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October 2016

CRES-UPF Working Paper #201610-94

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Abstract

Cesarean sections have been associated in the literature with poorer newborn health and, in particular, with higher incidence of respiratory morbidity. However, most studies suffer from potential omitted variable bias, since they are based on simple comparisons of mothers who give birth vaginally and mothers who give birth through a cesarean section. We try to overcome this limitation by using variation in the probability of getting a c-section that is arguably unrelated to maternal and fetal characteristics: variation between hours. It has been found that, although nature distributes births and associated problems uniformly, time-dependent variables related to the physicians' demand for leisure are significant predictors of unplanned c-sections. We document in our sample how the rate of c-sections is higher during the beginning of the night than during the rest of the day. We thus instrument the type of birth with the time of delivery. Our results suggest that non-medically indicated c-sections have a negative and significant impact on the newborn's health, as measured by Apgar scores and the pH level of the umbilical cord.

Keywords: Cesarean section, c-section, newborn health, time variation.
JEL Codes: I10, I12.

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1 Introduction

In recent years, there has been an increasing concern about the rise in cesarean section births. On average, in 2013 in OECD countries, more than 1 birth out of 4 involved a c-section, while in 2000 it was only 1 out of 5 (OECD, 2013). These numbers contrast sharply with the recommendations of the WHO to have cesarean rates not above 15%.

This excessive use of c-sections has been largely debated because they are associated with greater complications and higher maternal and infant mortality and morbidity than vaginal deliveries. However, the available evidence consists mostly of comparisons between cesareans and vaginal deliveries, and these studies may suffer from omitted variable bias, as mothers who give birth by cesareans may be different to those who give birth by vaginal delivery in characteristics that can affect the health outcomes of the child and the mother after birth. In this line, in 2015, the WHO pointed out the need for more research to understand the health effects of cesarean section on immediate and future outcomes, and remarked that "the effects of cesarean section rates on other outcomes, such as maternal and neonatal morbidity, pediatric outcomes and psychological or social well-being, are still unclear" (WHO, 2015).

This paper aims to contribute to filling this gap by providing new evidence of a causal link between non-medically indicated cesarean sections and newborn health outcomes. In particular, we look at the impact of c-sections on Apgar scores and the pH of the umbilical cord, both widely used measures of newborn wellbeing. Understanding the impact of c-sections on infant health is of relevance, as fetal and neonatal health have been shown to be determinants not only of future health, but also of other later life outcomes, such as test scores, educational attainment, and income (Almond and Currie, 2011).

In order to show the existence of a causal link between non-medically indicated c-sections and health we use the exogenous variation in the probability of getting a c-section that exists between hours. It has been studied that, although nature distributes births and associated problems uniformly, time-dependent variables related to the physicians' demand for leisure are significant predictors of unplanned c-sections (Brown, 1996). We first document how, in our sample, emergency c-sections are more likely to be performed during the first hours of the night. We discuss how the structure of medical shifts and the higher opportunity cost in terms of time that vaginal deliveries imply might explain physicians' incentives to perform more c-sections in this time period. We then show that mothers giving birth at different times of the day are observationally similar, also in pregnancy and labor characteristics that could predict a medically-indicated c-section. Therefore, the excess c-sections that we observe at night seem to be due to non-medical reasons. We thus adopt an instrumental variables approach, using the time of birth as an instrument for the mode of delivery: this allows us to interpret our estimates as causal and to focus on non-medically indicated c-sections. We discuss the necessary assumptions and their plausibility in the coming sections. Our results suggest that non-medically indicated c-sections lead to a significant worsening of Apgar scores of approximately one standard deviation, and an increased probability of having the pH of the umbilical cord below normal levels. Our findings are robust to a number of robustness checks.

This paper contributes to two different strands of the literature. First, we contribute to the literature that studies the effects of c-sections on newborn health outcomes. There are a large number of papers that have documented a robust association between c-sections and respiratory morbidity, both at birth (Zanardo et al., 2004; Hansen et al., 2008) and in the longer term in the form of asthma (Davidson et al., 2010; Sevelsted et al., 2015).

To the best of our knowledge, the only paper that tries to identify the causal impact of cesareans on later infant asthma is Jachetta (2015). The author uses variation in medical malpractice premia at the MSA-level as an instrument for the rate of risk-adjusted cesarean sections and finds an increase in the rate of total hospitalizations and the rate of hospitalizations that present asthma and other chronic pulmonary diseases. However, the identification strategy of the paper faces a number of limitations. For example, malpractice premia could be higher in states where health care or neonatal health are already poorer, or it could be the case that malpractice premia affect asthma through mechanisms other than c-sections – for instance if physicians not only perform more c-sections but also perform them earlier in the pregnancy, and thus the effect on asthma is due to the reduced gestational age. We contribute to this literature using a new instrument that allows us to isolate the impact of non-medically indicated c-sections on the newborn's health. In particular, our setting allows us to focus on mothers that give birth in the same hospital and are similar in observable characteristics, but that only differ in the hour of delivery. Moreover, we are able to provide evidence that time-variation in the quality of care is not driving our results. Finally, since we measure the impact on health at birth, we are able to gather more evidence of the direct impact of c-sections on health.

Second, our work is also related to the literature that documents or uses time variation in the probability of getting a c-section. Brown (1996) was one of the first to document how the probability of unplanned c-sections is non-uniformly distributed across time. Using data from military hospitals, he shows that cesarean sections were less likely during the weekend and more likely from 6 PM to midnight. He interprets these findings as evidence that non-clinical variables, and in particular physicians' demand for leisure, also play a role in doctors' decision making. In our setting, we find that the probability of unplanned c-sections is highest during the first hours of the night. We discuss how this is the period when the trade-off doctors face between rest and quality of care becomes more salient, as the opportunity cost in terms of time of a vaginal delivery increases.

There is one paper that uses this exogenous time variation in the probability of getting a c-section to study maternal outcomes. In particular, Halla et al. (2016) use administrative data from Austria to show that the probability of getting a c-section is lower on weekends and public holidays, and they use this as an instrument for the mode of delivery to study the impact of c-sections on subsequent fertility and maternal labor supply. One potential limitation of this study is that the authors are not able to completely rule out that the variation in the probability of getting a c-section across weekdays is not driven by scheduled c-sections, which are more frequent during the week. This could be a problem as scheduled c-sections are likely to be medically-indicated and this could compromise the exogeneity of their instrument. Our paper also makes use of time variation but our data allow us to use finer variation: we study mothers in the same hospital, in the same day, but giving birth at different hours. Moreover, we are also able to precisely identify and restrict our sample to non-scheduled c-sections.

The structure of the rest of the paper is as follows. In the next section we provide some background information on the choice of the mode of delivery, on physicians' shifts and on why we would expect to find an adverse effect of c-sections on health outcomes. The third section introduces the data, describes the variation in the c-section rate across hours and presents the empirical strategy. In section 4 we show and discuss our results. Section 5 presents some robustness checks and, finally, section 6 concludes.

2 Background

2.1 Choice of the mode of delivery

Cesarean sections can be performed for several reasons and at different times of the pregnancy. First, c-sections can be scheduled in advance – what are known as planned c-sections – if there are medical indications that make a vaginal delivery not advisable. Examples of such indications include multiple pregnancies with non-cephalic presentation of the first twin or placenta previa (NICE, 2016). In principle, c-sections can also be scheduled if they are demand-determined; that is, if the mother requests to deliver via a c-section. However, in the context of public hospitals in Spain, elective c-sections are very uncommon and, in fact, are not covered or supported by the public health system (Marcos, 2008). In any case, we exclude scheduled c-sections from our sample since these women are likely to be different to those delivering vaginally.

