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Identifying the Effect of Cesarean Delivery on Subsequent Childbearing

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Abstract

Cesarean delivery is a surgery occurring in about 33% of births in the United States. Cesarean delivery has lower maternal and fetal risks, offers greater scheduling convenience, and its utilization has increased over time. However, Cesarean delivery has also been tentatively linked to decreased subsequent fertility. Previous studies do not address the endogeneity of Cesarean delivery to reproductive health. We used fetal malpresentation (position of the infant in the uterus at the time of delivery) as a conditionally exogenous indicator of Cesarean delivery. Using data for 96,258 first-time mothers giving birth in 31 hospitals in the state of WI from 2006 to 2013, we compared subsequent fertility between mothers who delivered via Cesarean due to fetal malpresentation and mothers who delivered vaginally, conditional on known medical risk factors for fetal malpresentation. We found that Cesarean delivery reduced the likelihood of subsequent childbearing by 6 to 33% compared to vaginal delivery.

Cesarean delivery is the most common surgery in the U.S. occurring in 32 percent of all live births.[1,2] Rates of Cesareans have increased steadily from a low of 21 percent in 1996 to almost 33 percent where the rate has remained since 2009.[3-5] Although a major surgery, Cesarean delivery has a long track record of safety and improved maternal and fetal outcomes.[6] The majority of Cesarean deliveries are planned, offering convenience of scheduling, shorter duration of labor, and reduced pain.[7] Many believe that the rise in the use of Cesarean delivery is the reflection of physician and maternal preferences rather than objective medical indications, especially in light of increased prevalence of Cesarean delivery on maternal request without a medical indication. [6,8] The concern, however, is the potential longer-term impact of Cesarean delivery on subsequent fertility and childbearing, with studies indicating significantly increased risk of placental abnormalities and hysterectomy (surgical removal of uterus) following a Cesarean delivery compared to an uncomplicated vaginal birth. [9-11] [9,12-14]

Several observational studies have documented evidence of an association between Cesarean delivery and subsequent reduced fertility, as measured by both a reduced probability of a subsequent childbirth and an increased interval between pregnancies.[15,16] A meta-analytic study found that Cesarean deliveries are associated with reduced fertility – women who had Cesarean deliveries were 9% less likely to have a subsequent pregnancy and 11% less likely to have a subsequent birth.[15] Moreover, the median interpregnancy interval – the length of time in between delivery of a pregnancy and delivery of the subsequent pregnancy – following Cesarean delivery was 2-6 months longer than after vaginal deliveries although this difference was statistically insignificant in most of the reviewed studies.[15]

The challenge in identifying a causal effect of Cesarean delivery on subsequent childbearing, however, lies in the fact that many of the medical indications for Cesarean delivery are also independently associated with the woman's reproductive health. Most of the existing evidence relies on a comparison of fertility outcomes between women who had an Cesarean delivery to those who had a vaginal delivery, which produces findings that are potentially seriously biased due to "selection bias by indication."[15-21] For example, Cesarean delivery is more common in high-risk pregnancies conceived using in-vitro fertilizations and other assisted reproductive medicine procedures used to treat infertility.[22] The probability of having a Cesarean delivery also increases with maternal age and the number of previous pregnancies (especially previous Cesarean deliveries), which are both likely to be negatively associated with subsequent fertility. Unobserved selection may also result from a number of other factors including maternal weight, twin pregnancies, and preterm delivery, which are all correlated with Cesarean delivery.[5,23] Therefore, the established association of Cesarean delivery with lower subsequent fertility may be driven by the endogeneity of Cesarean delivery and not necessarily indicate a causal relationship.[15-17]

Establishing the extent to which reduced reproductive ability might be causally linked to the mode of delivery (Cesarean versus vaginal) is needed to inform the ongoing debate about the risks and benefits of Cesarean delivery. First, improved knowledge regarding the causal effect of Cesarean delivery on subsequent reproductive ability could emphasize the need to consider the woman's optimal fertility expectations when risks and benefits of Cesarean delivery are discussed during her first pregnancy. Second, in light of increases in maternal age at first birth and Cesarean delivery use, a better understanding of the causal effect on subsequent fertility is important at the population level, as a potential determinant of the U.S.' reproductive capacity and population growth.

