proportion of CS attributed to breech decreased by 9.8% between 2002 and 2003.

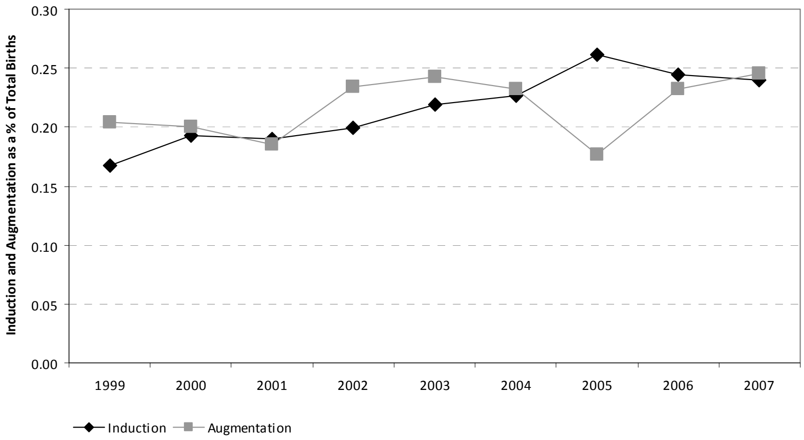
Figure 7: *Indications for Caesarean section, 1999-2007*



The Changing Pattern of Induction

It was suggested in Section II that the use of induction and augmentation may also have contributed to the rise in CS in recent years. They have certainly become more common as shown by Figure 8. The probability of induction rose from 16.7% in 1999 to 23.9% in 2007 and augmentation from 20.4% in 1999 to 24.5% in 2007.

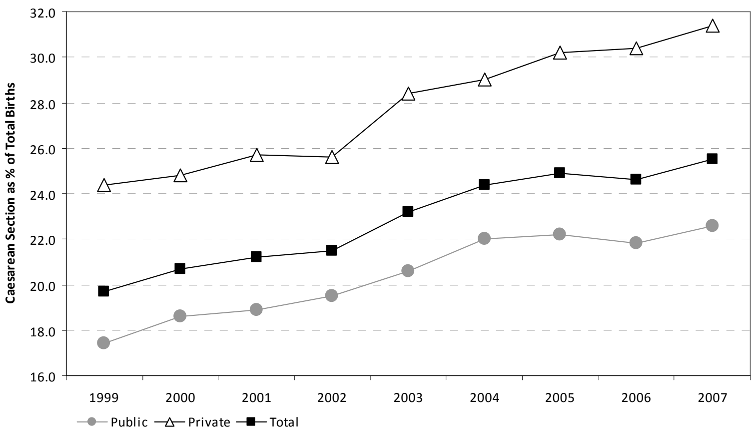
Figure 8: Prevalence of Induction and Augmentation,1999-2007



The Influence of Non-Clinical Incentives

Figure 9 shows the CS rate for HIPE discharges disaggregated by public/private status. The public/private status of a discharge in HIPE refers to the public/private status of the patient on discharge and not to the type of bed occupied. The proportion of private births in Irish hospitals participating in HIPE has been stable at approximately one-third of total births over the whole period from 1999 to 2007. Whilst the CS rate has increased for both private and public patients, it increased by 7% for private patients (from 24.4% to 31.4%) compared to 5% for public (from 17.4% to 22.6%).

Figure 9: *Caesarean section rate by public/private status, 1999-2007*



Note: The overall CS rate is lower in HIPE than in NPRS as private hospitals are not included in HIPE and as the records in HIPE are for the mother and not the baby, multiple births are counted once.