On the other hand, if there is no c-section scheduled, an attempt of vaginal delivery starts with the onset of labour or with the medical induction. If before or during labor the midwife or doctor detects evident health risks for the mother or the fetus, then a medically indicated emergency c-section will be performed. In some cases, however, whether a c-section is needed or not is not obvious, and thus the choice between a vaginal delivery, a c-section or other kinds of instrumented delivery will depend on the subjective assessment of the doctor. In fact, as

Shurtz (2013) points out, a c-section is a common procedure that is known to be sensitive to physician incentives. For example, some papers have found that financial fees can influence the behavior of the doctor (Grant, 2009). When fees are higher for a c-section than for a vaginal delivery, physicians have larger incentives to perform a c-section. Other papers have pointed out that physicians perform more c-sections as a defensive strategy to the fear of malpractice suit (Shurtz, 2013; Jachetta, 2015). And, finally, physicians have higher incentives to perform c-sections when the opportunity cost of time is higher, as vaginal deliveries typically last longer than c-sections and thus the latter can be seen as a time-saving device (Lefèvre, 2014). This last type of incentive is the one we focus on in our study, since by performing our analysis within hospital we abstract from variations in malpractice premiums and financial fees.

2.2 Physicians' shifts

In our setting, the normal work shift for a doctor is from 8am to 3pm, and night shifts are covered by doctors that are on duty and have to stay in the hospital for 24 hours (from 8am to 8am next morning). When doctors are on duty, they have to provide assistance to gynecological emergences, which are not very usual, monitor newborns' health from time to time and be in the labor room when decisions regarding a delivery have to be taken, or if there are complications during the delivery. On average in our sample doctors assist between 1 and 2 deliveries per night. Therefore, during the night shift, each delivery accounts for a major part of a doctor's duties. Although in our setting doctors cannot leave the hospital while they are on duty, they have beds available to rest when there is no emergency or complication that requires their presence.

This medical shift structure and the larger time-cost implied by vaginal deliveries make the doctors' incentives to perform c-sections in ambiguous cases vary with time. In particular, we argue that doctors have a larger incentive to perform c-sections at the beginning of the night. At this time doctors have already been working for more than 12 hours straight (see figure A4 in the Appendix). If they perform a c-section and do not have other mothers to take care of they can expect to rest for the remainder of their shift; alternatively, if they do not perform a c-section they will have to monitor from time to time the vaginal delivery during the rest of the night. Moreover, ongoing deliveries at the beginning of the night have a high probability of falling under the responsibility of the doctor on duty[1], while this is not true for deliveries starting later on, which are more likely to finish outside the doctor's shift. All in all, we expect a higher share of deliveries with ambiguous indications to end up in cesarean section during the first hours of the night, as compared to the rest of the day.

[1]The average duration of eutocic deliveries is around 8 hours.

2.3 The impact of c-sections on the newborn's health

Cesarean sections have been associated with several adverse health outcomes of the newborn. Hyde et al. (2012) provide an extensive review of such findings. They reckon that, while further research is needed, the available evidence suggests that "normal vaginal delivery is an important programming event with life-long health consequences". The absence or modification of such event is thus related to several health alterations, which they classify either as short or long term.

The most relevant for our study, among the short-term outcomes, are the increased hazard of impaired lung functioning and altered behavioral responses to stress. Regarding the former, one of the most common causes of respiratory distress among newborns is transient tachypnea or the presence of retained lung fluid. While babies in the amniotic sac have their lungs filled with amniotic liquid, during labor the fetus releases chemicals that help expel the amniotic liquid from their lungs, and also the pressure of the birth canal on the baby's chest helps push out the fluid. This process does not play a role for babies born by cesarean section, so the presence of liquid in their lungs after birth is more common in them. Moreover, catecholamines, one of the chemicals released by the fetus during labor, are also correlated with muscle tone and excitability (Otamiri et al., 1991). These authors find that babies born by cesarean sections responded worse to neurological tests a few days after birth. In our setting, we can proxy the impact of c-sections on these outcomes by looking at Apgar scores at the minute 1 and 5 after birth, which capture Appearance (skin color), Pulse (heart rate), Grimace (reflex irritability), Activity (muscle tone) and Respiration.

In the longer term, cesarean births have also been associated with higher risk of asthma (Sevelsted et al., 2015). While a possible mechanism for this relation are the changes in the microbiome of the newborn with respect to those born by vaginal delivery due to not passing through the birth canal, Hyde et al. (2012) also discuss that the differences in lung functioning at birth between these two groups might also lead to the development of future respiratory problems. Finally, there is also evidence that the excitability reduction in cesarean newborns might be a sympton of further alterations in the central nervous system, as the catecholamine surge at birth might affect its programming (Boksa and Zhang, 2008). These findings suggest that whatever health worsening at birth we detect might have long-lasting consequences.

Besides Apgar scores, we also inspect the impact of cesarean sections on the pH of the umbilical cord. The examination of the umbilical artery is a measure of fetal suffering and determines if a baby has experienced an oxygen-depriving event. PH values below 7.20 reflect that the newborn suffered a moderate lack of oxygen; values under 7.15 suggest a severe lack of oxygen and below 7.10 very severe suffering.

Although the relationship between pH levels and Apgar scores is not one-to-one, they are positively correlated. Figure A2 in the Appendix shows the distributions of umbilical cord pH for babies with Apgar scores 1 above and below 9 (first panel), and for babies with Apgar scores 5 above and below 9 (second panel). We can see that the distribution of pH levels for babies with Apgar scores below 9 is shifted to the left compared to that for babies with higher scores, with this being more salient for Apgar score 5. The medical literature recommendation is to consider pH levels together with Apgar scores in order to assess the wellbeing of the newborn (Hannah, 1989; Gao et al., 2009).

3 Data and Methods

3.1 Description of the data

Our data consists of 6,163 birth records from four different public hospitals in different Autonomous Regions in Spain during the years 2014-2016. The distribution of the number of births across hospitals can be seen in Table 1.

Table 1: Data by hospital

Hospital	Freq.	Percent
Hospital A	893	14.49
Hospital B	1,924	31.22
Hospital C	2,458	39.88
Hospital D	888	14.41
Total	6,163	100.00

Each birth registry contains information on mother characteristics (age, nationality, studies, marital status, etc.), on the pregnancy, on the type of birth (elective cesarean, emergency cesarean, eutocic delivery, etc.), on medical interventions during labor, on a series of medical indicators collected before, during and after the delivery, on the newborn (birthweight, APGAR scores, etc.) and on the date and time of birth.

Table A1 shows some summary statistics of the variables of interest. In our data, 5% of women deliver via a planned c-section, more than 11% via an emergency c-section and 68% have an eutocic delivery, that is, a vaginal delivery without other interventions (spatula, forceps and vacuum). Vaginal deliveries with these interventions represent around 15% of the sample. We restrict our sample to single births that are either eutocic or by unplanned c-section: our final sample consists of 4,886 observations.

3.2 Variation in the c-section rate between hours

As explained in the previous section, taking into account that doctors are on duty from 8am to 8am next morning, we expect doctors to have higher incentives to perform c-sections early at night, when the trade-off they face is likely to be more salient: deliveries at these times imply a high opportunity cost in terms of time of leisure and rest and have a higher probability of coming to an end in their shift than later deliveries.