This study aims to establish causal evidence on the role of Cesarean delivery on subsequent fertility by relying on a natural experiment using fetal malpresentation – any fetal position other than vertex (head down, crown entering the birth canal first), one of the main indicators for Cesarean delivery in uncomplicated low-risk pregnancies. We show that fetal malpresentation is plausibly unrelated to fertility prior to pregnancy and is unlikely to impact future childbearing, other than through Cesarean delivery. We use rich administrative data of hospital births in the state of Wisconsin over 7 years (PeriData.Net®) that allows us to compare subsequent childbearing of mothers who have a Cesarean delivery due to fetal malpresentation to those who delivery vaginally.

Fetal malpresenation as a natural experiment

Our identification strategy relies on fetal malpresentation being uncorrelated with risk factors and characteristics that might influence the likelihood of Cesarean delivery and subsequent childbearing, conditional on an observable set of characteristics that we can control for in our analyses.

Nearly 19 percent of all primary Cesarean deliveries are due to fetal malpresentation[1], which occurs in approximately 3 percent of all term deliveries with breech presentation (feet down) being the most common form of fetal malpresentation.[24] Other less common fetal malpresentations include fetal shoulder, face, or brow entering the birth canal first. Consistent with a large body of evidence documenting inferior health outcomes among breech infants delivered vaginally relative to Cesarean,[21,25-27] the leading U.S. authority on obstetric and gynecological practice, the American College of Obstetricians and Gynecologists' (ACOG) , issued a clinical guideline that breech infants should be delivered via cesarean delivery.[28] As such, nearly all breech infants are delivered by Cesarean in the U.S.[i]

Fetal malpresentation at delivery is largely unrelated to maternal health or behaviors, with approximately 85 to 91 percent of fetal malpresentations having no identifiable causes or risk factors.[29] However, fetal malpresentation is more likely in preterm infants (before the natural transition to the vertex presentation for delivery), and among shorter and older women (although the association with maternal statute and age could be secondary to gestational age of the infant).[29-32] Limited evidence also suggests that a greater risk for malpresentation may be associated with uterine abnormalities (shape,

[i] Among first-time mothers with a term malpresenting fetus, 92 percent delivered via Cesarean in 2013 based on the authors' calculations using the 2013 National Vital Statistics Systems births data.

lesions), placental abnormalities, abnormal amniotic fluid volume, or fetal anomalies (e.g., anencephaly).[30,33-38] Similar to maternal age and statue, however, many of these associations may be secondary to the low gestational age of the infant at delivery.[31,37] In this study we are able to adjust for all of these potential malpresentation risk factors.

Two earlier studies compared fertility after Cesarean deliveries due to malpresentation with vaginal deliveries, as we propose to do in our study.[17,18] Counter to the preponderance of correlational evidence of negative effects on subsequent fertility, these authors found the effect of Cesarean delivery to be small in magnitude and statistically insignificant, disputing the causal pathway from the delivery method to subsequent fertility outcomes. However, both studies used women from Northern European countries with lower fertility rates than in the U.S., and both included second and higher-order births potentially limiting subsequent fertility effects.

Our study is the first to examine the causal effect of Cesarean delivery using fetal malpresentation as a natural experiment among first-time mothers in the U.S., a population that is more relevant for U.S. policy and clinical practice than the earlier studies.

Data and Methods

Data

We relied on data previously obtained from PeriData.Net®, a data platform developed through the leadership of the Wisconsin Association for Perinatal Care (WAPC) that contains data from 87 of approximately 100 birth hospitals (92% of births) in Wisconsin from 2006 to 2013. Having served as a source system for electronic submission of birth vital records until 2010, the system contains more than 650 data fields of which about 40% are formatted to 2003 birth certificate specifications used in reporting vital statistics. Hospitals submit required birth certificate fields and any portion of the additional fields to PeriData.Net®'s web-based platform. Following IRB approval at Marquette University

(Weiss, PI), 31 (35.6%) hospitals agreed to the use of their data in studies of obesity and pregnancy outcomes. Under data use agreements with each hospital, a de-identified dataset was extracted by the dataset administrator and provided to the research team. A total of 236,820 birth records were extracted (64.78% of the total database).