V ECONOMETRIC ANALYSIS OF THE CAESAREAN SECTION TREND

In the previous section we have reviewed trends across a number of different factors which could be seen to be associated with CS in Ireland. To examine the independent role of different factors and control for the distribution of both births and CS across hospitals we use the methodology outlined in Section III and estimate the probability of CS across the period from January 1999 to December 2007 using a grouped logit model and maximum likelihood estimation. We first fit a base model controlling for the year-quarter, the hospital and the hospital specific trend in CS. We then fit seven additional models to examine the impact of specific factors on probability of CS. After fitting all the variables we will be in a position to assess the extent to which we can statistically account for the CS trend between 1999 and 2007.

Table 3 gives the odds ratios for a set of models with levels of significance. For ease of presentation we do not show the quarter effects, individual hospital parameters or interactions of hospital with quarter (38 terms). The base model estimates have also been omitted. Model 1 fits variables representing the hospital and quarter specific distributions of older mothers, mothers of first births and multiple births. Higher proportions of older mothers are associated with increased odds of CS in Model 1, though the terms are rendered insignificant by the entry of the variables representing the proportion of first-time mothers and older first-time mothers in particular. Births to first-time mothers are associated with an increase in risk but this term is rendered insignificant by the inclusion of the term for the proportion of older first-time mothers which is associated with a five fold increase in the odds of CS. An increase in the proportion of multiple births is also associated with an eight fold increase in the odds of CS.

Table 3: Grouped Logit Model of Caesarean Section by Hospital and Period

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7	
	Odds	Sig.	Odds	Sig.	Odds	Sig.	Odds	Sig.	Odds	Sig.	Odds	Sig.	Odds	Sig.
Age 35-39	1.55	*											1.20	n.s
Age 40+	1.40	n.s											0.80	n.s
First Birth	0.81	n.s											1.19	n.s
First Birth + Aged 35+	5.05	***											3.99	***
Multiple Birth	8.06	***											8.90	***
Induction			1.20	***									0.97	n.s
Augmentation			0.92	**									0.83	***
Private Patient					1.49	***							0.82	*
Previous CS							14.68	***			13.29	***	22.43	***
Breech Presentation									9.93	***	9.45	***	7.42	***
Dystocia									1.38	***	1.27	***	1.34	***
Fetal Distress (including cord prolapse)									1.09	n.s	1.04	n.s	1.08	n.s
Other									1.59	*	1.19	n.s	1.57	n.s
LL	-274,290		-274,312		-274,312		-274,260		-274,241		-274,189		-274,148	
N	511,695		511,695		511,695		511,695		511,695		511,695		511,695	
LR	6,386		6,342		6,342		6,447		6,484		6,588		6,670	
Pseudo R2	0.0115		0.0114		0.0114		0.0116		0.0117		0.0119		0.0120	

*** p<0.01, ** p<0.05, * p<0.1

Our earlier discussion had suggested that increases in induction and augmentation may have contributed to increasing CS rates. Model 2 shows that both factors have a significant impact on CS probability with induction rates increasing the odds and augmentation decreasing them. Model 3 estimates the effect of proportion of private births per hospital period. This shows a significant positive effect for being private with a 49% increase in the odds.

The variables entered up to this point can be viewed as the 'distal' influences on CS rates. Models 4, 5 and 6 on the other hand show the results for the clinical indicators which are the proximate or immediate factors leading to CS. Model 4 shows the effect for proportion of women with a previous CS. This is clearly a powerful predictor increasing the odds by 14.7. Model 5 shows the coefficients for a number of clinical indictors. Model 5 shows that other risk factors for CS are also important. Breech and dystocia are both associated with a greater odds of CS (9.9 and 1.4 respectively), as is 'fetal distress (including cord prolapse)' (1.1) and 'other' (1.6). Here we simply use the proportion of births with a principal indicator, as per the Henry *et al.* (1995) hierarchy, of each characteristic within each hospital period. Model 6 enters the clinical risk factors alongside the proportion of births where the mother has had a previous CS and this moderates the effect of the other clinical indicators. Finally, Model 7 enters all variables simultaneously. As expected, many of the more 'distal' factors now become insignificant or their effects are moderated. The proportion of private patients now becomes negative, reducing the odds by 18%. On the other hand, the effect for the proportion of mothers with a previous CS actually increases to 22.4.