Figure 1 documents the variation in the c-section rate between hours for our sample of public hospitals in Spain. We can observe that the distribution of emergency c-sections by hours of birth is not uniformly distributed. One important finding is that the proportion of women that deliver via an emergency c-section is higher at early night (from 23 to 4 am) and much lower during the last hours of the night and for the rest of the day. This pattern is not matched by either the total number of births or the number of eutocic births (see figure A3 in the Appendix). We thus hypothesize that this variation is driven, at least in part, by doctors' incentives.

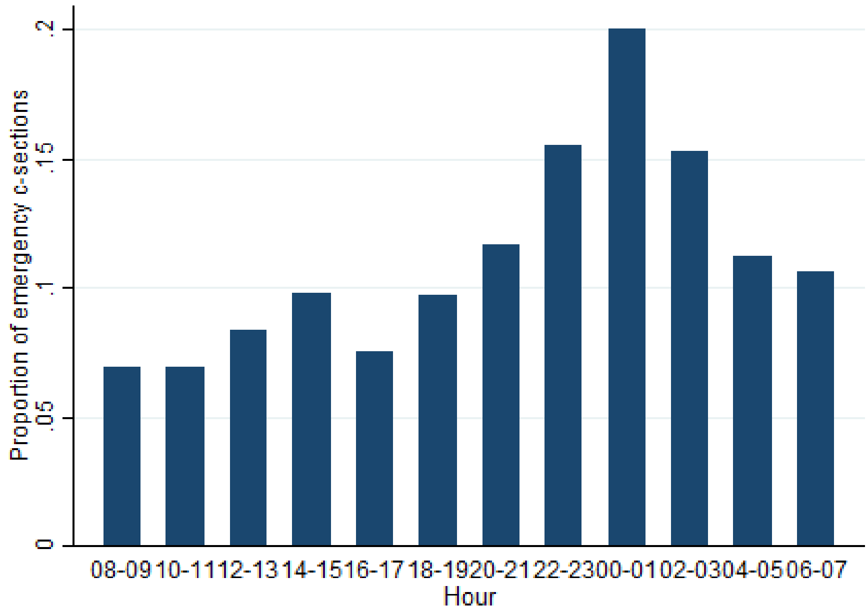


Figure 1: Proportion of unplanned c-sections by hour

3.3 Identification Strategy

Our objective is to identify the causal impact of non-medically indicated c-sections on child's health at birth. The simple comparison of women who got a c-section and those who delivered vaginally is likely to suffer from omitted variable bias, as these groups are likely to be different in characteristics that influence the outcome variables. Table 2 compares observable characteristics of mothers who delivered vaginally and through a cesarean section: we see that, in fact, these mothers are significantly different along several relevant aspects, such as age, gestational length, obstetric risk or educational achievement, all of them potentially related to the health of the newborn. There is thus reasons to be worried that they might also be different in other characteristics we cannot observe. Besides, by comparing vaginal deliveries with births by emergency c-section we cannot identify which kind of emergency c-sections are causing whatever health effects we find, since we observe the outcomes of both medically and non-medically indicated interventions. In order to overcome these issues, we will use the variation in the probability of getting a c-section between hours. The purpose of the instrument is thus twofold: we want to be able to compare similar women, and we want to identify precisely the impact of non-medically necessary cesareans.

Table 2: Maternal characteristics by type of birth

	Means		p-value
	Eutocic birth	C-section	for difference
Mother age	31.466	32.828	0.000
No studies	0.037	0.022	0.044
Primary school	0.278	0.206	0.000
Secondary school	0.502	0.609	0.000
University education	0.182	0.164	0.234
Non-Spanish	0.278	0.199	0.000
Single	0.017	0.015	0.602
Mother weight	65.471	67.830	0.000
Mother height	1.653	1.595	0.547
Tobacco during pregnancy	0.119	0.134	0.256
Alcohol during pregnancy	0.003	0.007	0.067
Gestation weeks	39.267	38.863	0.000
Previous c-section	0.064	0.223	0.000
Obstetric risk	0.350	0.580	0.000
Intrapartum pH	7.296	7.245	0.000
Observations	4201	685	4886

We define a binary variable CS_i equal to one if the mode of delivery is an emergency c-section and zero if it is an eutocic delivery, that is, a vaginal delivery with no interventions[2]. Child's health H_i refers to either Apgar scores or umbilical cord pH. We would thus like to estimate the following equation:

[2]We thus exclude births through other kinds of interventions such as vacuum, forceps or planned c-sections.

$$H_i = \beta_0 + \beta_1 CS_i + \beta_2 X_i + \epsilon_i^1 \quad (1)$$

where X_i is a set of covariates that include information on maternal characteristics and pregnancy indicators. But, as discussed earlier, the estimation of equation (1) is likely to provide biased estimates of β_1. To overcome this potential endogeneity we use an IV approach, instrumenting the type of birth with an indicator for the time the baby is born. Therefore, our first stage would be the following:

$$CS_i = \gamma_0 + \gamma_1 earlynight_i + \gamma_2 X_i + v_i \quad (2)$$

where $earlynight_i$ is an indicator variable equal to 1 if woman i gives birth during the beginning of the night shift (from 23h to 04h). Therefore, we expect a positive γ_1 since obstetricians are more likely to initiate a c-section during the night (in particular during the first hours) in order to gain time for leisure.

The identifying assumption is that $earlynight_i$ is not correlated with ϵ_i^1. We provide suggestive evidence that this is the case by comparing maternal and pregnancy characteristics of mothers who give birth in the different shifts. This comparison can be found in table 3. Mothers are similar with respect to their educational level, weight and height, alcohol and tobacco consumption habits during pregnancy, gestational length, obstetric risk or previous c-sections. The level of intrapartum pH, a measure of fetal suffering during labor – a major cause of emergency c-sections – is also equivalent (see more on this on section 5.2). The only slight differences that we find between mothers across time are with respect to their nationality (there are slightly more non-Spanish women during the day shift) and their marital status (more non married women during the day). However these differences are also very small in magnitude. We thus feel more confident with the assumption that there is no selection of women into the different shifts that could bias our estimates.

Second, in order for the exclusion restriction to hold, the instrument should affect child's health only through the increased probability of having a c-section. One potential concern is that the quality of medical care could change depending on the hour/shift. In order to overcome this problem, as a robustness check, we perform the analysis using variation in the probability of getting a c-section only within the night shift, and thus holding the quality of medical care constant (see section 5.1).

Table 3: Maternal characteristics by delivery time

	Means		p-value
	Not early night	Early night	for difference
Mother age	31.592	31.883	0.120
No studies	0.037	0.028	0.181
Primary school	0.267	0.271	0.817
Secondary school	0.517	0.518	0.943
University education	0.179	0.183	0.779
Non-Spanish	0.275	0.237	0.012
Single	0.019	0.009	0.024
Mother weight	65.698	66.164	0.355
Mother height	1.655	1.608	0.556
Tobacco during pregnancy	0.120	0.125	0.679
Alcohol during pregnancy	0.003	0.005	0.481
Gestation weeks	39.209	39.215	0.923
Previous c-section	0.084	0.095	0.228
Obstetric Risk	0.379	0.394	0.394
Intrapartum pH	7.269	7.277	0.439
Observations	3796	1090	4886

4 Results

Tables 4 and 5 present the results for the OLS estimation of equation (1) for the different measures of neonatal health. In Table 4, the first column for each outcome presents the results without controls, the second column incorporates controls for maternal characteristics, and finally the third column adds information about the pregnancy. All specifications include hospital and weekday fixed effects, the sample is restricted to single births and we estimate robust standard errors. The results show that delivering via a c-section is associated with a significant worsening of the Apgar Scores 1 and 5 and with a lower probability of having moderate pH, but not of having severe pH.