We restricted our analytic sample to 126,934 fist-time mothers age 18 or older at the time of the first birth and whose first birth was a singleton delivered between 28 and 42 weeks of gestation. After excluding Cesarean deliveries not due to fetal malpresentation (n=37,007), our sample includes 96,487 first-time mothers: 93,373 had vaginal births (96.78%) and 3,114 had Cesarean deliveries due to fetal malpresentation (3.22%). From this sample, we estimated the effect of Cesarean delivery on the total number of births and on a categorical measure of the total number of subsequent births (0, 1, or 2+ additional births) to capture potential non-linearities. We also examined the interpregnancy interval for women who had at least two births, calculated as the number of months in between the delivery of the first and second child.

We note that our follow-up is subject to attrition for two reasons. First, we do not observe subsequent fertility for mothers who have subsequent births either at hospitals in Wisconsin not in our sample or in other states. Second, while women who are observed for the first time 2006 have a 7-year follow-up period, women who enter the sample in the later years of the study period have shorter follow-up periods. The average follow-up period of all women in our sample is 3.5 years. If the duration of follow-up was systematically correlated with the probability of fetal malpresentation, the attrition could bias our estimates. We discuss this in more detail later.

Statistical Approach

To examine the effect on subsequent fertility, we estimated two separate regressions of the following form:

$$Y_i = \beta_0 + \beta_1 Z_i + \beta_2 X_i + \beta_3 P_i + \varepsilon_i \qquad [1]$$

where Y_i is 1) a measure of the total number of subsequent births (not including the first birth) that mother i had during our sample period across all hospitals in our dataset and 2) a categorical measure equal to zero if the mother did not have subsequent births, one if the mother had exactly one subsequent birth, or two if the mother had two or more subsequent births in our sample; Z_i is an indicator equal to 1 if delivery was a malpresenting Cesarean, and 0 if vaginal; X_i is a vector of *maternal individual-level control variables* and includes maternal socio-demographic measures, including an indicator for white race, an indicator for Hispanic/Latino ethnicity, an indicator for whether the mother had at least a college degree, marital status, and two sources of payment for the delivery (private health insurance, Medicaid, and other as the reference) and whether the mother used WIC during the pregnancy; P_i includes measures of *risk factors for malpresentation*: maternal age, maternal weight at pre-pregnancy and at delivery, maternal height, gestational age at delivery, an indicator for any congenital anomalies of the newborn or infant death, an indicator for any uterine or placental anomalies (any uterine or cervical anomaly, inverted uterus, incompetent cervix, placenta previa, too much/too little amniotic fluid – polyhydramnios or oligohydramnios, eclampsia, uterine or cervical bleeding during the pregnancy), whether the mother reported alcohol or tobacco use during pregnancy; and ε is the error term. In all models, we present predicted or adjusted means post-estimation (see Table 1 for the full list of covariates and Appendix for full set of regression coefficients). We estimated the model with the number of total subsequent births as the dependent variable using a Poisson regression and the model with the categorical measure as the dependent variable using a multinomial logistic regression. Standard errors in all models are clustered at the hospital level.

We also used a propensity score matching (PSM) model as a robustness check, where we restricted the sample to mothers with fetal malpresentation matched to statistically similar mothers who delivered vaginally.[39] We do this in three ways using a regression-adjusted nearest-neighbor method for matching without replacement. Specifically, we estimated the propensity score, obtained as the predicted values after estimating a logistic regression of the malpresenting Cesarean indicator Z_i on the maternal and pregnancy controls, X_i and P_i in equation [1] (see Appendix Table 1 for the propensity score regression results). We then selected comparison mothers who had vaginal deliveries that are "nearest" to each treatment mother who delivered via Cesarean. In our first robustness check, we allowed only one comparison mother per treatment mother, i.e. one-to-one matching. Second, we used the full set of all potential controls – mothers who had vaginal births within the common support – to serve as matches; in this case, a treatment mother could have more than one statistically matched comparison mother. Finally, we also re-estimated equation [1] by including our estimated propensity scores as inverse probability weights. Although we found some differences in pre-delivery measures by delivery mode for our sample, these differences become statistically insignificant in our sample of one-to-one matched mothers.[ii] For example, as shown in our propensity score model (Appendix Table 1), malpresenting Cesarean mothers (Z_i=1) weighed slightly less prior to pregnancy and, not surprisingly, were more likely to have risk factors for malpresentation, but these differences do not persist in the one-to-one matched samples.