It is clear that a number of variables in the analysis are associated with a higher probability of CS but we have still to assess their impact on the overall trend in CS between 1999 and 2007. The extent to which the variables in the seven models account for the hospital specific growth coefficients is taken as a measure of their value in explaining the overall trend. Table 4, shows that when entered together in Model 7, the variables account for 63% of the hospital trend coefficients. Although all of the variables contribute to this conclusion, the largest contribution is made by Models 4 and 6, the models containing the proportion of women who have previously had a CS. This is understandable, but the models only perform marginally better than Model 3 which estimates the effect for proportion of private births. Given that the proportion of private births did not change substantially over the period this suggests that private status is correlated with other factors at the level of the hospital which are impacting on CS risk but which are not specified in our model.

Table 4: Reduction in Hospital Specific Time Trend in CS by Addition of Variables

	Base Model	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
% Change	0%	8%	20%	34%	36%	17%	50%	63%

VI DISCUSSION

The CS rate in Ireland has increased by over 28% in the nine-year period from 1999 to 2007. The rate is now over 10% higher than the threshold recommended by the WHO and is amongst the highest in Europe. Given the significant affect CSs have on mothers and their babies and the cost implications for health service providers it is important to investigate the factors which are driving the rate in Ireland higher.

Analysis of the literature suggested three main processes may explain recent CS trends: first, the changing pattern of clinical indicators, perhaps driven partially by the second – the changing characteristics of mothers; third changing physician practices in respect of the clinical indictors and fourth, changing physician practices for non-clinical reasons.

If we put aside for the moment the influence of previous CS as a driver of the increasing probability of CS, it is clear that the prevalence of some clinical indicators of CS have increased between 1999 and 2007 but not by the level necessary to explain the overall change in CS rate in Irish hospitals. None the less, our models did show that controlling for rates of these clinical indicators alone explained around 17% of the variance in hospital trends in the model. This could result from the increase in prevalence of the indicators but it is more likely to reflect changing physician practices around them, e.g. increasing use of CS for breech or multiple births.

A bigger proportion of variance, around 20% could be explained by changes in the prevalence of induction and augmentation of birth in Irish hospitals. It should be said that these two factors are not independent since both procedures may be used in the face of some of the clinical indicators analysed but the effect here suggests these procedures may be important.

Non-clinical changes in physician behaviour may also play a crucial role. One of the most powerful factors in explaining the growth trend in CS in the models in the previous Section was the mother being a private patient. We controlled for clinical and other factors that may explain this large effect which suggests that the private practice is influencing clinical practice via other mechanisms. This may include a greater likelihood of request for CS from private patients or readiness to accept on the part of obstetrician. Given that private patients are more likely to see their consultant than a public patient and that consultants are more interventionist than midwives in the birthing process, it might be that we see higher rates of CS for private births simply because consultants are present more often.

Alternatively the private patient effect may reflect a process of supplier induced demand. Private maternity charges are levied by maternity hospitals to cover use of private or semi-private rooms and consultant fees are levied on top of this. CS attracts an additional fee which varies by hospital, as does the use of epidural anaesthesia. Further analysis is required to establish the real incentive that this represents but it is possible that changing behaviour relative to private practice has contributed to the overall rise in CS.

Our analysis has confirmed that many of the international trends are also true for Ireland. Women are having fewer children and they are having them later in life leading to a large increase in the proportion of women giving birth over the age of 35. Older age of mother is associated with a higher risk of a number of complications that can contribute to the risk of CS and this has clearly been a substantial contributor to increases in the Irish rate. The CS rate has increased for mothers of all ages but the highest rate of increase has been for mothers aged 35 years and over where rates have increased by over 30%. Our model showed that a 1% rise in the proportion of first-time mothers aged 35+ in Irish hospitals was associated with a five-fold increase in the risk of CS for each birth.

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