Table 5 presents the results for other outcomes of neonatal health. As it can be seen, babies born by cesarean section are more likely to need reanimation and to go to the Intensive Care Unit, but they are less likely to die.

As explained before, these estimates are likely to be biased because the mothers giving birth by c-section and vaginally are not comparable, and because we cannot identify which kind of c-sections is driving the results. The results for the IV estimation of the effects of non-medically indicated c-sections on Apgar scores 1 and 5 are shown in Table 6. The first stage F-statistics are larger than 39 for the different specifications, so following Stock and Yogo (2005) critical

Table 4: OLS results – Neonatal health

Panel A. Apgar Scores	Apgar Score 1			Apgar Score 5		
	(1)	(2)	(3)	(1)	(2)	(3)
Emergency CS	-0.590***	-0.586***	-0.488***	-0.236***	-0.238***	-0.156***
	(0.058)	(0.057)	(0.063)	(0.039)	(0.038)	(0.047)
Mean of Y		8.945			9.809	
Observations		4886			4884	
Panel B. pH Level	pH < 7.2			pH < 7.15		
	(1)	(2)	(3)	(1)	(2)	(3)
Emergency CS	-0.057***	-0.058***	-0.070***	0.002	0.001	-0.010
	(0.019)	(0.019)	(0.021)	(0.015)	(0.015)	(0.016)
Mean of Y		0.215			0.098	
Observations		3758			3758	
Maternal controls		✓	✓			✓
Pregnancy controls			✓		✓	✓

Notes: Robust standard errors in parentheses. All specifications include hospital and weekday fixed effects. Sample is restricted to single births. Maternal controls include: level of education, maternal weight, height, age and marital status. Pregnancy controls include: previous c-section, prenatal care, obstetric risk, gestation weeks and induced labor. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5: OLS results – Other Outcomes

	Intensive Care Unit		Reanimation		Exitus	
	(1)	(2)	(3)	(4)	(5)	(6)
Emergency CS	0.143***	0.112***	0.095***	0.077***	-0.002	-0.007*
	(0.015)	(0.014)	(0.013)	(0.014)	(0.002)	(0.004)
Mean of Y	0.057		0.073		0.005	
Observations	4886	4886	4886	4886	4886	4886
Maternal controls	✓	✓	✓	✓	✓	✓
Pregnancy controls		✓		✓		✓

Notes: Robust standard errors in parentheses. All specifications include hospital and weekday fixed effects. Sample is restricted to single births. Maternal controls include: level of education, maternal weight, height, age and marital status. Pregnancy controls include: previous c-section, prenatal care, obstetric risk, gestation weeks and induced labor. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

values with one endogenous variable and one IV (16.38), we can reject the null hypothesis that our instrument is weak.

In the first row of the table, we can see that a c-section has a negative impact on both Apgar Score 1 and Apgar Score 5. The estimated effects are large and significant. In the specification with the full set of controls (column 3), an emergency c-section reduces the Apgar Score 1 by 1.161 points. This effect is larger than one standard deviation (1.117) and is significant at the 5% significance level. An emergency c-section also has a negative impact on the Apgar Score 5. In this case the coefficient is -0.942, and again, is larger than one standard deviation (0.818) and significant at the 5% significance level.

Table 6: IV estimation – Apgar Scores

	Apgar Score 1			Apgar Score 5		
	(1)	(2)	(3)	(1)	(2)	(3)
Panel A. 2SLS						
Emergency CS	-1.179***	-1.218***	-1.161**	-0.907**	-0.954**	-0.942**
	(0.452)	(0.462)	(0.516)	(0.379)	(0.389)	(0.433)
Mean of Y		8.945			9.809	
Panel B. First stage						
Early night	0.090***	0.088***	0.078***	0.090***	0.088***	0.078***
	(0.013)	(0.013)	(0.012)	(0.013)	(0.013)	(0.012)
Observations	4886	4886	4886	4884	4884	4884
First-stage F	45.524	44.170	39.268	45.421	44.053	39.178
Maternal controls		✓	✓		✓	✓
Pregnancy controls			✓			✓

Notes: Robust standard errors in parentheses. All specifications include hospital and weekday fixed effects. Sample is restricted to single births. Maternal controls include: level of education, maternal weight, height, age and marital status. Pregnancy controls include: previous c-section, prenatal care, obstetric risk, gestation weeks and induced labor. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Because most of the newborns in our sample have Apgar scores equal to 10 (see figure A1), we also perform a similar analysis but using as dependent variable an indicator for having Apgar scores 1 and 5, respectively, lower than 10. Results can be found in table A3 in the appendix. Our qualitative conclusions hold, as we find that a c-section, as compared to an eutocic delivery, increases by around 30% and 40% the probability of having Apgar scores 1 and 5, respectively, below 10. Similarly, in table A4 we repeat this analysis using as dependent variables indicators for Apgar scores 1 and 5, respectively, below 9. This is relevant since decreases in Apgar scores are non-lineally related to the health of the newborn, with a decrease of the score below 9 being related to a more serious worsening in health than an equivalent decrease from 10 to 9. Our results suggest that non-medically indicated c-sections are related to a 40% higher probability of having Apgar score 1 below 9, and 17% higher probability of having Apgar 5 below 9.

In Table 7 we estimate the impact of a c-section on the probability of the pH level being below different thresholds: pH levels below 7.2 (low pH) and pH below 7.15 (very low pH). As can be seen, a c-section increases the probability of both indicators and the coefficients are significant for all the specifications, at the 10% significance level for low pH and at the 5% significance level for very low pH. In particular, a c-section increases the probability of low and very low pH by approximately 45%.

Table 7: IV estimation – pH Level Indicators

	pH $<$ 7.2			pH $<$ 7.15		
	(1)	(2)	(3)	(1)	(2)	(3)
Panel A. 2SLS						
Emergency CS	0.408*	0.417*	0.451*	0.406**	0.413**	0.445**
	(0.214)	(0.215)	(0.238)	(0.166)	(0.167)	(0.185)
Mean of Y		0.215			0.098	
Panel B. First stage						
Early night	0.085***	0.085***	0.077***	0.085***	0.085***	0.077***
	(0.015)	(0.015)	(0.014)	(0.015)	(0.015)	(0.014)
Observations	3751	3751	3751	3751	3751	3751
First-stage F	31.402	31.464	29.784	31.402	31.464	29.784
Maternal controls		✓	✓		✓	✓
Pregnancy controls			✓			✓

Notes: Robust standard errors in parentheses. All specifications include hospital and weekday fixed effects. Sample is restricted to single births. Maternal controls include: level of education, maternal weight, height, age and marital status. Pregnancy controls include: previous c-section, prenatal care, obstetric risk, gestation weeks and induced labor. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

We also perform the same analysis for other health outcomes of the child. Results can be found in Table 8. Although we could expect an effect on needing intensive care, reanimation or neonatal mortality, we only observe a slightly significant impact on intensive care unit utilization in one specification.