As a second set of robustness checks, we re-estimated all of the models excluding all mothers (both Cesarean and vaginal delivery) with 1) any uterine, placental, or fetal/congenital anomalies[iii] plus 2) any complications of labor and delivery that might be related to malpresentation risk factors (e.g. uterine shape).[iv] These sample exclusions result in a reduction of 7 to 19 percent of our sample of mothers with

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[ii] Results not reported here, but available upon request.

[iii] This includes any anomalies of the newborn, perinatal death, or diagnosed fetal anomalies prior to delivery, any uterine or cervical anomaly, inverted uterus, incompetent cervix, placenta previa, too much/too little amniotic fluid – polyhydramnios or oligohydramnios, eclampsia, uterine or cervical bleeding during the pregnancy.

[iv] This included cephalopelvic disproportion (mother's pelvis determined to be too small for delivery), shoulder dystocia (infant's shoulder is obstructed), fetal intolerance of labor, or chorioamnionitis (infection of fetal amnion and chorion membranes).

2 births and 8 to 22 percent of our full sample of all mothers. In all cases, our estimates using these restricted samples are similar to those presented here.[v] We also estimated models with the full samples that control for any labor and delivery complications and the results are consistent with those presented here.

One additional concern with using fetal malpresentation as a conditionally random source of variation in Cesarean delivery is the fact that we do not observe fetal presentation for mothers who deliver vaginally, and there may actually be mothers in our sample of vaginal deliveries whose infant was malpresenting at delivery but who chose to delivery vaginally against medical advice. Mothers who choose to deliver a malpresenting infant vaginally may be systematically different (possibly healthier) than malpresenting Cesarean mothers, causing a bias toward finding a negative effect of Cesarean on subsequent outcomes. However, due to the clinical recommendation that malpresentating infants be delivered via Cesarean delivery, only a very small proportion of non-vertex presenting infants are born vaginally. In a national sample of over 1 million first singleton births delivered between 28 and 42 weeks of gestation to mothers age 18 or older in the National Vital Statistics System (NVSS) data (U.S. national births data), we find that of the 35,992 breech births in 2013, only 3.6 percent were delivered vaginally.[vi] Back of the envelope calculations suggest that our full sample of 93,149 vaginal deliveries may include only about 120 unreported breech presentations. Therefore, the extent to which we might be misclassifying some vaginal delivery mothers' presentation is likely to be very small.

Results

[v] Full results available upon request.

[vi] Authors' calculations using the 2013 NVSS births data. We note that a few states are missing presentation information for a small fraction of births with the exception of Virginia (missing about 50%) and Wyoming (missing on 100%).

In Table 1, we present the descriptive statistics of our two analytic samples: first-time mothers for whom we observe at the first and second births (column 1) and all first-time mothers. About three percent of the mothers in both samples had a Cesarean delivery with their first birth due to fetal malpresentation, which is similar to the national rate among all hospital births in the U.S. that ended in a Cesarean section due to malpresentation in 2013.[vii] On average, mothers with two births in our sample delivered about 30 months apart. About two-thirds of mothers in our sample gave birth only once and had no subsequent births, but this rate was slightly higher for mothers delivering by Cesarean due to fetal malpresentation at 73 percent relative to 63 percent for mothers delivering vaginally ($p< 0.01$). Mothers delivering by Cesarean tended to be older, are more likely to be white, college educated, married, and privately insured, on average, than mothers delivering vaginally. Consistent with previous research, mothers delivering by Cesarean due to fetal malpresentation tended to deliver earlier (at about 38 weeks of gestation vs. 39) and were more likely to have a risk factor for fetal malpresentation – fetal or maternal anomalies, but were not significantly shorter in stature that mothers who deliver vaginally.

We present results examining subsequent childbearing (Tables 2-3). Among mothers who have a first and second delivery in our sample, there is no significant difference in the amount of time in between pregnancies when comparing mothers whose first birth was a Cesarean to those whose first birth was delivered vaginally (see Panel A, column 1 of Table 2; full set of regression results in Appendix Tables 2 and 3). We didd find evidence of an effect of Cesarean delivery on the number of total births (Table 2, Panel B). Although the effect on the total number of births is statistically significant ($p = 0.05$), the difference is small in magnitude with mothers whose first birth is delivered by Cesarean having 0.36 subsequent births, on average, relative to 0.39 births among mothers whose first birth is delivered

[vii] Based on authors' calculations using the National Vital Statistics System births data for 2013, 3.34 percent of all births were delivered via Cesarean due to malpresentation.

vaginally. This represents about an 8 percent difference, however. Our PSM results suggest a difference in number of subsequent births ranging from 0.02 to 0.10, all estimates of which are statistically significant and represent between a 6 and 33 percent difference. Consistent with our results reported in Table 2, our propensity score models suggest no relationship between breech Cesarean delivery and interpregnancy interval (columns 2-4). The effect is driven primarily by a difference in the likelihood of Cesarean mothers with fetal malpresentation to have 3 or more total births relative to their vaginal birth counterparts.

In Table 3, we present the predicted probability of having 1) no subsequent births, 2) one subsequent birth, and 3) 2 or more subsequent births. Mothers whose first birth was delivered vaginally were 2 percentage points more likely to have two or more subsequent births, for at least three children, relative to mothers whose first birth is delivered by Cesarean. Our propensity score models also largely support the finding that Cesarean delivery negatively affects subsequent future childbearing, whether measured as a continuous measure of subsequent births or a categorical measure (columns 2-4 of Table 3).

The study has several limitations. First, the data do not include fetal presentation for non-Cesarean births so we are unable to execute a formal instrumental variable estimation approach and instead present reduced-form models. Although our results are robust to controlling for a wide set of risk factors, some residual bias from systematic differences between breech Cesareans and vaginal deliveries may remain. As noted above, we estimated models with additional labor/delivery and maternal health controls, however, and found similar effect sizes to those reported. Second, although our sample links births across multiple hospitals in one state, it is likely that we are missing some births that happened in hospitals not included in our study. This could pose a bias; if for example, mothers who delivered their first birth as a Cesarean chose hospitals out of our sample for subsequent deliveries at a systematically different rate than mothers who delivered their first births vaginally. Related to this, our study covers a period of 6 years so we are unable to examine the entire fertility histories for all women; our data on high-order births (4 and higher) is particularly limited. There is no a priori reason, however, to suspect that this data censoring is occurring in systematically different ways for our two groups.

Nonetheless, our study contributes to the literature on the causal effects of Cesarean deliveries in by using fetal malpresentation as a natural experiment coupled with unique data that allows us to link birth records across mothers over time. We address potential concerns of selection or other bias and our findings reported here are robust to those sensitivity analyses.

Conclusion

Our study is a first examination of the effect of Cesarean delivery on subsequent fertility using fetal malpresentation as a natural experiment in a large sample of births. Fetal malpresentation is plausibly random and is unknown to impact maternal weight and subsequent fertility other than through its role as a main indicator for Cesarean delivery in low-risk pregnancies. While Cesarean deliveries are associated with older maternal age and greater likelihood of fertility treatments, we are able to match women who deliver their first births via Cesarean due to fetal malpresentation to statistically similar women whose first births are delivered vaginally.

Our estimates are consistent with a negative effect of Cesarean delivery on subsequent fertility. Women who deliver by Cesarean have between 0.02 and 0.10 fewer subsequent births, representing between 6 and 33 percent fewer subsequent children. The fertility reduction occurs at higher-order birth order, with the probability of a second birth virtually unaffected. This likely is due to the fact that after one Cesarean delivery, each subsequent delivery is usually via Cesarean, despite the availability of vaginal birth after Cesarean. Although the second Cesarean is generally considered safe, women may choose to limit the number of pregnancies due to their experiences with post-surgical recovery or due to provider recommendations for avoidance of high multiparity in the presence of repeated Cesarean incisions. Therefore, women who had a Cesarean might be less likely to have multiple repeated Cesarean births either by choice or by their physician's recommendation.