If we compare the results from the IV with the results from the OLS estimation, we can see that the IV coefficients are more negative both for Apgar scores and for the pH measures. This can be explained by the fact that with the OLS estimation we are including medically indicated c-sections, which reduce fetal suffering and, thus, this partially offsets the negative effects of the non-medically indicated c-sections that we find when using our instrument.

Table 8: IV estimation – Other Outcomes

	Intensive Care Unit		Reanimation		Exitus	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. 2SLS						
Emergency CS	0.161*	0.137	0.109	0.089	0.030	0.028
	(0.093)	(0.099)	(0.101)	(0.115)	(0.030)	(0.034)
Mean of Y	0.057		0.073		0.005	
Panel B. First stage						
Early night	0.088***	0.078***	0.088***	0.078***	0.088***	0.078***
	(0.013)	(0.012)	(0.013)	(0.012)	(0.013)	(0.012)
Observations	4886	4886	4885	4885	4886	4886
First-stage F	44.170	39.268	44.154	39.154	44.170	39.268
Maternal controls	✓	✓	✓	✓	✓	✓
Pregnancy controls		✓		✓		✓

Notes: Robust standard errors in parentheses. All specifications include hospital and weekday fixed effects. Sample is restricted to single births. Maternal controls include: level of education, maternal weight, height, age and marital status. Pregnancy controls include: previous c-section, prenatal care, obstetric risk, gestation weeks and induced labor. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

However, if we compare the results for the other outcomes (see tables 5 and 8), we can see that in this case the coefficients for the OLS are larger and significant: c-sections are associated with an increased probability of needing intensive care and reanimation, but with a reduction of neonatal mortality. It seems that these medically-indicated c-sections are performed to suffering babies who need immediate support. On the other hand, the IV estimates are not significant, suggesting that the effects of non-medically indicated c-sections are short-lived: in spite of the worsening in Apgar score and pH, we do not find that these negative effects translate into needing intensive care, reanimation or increased mortality risk.

5 Robustness checks

5.1 Exclusion restriction: variation within the night shift

One potential concern of our identification strategy is that the quality of medical care could be different during the day and the night shift. Hence, it could be the case that the negative effects on the child's health that we find are not due to the increased probability of getting a c-section, but due to a reduction of the quality of care during the night shift.

In order to provide evidence that this is not the case, we perform the same IV estimation but restricting the sample to mothers that gave birth during the night shift. Thus, in this case, we will use variation in the probability of getting a c-section within the night shift, holding the quality of care constant. As before, our instrument is an indicator variable equal to 1 if the woman gives birth during the early night (from 23 to 04 am). The sample is restricted to deliveries taking place at night: from 8pm to 8am; i.e., in the last half of physicians' shift.

Results for the IV estimation using variation within the night shift can be found in Table 9 and 10. We can again reject the null hypothesis that the instrument is weak, and we find that an emergency c-section reduces both Apgar Score 1 and Apgar Score 5 and increases the probability of having a pH lower than 7.2 and 7.15 . The coefficients remain large and significant at the 5% significance level. We interpret these results as evidence in favour of our exclusion restriction.

Table 9: IV estimation – Apgar Scores within the night

	Apgar Score 1			Apgar Score 5		
	(1)	(2)	(3)	(1)	(2)	(3)
Panel A. 2SLS						
Emergency CS	-1.333**	-1.353**	-1.255*	-1.054**	-1.057**	-1.030*
	(0.601)	(0.619)	(0.748)	(0.489)	(0.503)	(0.602)
Mean of Y		8.924			9.793	
Panel B. First stage						
Early night	0.076***	0.074***	0.060***	0.076***	0.074***	0.060***
	(0.015)	(0.015)	(0.014)	(0.015)	(0.015)	(0.014)
Observations	2720	2720	2720	2719	2719	2719
First-stage F	26.360	25.192	19.123	26.268	25.089	19.062
Maternal controls		✓	✓		✓	✓
Pregnancy controls			✓			✓

Notes: Robust standard errors in parentheses. All specifications include hospital and weekday fixed effects. Sample is restricted to single births and to births taking place between 8pm and 8am. Maternal controls include: level of education, maternal weight, height, age and marital status. Pregnancy controls include: previous c-section, prenatal care, obstetric risk, gestation weeks and induced labor. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5.2 Emergency c-sections: medically indicated versus non-medically indicated

One of the main reasons why emergency c-sections are medically indicated is if there is risk to the health of the mother or the baby during labor. The health of the baby is monitored during labor by several means, like watching their cardiac frequency or measuring the fetal scalp pH.

Table 10: IV estimation – pH Level Indicators within the night shift

	pH < 7.2			pH < 7.15		
	(1)	(2)	(3)	(1)	(2)	(3)
Panel A. 2SLS						
Emergency CS	0.670**	0.698**	0.822**	0.590**	0.621**	0.727**
	(0.312)	(0.322)	(0.387)	(0.238)	(0.247)	(0.299)
Mean of Y		0.214			0.099	
Panel B. First stage						
Early night	0.072***	0.070***	0.060***	0.072***	0.070***	0.060***
	(0.017)	(0.017)	(0.016)	(0.017)	(0.017)	(0.016)
Observations	2085	2085	2085	2085	2085	2085
First-stage F	18.050	17.257	14.893	18.050	17.257	14.893
Maternal controls		✓	✓			✓
Pregnancy controls			✓		✓	✓

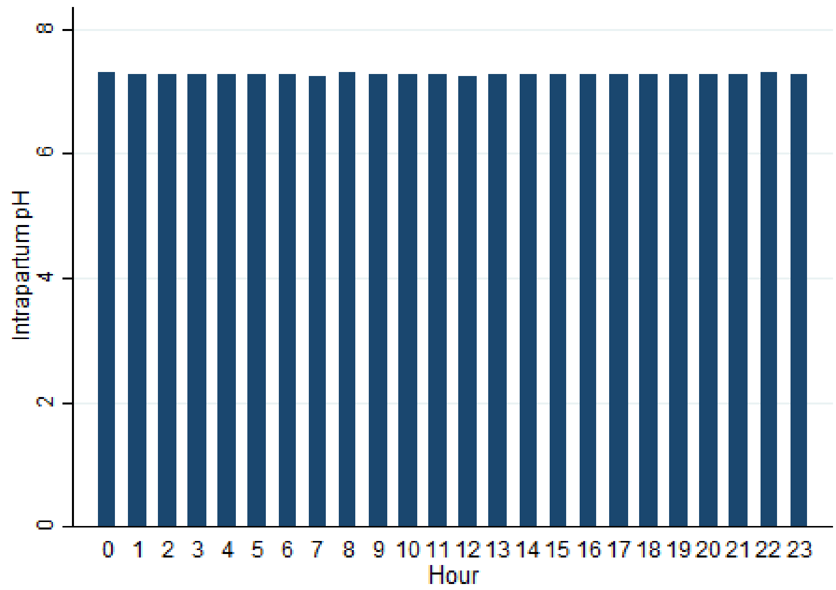
Notes: Robust standard errors in parentheses. All specifications include hospital and weekday fixed effects. Sample is restricted to single births and to births taking place from 8pm to 8am. Maternal controls include: level of education, maternal weight, height, age and marital status. Pregnancy controls include: previous c-section, prenatal care, obstetric risk, gestation weeks and induced labor. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Similar to the umbilical cord pH, if the fetal scalp pH is too low (namely, below 7.20) it suggests that the fetus is not getting enough oxygen. If this situation persists for too long, it could be threatening to the baby's health and the clinical advice is to perform an emergency c-section.