The negative impact of Cesarean delivery on childbearing is important at the population level and at the individual household level. Using our study results in back of the envelope calculations, the effect on subsequent fertility translates to 1,227 fewer births out of a total of 30,676 Cesarean deliveries in our full sample, and over 50,000 fewer subsequent births annually per approximately 1.3 million Cesarean deliveries that happen in the US each year, according to the Center for Disease Control and Prevention.[40] Although we are unable to examine total maternal fertility with our data, our findings have implications for total fertility rates and replacement rates (fertility rate needed to sustain current population levels).[41] the micro-level of the family unit, a reduction in subsequent childbearing is likely to have implications for future parental labor supply and the distribution of family resources among the existing children; these effects need to be examined further in future studies. As the number of Cesarean deliveries continues to rise, and Cesarean deliveries on maternal request without clinical indications continue, these fertility effects are likely to become more notable at both the population and the family levels.

The negative impact on subsequent fertility suggests that clinical benefits of Cesarean delivery should be weighed against potential negative fertility effects. While most Cesarean may not be avoidable, a clear articulation of the potential unintended effects of Cesarean delivery is key to informing an effective decision-making process between the woman and her clinician, especially in low-risk pregnancies where Cesarean delivery is not medically necessary.

Table 1. Descriptive statistics

	Analysis sample				Excluded	
	Vaginal Deliveries (n=93,373)		Malpresenting Cesareans (n=3,114)		Non-malpresenting Cesareans (n=37,007)	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Fertility Measures						
Interpregnancy interval (months)	30.06	14.58	29.42	12.62	30.79	15.65
Total number of subsequent births	1.40	0.63	1.30	0.53	1.56	0.71
Categorical number of subsequent births						
0	0.67	0.47	0.73	0.44	0.77	0.42
1	0.27	0.44	0.24	0.43	0.20	0.40
2 +	0.06	0.24	0.03	0.17	0.03	0.16
Maternal Characteristics						
Maternal age	27.80	5.55	29.84	5.55	29.92	5.73
Maternal race = white	0.74	0.44	0.85	0.36	0.77	0.42
Mother Hispanic/Latino	0.13	0.34	0.09	0.29	0.12	0.32
Maternal education = College or more	0.31	0.46	0.41	0.49	0.35	0.48
Mother married	0.57	0.49	0.70	0.46	0.65	0.48
Payer = Private health insurance	0.47	0.50	0.64	0.48	0.43	0.49
Payer = Medicaid	0.36	0.48	0.25	0.43	0.26	0.44
Received WIC during pregnancy	0.28	0.45	0.22	0.42	0.20	0.40
Malpresentation risk factors						
Maternal weight at delivery (pounds)	185.09	38.07	191.00	42.09	199.78	45.70
Maternal weight pre-pregnancy (pounds)	153.99	38.32	159.22	42.79	167.78	46.56
Maternal height (inches)	64.72	3.04	64.77	2.82	64.31	3.00
Weeks of gestation at delivery	39.05	1.58	38.11	2.38	38.47	2.09
Fetal/congenital anomaly/ infant death	0.03	0.18	0.08	0.27	0.04	0.20
Uterine/placental anomalies	0.05	0.23	0.16	0.37	0.08	0.27

Notes.

Table 2. Interpregnancy Interval and Total Number of Births

Panel A. Interpregnancy Interval		*Propensity Score Matched Models*		
	OLS Regression	One-to-One	All in common support	Propensity scores as weights
	(1)	(2)	(3)	(4)
Cesarean Delivery (Malpresentation)	29.99	29.49	29.44	29.46
	(0.42)	(0.51)	(0.45)	(0.60)
Vaginal Delivery	30.05	29.44	30.06	29.40
	(0.15)	(0.45)	(0.09)	(0.18)
P-value (statistically different)	0.89	0.95	0.24	0.92
n	29,463	1,554	29,463	29,463

Panel B. Total Number of Subsequent Births		*Propensity Score Matched Models*		
	Poisson Regression	One-to-One	All in common support	Propensity scores as weights
Cesarean Delivery (Malpresentation)	0.36	0.30	0.30	0.32
	(0.03)	(0.01)	(0.01)	(0.02)
Vaginal Delivery	0.39	0.34	0.40	0.34
	(0.02)	(0.01)	(0.002)	(0.02)
P-value (statistically different)	0.05	0.01	0.00	0.21
n	96,258	6,218	96,258	96,258

Notes: Panels A – B contain Poisson/multinomial logit regression and propensity score matching methods results for interpregnancy interval for mothers who have two or more births in our sample and total number of births, respectively. Column 1 represents predicted means obtained after estimating equation [1] (see Appendix Table xx for full set of coefficients). Column 2 compares mean postpartum outcomes with breech Cesarean and vaginal delivery where we have allowed *only one* comparison match per treatment observation (means adjusted for all covariates as in equation 1). Column 3 compares adjusted means in the same way, but allows multiple comparison matches per treatment. Column 4 is a re-estimation of column 1 including the propensity scores as weights. The p-value listed corresponds to the difference between breech Cesarean and vaginal deliveries in each model (column).

Table 3. Categorical Number of Subsequent Births

	Main Model, Multinomial Logit Regression (1)			One-to-One (2)			All in common support (3)			Propensity scores as weights (4)		
	=0	=1	=2+	=0	=1	=2+	=0	=1	=2+	=0	=1	=2+
Cesarean Delivery (Malpresentation)	0.72	0.25	0.03	0.73	0.24	0.03	0.73	0.24	0.03	0.74	0.23	0.02
	(0.03)	(0.02)	(0.005)	(0.01)	(0.01)	(0.003)	(0.01)	(0.01)	(0.003)	(0.02)	(0.02)	(0.006)
Vaginal Delivery	0.70	0.25	0.05	0.68	0.26	0.06	0.67	0.27	0.06	0.74	0.22	0.04
	(0.02)	(0.01)	(0.004)	(0.01)	(0.01)	(0.003)	(0.002)	(0.001)	(0.01)	(0.02)	(0.01)	(0.004)
P-value (statistically different)	0.26	0.93	0.00	0.00	0.07	0	0.00	0.001	0.00	0.7	0.47	0.00
n		96,258			6,218			96,258			96,258	

Notes: Column 1 represents predicted means obtained after estimating equation [1] (from Table 3). Column 2 compares percentages of mothers in each number of children category with breech Cesarean and vaginal delivery where we have allowed *only one* comparison match per treatment observation (means adjusted for all covariates as in equation 1). Column 3 compares adjusted means in the same way, but allows multiple comparison matches per treatment. Column 4 is a re-estimation of column 1 including the propensity scores as weights. In columns 2 through 4, we have excluded all observations not in the common support. The p-value listed corresponds to the difference between breech Cesarean and vaginal deliveries in each model (column).

Appendix – Sample Construction

		Breech Cesarean	Cesarean for Other Reason	Vaginal	Total
Starting Sample - unit of observation = births					
1)	n	5,845	54,497	176,478	236,820
	%	2.47	23.01	74.52	
Keep only if mother > = 18 & not missing key variables					
2)	n	5,230	40,091	131,658	176,979
	%	2.96	22.65	74.39	
Convert unit of observations to mothers					
3)	n	3,646	28,789	94,604	127,039
	%	2.87	22.66	74.47	
Keep only mothers whose first birth was singleton delivered between 28 and 42 weeks of gestation					
4)	n	3,109	27,567	93,149	123,825
	%	2.51	22.26	75.23	
Drop mothers whose first birth was a Cesarean for any reason besides presentation					
5)	n	3,109		93,149	**96,258**
	%	3.23		96.77	
Drop mothers who did not have a second birth in our sample or those without weight prior to pregnancy 2 or interpregnancy interval					
6)	n	777		28,686	**29,463**
	%	2.64		97.36	

Appendix Table 1. Propensity Score Logistic Regression Coefficients – Dependent Variable = Breech Cesarean

	Sample of Mothers with 2+ Births (1)		Full Sample (2)	
	Coeff.	SE	Coeff.	SE
Weight (pounds) prior to pregnancy 1	-0.01*	(.001)	-0.01***	(.001)
Weight (pounds) at delivery of pregnancy 1	0.01***	(.001)	0.01***	(.001)
Malpresentation Risk Factors				
Maternal age	0.05***	(.01)	0.05***	(.01)
Maternal age > 35	0.01	(.16)	-0.10	(.07)
Maternal height (inches)	-0.06***	(.01)	-0.04***	(.01)
Weeks of gestation at delivery	-0.23***	(.02)	-0.25***	(.01)
Any fetal or congenital anomaly or infant death	0.49***	(.16)	0.50***	(.07)
Any uterine or placental anomalies	0.86***	(.11)	0.85***	(.05)
Maternal Socio-demographics & self-reported health				
Mother married	0.32***	0.12	0.08	(.05)
Tobacco use during pregnancy	-0.08	(.13)	-0.03	(.06)
Alcohol use during pregnancy	0.04	(.47)	0.16	(.19)
Maternal education = College or more	0.06	(.09)	0.11**	(.05)
Maternal race = white	0.85***	(.13)	0.60***	(.06)
Mother Hispanic/Latino	-0.33**	(.15)	-0.26***	(.07)
Received WIC during pregnancy	0.21	(.13)	0.08	(.06)
Payer = Private health insurance	0.81***	(.1)	0.58***	(.06)
Payer = Medicaid	0.34**	(.15)	0.29***	(.07)
Constant	4.64***	(1.17)	5.35***	(.55)
n	29,463		96,258	
Pseudo R2	0.08		0.07	