Since in our analysis we want to study the effect of non-medically indicated c-sections, it is important to ensure that this is the kind of c-sections that we are capturing with our instrument. While medically-indicated c-sections should be predicted by fetal suffering, those which are not medically-indicated, but performed for the doctors' convenience, should not.

A priori we would not expect our instrument to be correlated with fetal suffering: there is no apparent reason why births starting at night should present more risks for the fetus. A quick glance at the distribution of the intrapartum pH across hours seems to confirm this (see figure 2): we see a uniform distribution along the hours of the day, suggesting that there are no systematic differences in average fetal suffering across time. However we can also test for this formally, although we only have information about fetal scalp pH for a small part of our sample (around 300 observations). We do this in table 11. Columns (1) and (3) present the results of regressing the dummy for all emergency c-sections on the level of intrapartum pH and on an indicator for low intrapartum pH (below 7.2), respectively. We can see that lower levels of pH are strongly associated with a higher probability of performing a c-section, and that having the

Figure 2: Average intrapartum pH by hour



intrapartum pH below 7.2 is also associated with a higher probability of getting a c-section. On the other hand, in columns (2) and (4) we perform the same analysis but substituting the dependent variable for the predicted c-sections from our first stage – that is, a variable keeping only the variation in the probability of getting a c-section that is predicted by our instrument. In this case, we do not see any significant correlation with the two measures of intrapartum pH. Therefore, the c-sections captured by our instrument do not seem to be predicted by fetal suffering but by other reasons. We interpret this as supporting evidence that the negative health impacts that we find are due to non-medically indicated cesarean sections.

5.3 Falsification test

A priori, we would not expect any effects of delivering via an emergency c-section on outcomes like birth weight which should not be affected by the mode of delivery. We perform a placebo test by estimating the effect of a c-section on birth weight and on the probability of being low birth weight ($<$ 2500g). As can be seen in Table 12, we do not find any significant effect of c-sections on birth weight or on the probability of having low birth weight. The coefficient of emergency c-sections is slightly significant, at the 10% level, in the regression of low birth weight. However this significance disappears once we include pregnancy controls. All in all, these results provide additional evidence in favour of our identification strategy.

Table 11: Robustness check: fetal suffering and c-sections

	(1) Emergency CS	(2) Predicted CS	(3) Emergency CS	(4) Predicted CS
Intrapartum pH	-1.863***	0.028		
	(0.294)	(0.026)		
Intra. pH < 7.2			0.317***	-0.006
			(0.059)	(0.005)
Observations	307	307	307	307

Notes: Robust standard errors in parentheses. Sample is restricted to single births. All specifications include hospital and weekday fixed effects, and the full set of maternal and pregnancy controls. Maternal controls include: level of education, maternal weight, height, age and marital status. Pregnancy controls include: previous c-section, prenatal care, obstetric risk, gestation weeks and induced labor. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 12: IV estimation – Birth weight

	Birth Weight			Low Birth Weight		
	(1)	(2)	(3)	(1)	(2)	(3)
Panel A. 2SLS						
Emergency CS	-45.028	-61.789	24.270	0.156	0.168*	0.129
	(199.389)	(198.031)	(197.721)	(0.099)	(0.100)	(0.097)
Mean of Y		3275.011			0.065	
Panel B. First stage						
Early night	0.090***	0.088***	0.078***	0.090***	0.088***	0.078***
	(0.013)	(0.013)	(0.012)	(0.013)	(0.013)	(0.012)
Observations	4886	4886	4886	4886	4886	4886
First-stage F	45.524	44.170	39.268	45.524	44.170	39.268
Maternal controls		✓	✓	✓	✓	✓
Pregnancy controls			✓			✓

Notes: Robust standard errors in parentheses. All specifications include hospital and weekday fixed effects. Sample is restricted to single births. Maternal controls include: level of education, maternal weight, height, age and marital status. Pregnancy controls include: previous c-section, prenatal care, obstetric risk, gestation weeks and induced labor. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

6 Conclusions

This paper provides new evidence of the adverse effects of non-medically necessary cesarean sections on the newborn's health. In order to overcome potential omitted variable bias and abstract from those cases in which c-sections respond to a clear clinical indication, we make use of a novel instrument that exploits variation in the probability of receiving a c-section that is unrelated to maternal and fetal health: variation between hours.

Our results suggest that these non-medically indicated c-sections lead to a significant worsening in two frequent measures of newborn health: Apgar scores and pH of the umbilical cord. In particular, the deterioration in these outcomes is likely to be capturing increased respiratory morbidity related to the presence of amniotic liquid in the newborn's lungs. The relative decline in Apgar scores might also capture reduced excitability and muscle tone. All in all, these findings are consistent with the medical literature that has identified the vaginal delivery as a crucial programming event in the baby's life (Hyde et al., 2012).

Although the size of the effects we find is of statistical and medical significance – declines range between 1 and 1.5 standard deviation for all neonatal health outcomes – we do not find evidence that these effects translate into a significant increase in the need for reanimation or intensive care or into increased risk of neonatal death. Therefore, the effects we find might not be severe enough or might fade after little time. More research is needed in order to obtain further causal evidence of the effect of these non-medically necessary c-sections on longer-term health outcomes of the baby.

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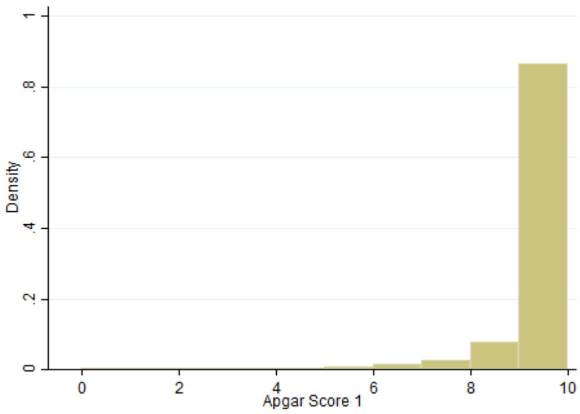
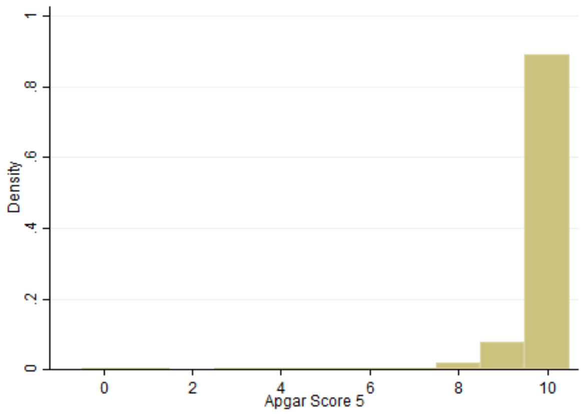
Appendix

Figure A1: Distribution of Apgar scores



(a) Apgar Score 1



(b) Apgar Score 5

Figure A2: Distribution of umbilical cord pH by levels of Apgar 1 and 5

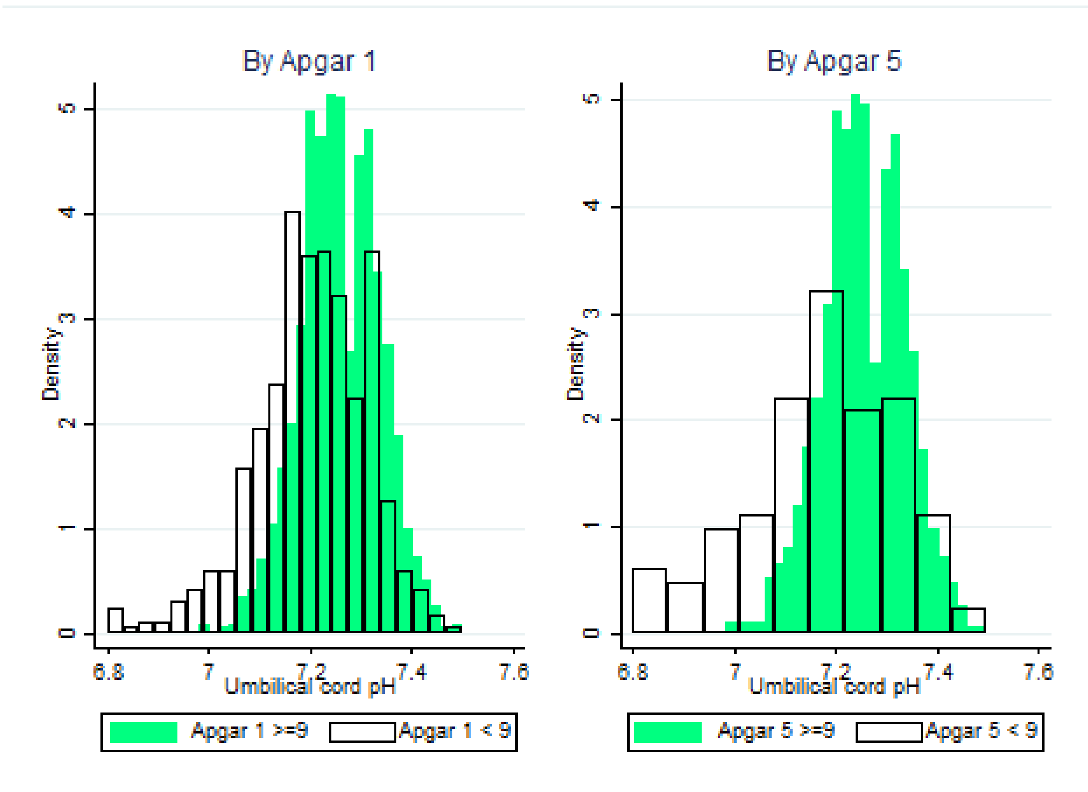
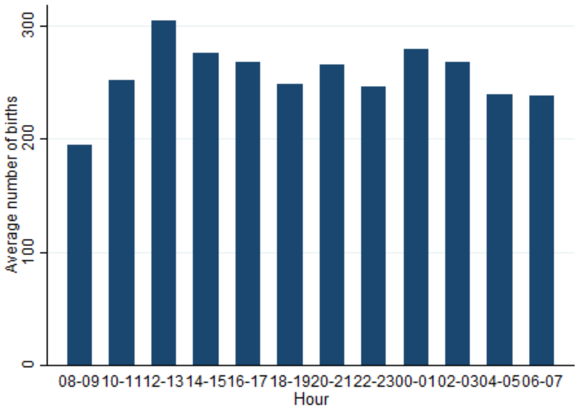
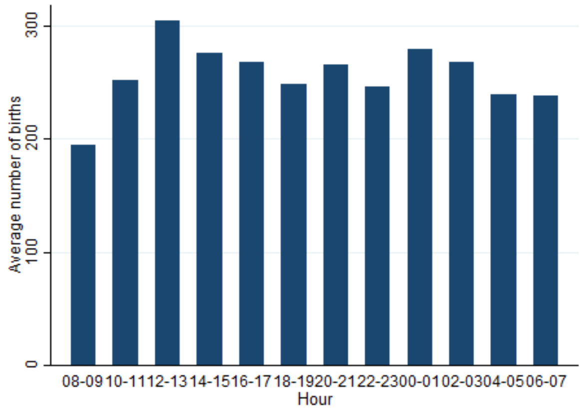


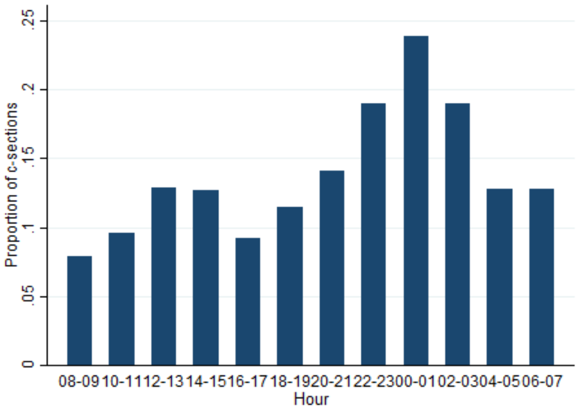
Figure A3: Distribution of different types of births across hours



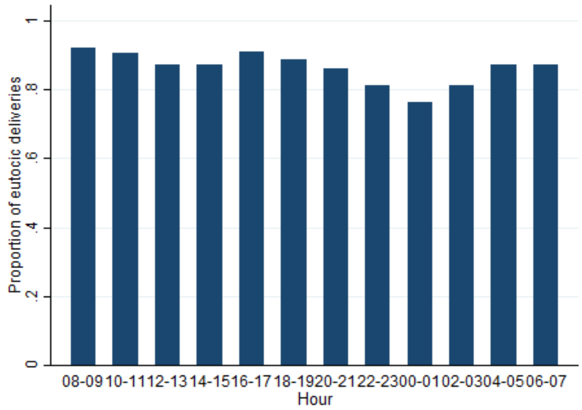
(a) All births



(b) Emergency c-sections and eutocic births



(c) Cesarean sections



(d) Eutocic deliveries

Figure A4: Proportion of Emergency C-sections by physicians' hours worked (loess estimate)

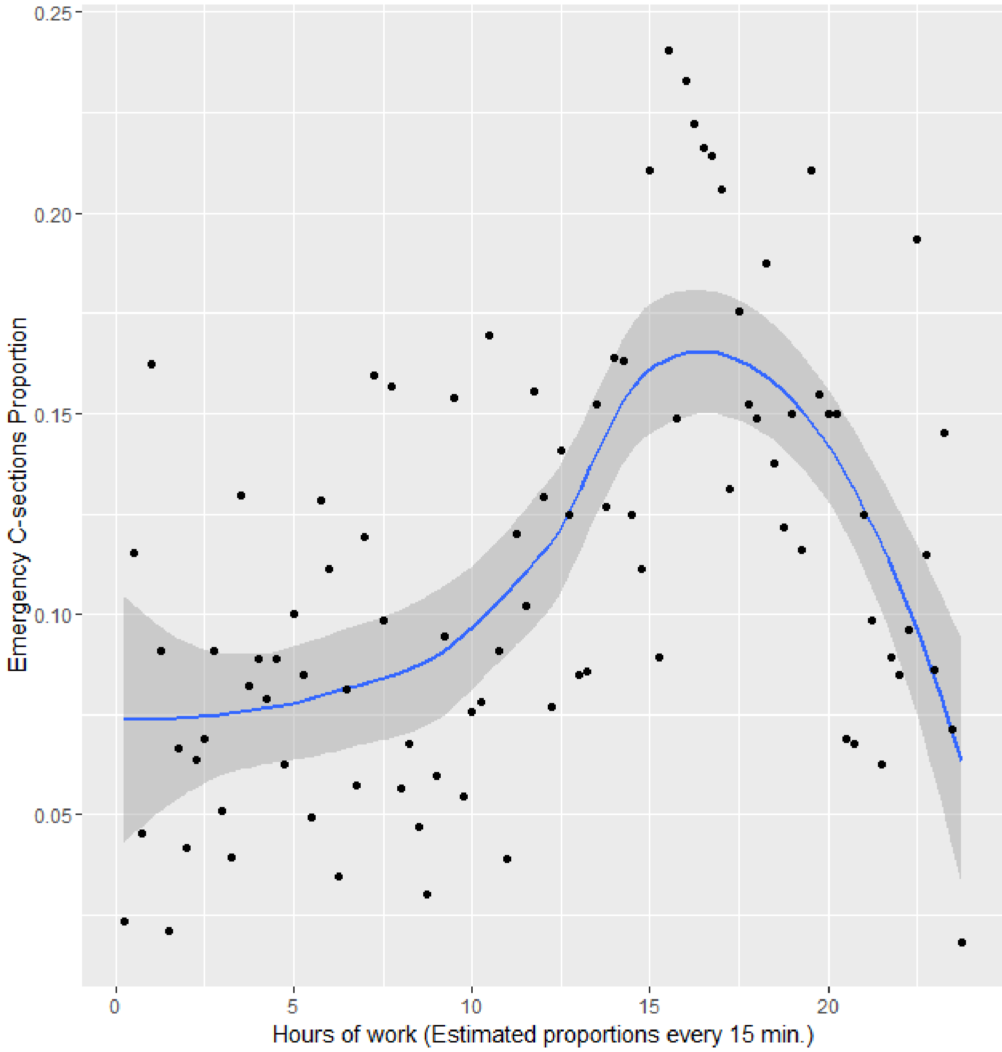


Table A1: Summary statistics

	Mean	SD
A. Mother characteristics		
Mother age	31.890	5.414
Level of education		
No studies	0.032	0.175
Primary school	0.257	0.437
Secondary school	0.523	0.500
University education	0.188	0.391
Non-Spanish	0.250	0.433
Single	0.017	0.130
Mother weight	65.715	14.536
Mother height	1.638	2.087
B. Pregnancy characteristics		
Tobacco during pregnancy	0.122	0.327
Alcohol during pregnancy	0.004	0.062
Previous c-section	0.113	0.317
Gestation weeks	39.204	1.785
Obstetric Risk	0.406	0.491
Induction	0.227	0.419
C. Type of birth		
Planned c-section	0.053	0.224
Emergency c-section	0.112	0.316
Spatula	0.007	0.084
Eutocic	0.687	0.464
Forceps	0.0141	0.118
Breech Vaginal	0.001	0.036
Vacuum	0.125	0.331
D. Newborn outcomes		
Apgar 1	8.884	1.117
Apgar 5	9.793	0.818
Birthweight (in gr.)	3267.970	519.988
Low birthweight (<2500 gr.)	0.068	0.252
Intensive care unit	0.064	0.244
Reanimation	0.084	0.277
Exitus	0.004	0.061
Umbilical cord pH	7.254	0.086
Intrapartum pH	7.273	0.073
Male	0.521	0.500
Observations	6163	

Table A2: Health outcomes by delivery type

	Means		p-value
	Eutocic	C-section	for difference
Apgar 1	9.028	8.435	0.000
Apgar 5	9.839	9.626	0.000
Birtweight	3290.334	3181.038	0.000
Low Birthweight	0.050	0.155	0.000
Male	0.507	0.555	0.019
Exitus	0.005	0.003	0.505
Intensive Care Unit	0.036	0.182	0.000
Reanimation	0.063	0.139	0.000
Umbilical cord pH	7.253	7.260	0.057
Observations	4201	685	4886

Table A3: IV estimation – Apgar Score < 10

	Apgar Score 1 <10			Apgar Score 5 <10		
	(1)	(2)	(3)	(1)	(2)	(3)
Panel A. 2SLS						
Emergency CS	0.296**	0.298**	0.285*	0.404***	0.420***	0.427***
	(0.142)	(0.144)	(0.162)	(0.129)	(0.132)	(0.148)
Mean of Y		0.777			0.109	
Panel B. First stage						
Early night	0.090***	0.088***	0.078***	0.090***	0.088***	0.078***
	(0.013)	(0.013)	(0.012)	(0.013)	(0.013)	(0.012)
Observations	4886	4886	4886	4884	4884	4884
First-stage F	45.524	44.170	39.268	45.421	44.053	39.178
Maternal controls		✓	✓		✓	✓
Pregnancy controls			✓			✓

Notes: Robust standard errors in parentheses. All specifications include hospital and weekday fixed effects. Sample is restricted to single births. Maternal controls include: level of education, maternal weight, height, age and marital status. Pregnancy controls include: previous c-section, prenatal care, obstetric risk, gestation weeks and induced labor. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A4: IV estimation – Apgar Score < 9

	Apgar Score 1 <9			Apgar Score 5 <9		
	(1)	(2)	(3)	(1)	(2)	(3)
Panel A. 2SLS						
Emergency CS	0.383***	0.403***	0.402***	0.160**	0.167**	0.172**
	(0.136)	(0.138)	(0.156)	(0.075)	(0.077)	(0.087)
Mean of Y		0.135			0.031	
Panel B. First stage						
Early night	0.090***	0.088***	0.078***	0.090***	0.088***	0.078***
	(0.013)	(0.013)	(0.012)	(0.013)	(0.013)	(0.012)
Observations	4886	4886	4886	4884	4884	4884
First-stage F	45.524	44.170	39.268	45.421	44.053	39.178
Maternal controls		✓	✓		✓	✓
Pregnancy controls			✓			✓

Notes: Robust standard errors in parentheses. All specifications include hospital and weekday fixed effects. Sample is restricted to single births. Maternal controls include: level of education, maternal weight, height, age and marital status. Pregnancy controls include: previous c-section, prenatal care, obstetric risk, gestation weeks and induced labor. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A5: IV estimation – Apgar Score < 8

	Apgar Score 1 <8			Apgar Score 5 <8		
	(1)	(2)	(3)	(1)	(2)	(3)
Panel A. 2SLS						
Emergency CS	0.175*	0.182*	0.173	0.098*	0.103*	0.105*
	(0.095)	(0.097)	(0.109)	(0.052)	(0.053)	(0.060)
Mean of Y		0.059			0.013	
Panel B. First stage						
Early night	0.090***	0.088***	0.078***	0.090***	0.088***	0.078***
	(0.013)	(0.013)	(0.012)	(0.013)	(0.013)	(0.012)
Observations	4886	4886	4886	4884	4884	4884
First-stage F	45.524	44.170	39.268	45.421	44.053	39.178
Maternal controls		✓	✓		✓	✓
Pregnancy controls			✓			✓

Notes: Robust standard errors in parentheses. All specifications include hospital and weekday fixed effects. Sample is restricted to single births. Maternal controls include: level of education, maternal weight, height, age and marital status. Pregnancy controls include: previous c-section, prenatal care, obstetric risk, gestation weeks and induced labor. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

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