Notes: In column 1, we present the estimated coefficients from the propensity score estimation using a logit regression and the sample of mothers with at least 2 births. In column 2, we use the full sample of all mothers. Standard errors are in parentheses.

* p<0.1; ** p<0.05; *** p<0.01

Appendix Table 2. Coefficients from Full Regression Results

	Maternal Weight Prior to Pregnancy 2 (col 1)	Maternal BMI Prior to Pregnancy 2 (col 2)	Mother Obese Prior to Pregnancy 2 (col 3)	Interpregnancy Interval (in months) (col 4)	Number of Total Births (col 5)
Breech Cesarean	-0.67	-0.14**	-0.20*	-0.05	-0.03**
	(0.40)	(0.06)	(0.10)	(0.40)	(0.01)
Maternal Age	-0.04	-0.0008	-0.01*	0.03	-0.01***
	(0.04)	(0.01)	(0.01)	(0.03)	(0.001)
Maternal Age > 35	1.43***	0.18**	0.20	-1.40***	-0.04***
	(0.46)	(0.08)	(0.15)	(0.44)	(0.01)
Maternal weight prior to pregnancy 1	0.59***	0.10***	0.05***	-0.02*	-0.0004*
	(0.02)	(0.004)	(0.003)	(0.01)	(0.0002)
Maternal weight at delivery of pregnancy 1	0.39***	0.06***	0.03***	0.01	0.0003
	(0.02)	(0.004)	(0.003)	(0.01)	(0.0002)
Weeks of gestation	-0.25***	-0.04***	-0.03**	0.13**	-0.002
	(0.06)	(0.01)	(0.01)	(0.05)	(0.001)
Any uterine or placental anomalies	-0.22	-0.07	-0.01	-0.46	-0.02**
	(0.45)	(0.08)	(0.06)	(0.42)	(0.01)
Any fetal or congenital anomaly or infant death	0.39	0.05	0.10	-0.73**	-0.01
	(0.61)	(0.10)	(0.11)	(0.34)	(0.01)
5 Minute APGAR	-0.29	-0.10**	-0.05	-0.15	-0.004*
	(0.23)	(0.04)	(0.03)	(0.16)	(0.002)
Maternal height (inches)	0.09	-0.67***	-0.42***	-0.03	0.001
	(0.10)	(0.02)	(0.03)	(0.04)	(0.001)
Mother married	-2.44***	-0.44***	-0.25***	-1.62***	0.05***
	(0.38)	(0.06)	(0.06)	(0.33)	(0.01)
Tobacco use during pregnancy	-0.80*	-0.20**	-0.07	-0.47	-0.03**
	(0.47)	(0.08)	(0.08)	(0.38)	(0.01)
Alcohol use during pregnancy	1.81	0.26	-0.07	-0.41	-0.02
	(1.80)	(0.29)	(0.27)	(0.97)	(0.03)
Maternal Education = College or more	-3.15***	-0.58***	-0.39***	-0.52**	0.06***
	(0.47)	(0.09)	(0.07)	(0.26)	(0.01)
Maternal race = White	-2.40***	-0.47***	-0.22***	0.57*	-0.05**
	(0.64)	(0.09)	(0.05)	(0.34)	(0.02)
Mother Hispanic/Latino	1.28***	0.51***	0.20***	0.11	-0.02
	(0.35)	(0.14)	(0.07)	(0.27)	(0.02)
Received WIC during pregnancy	-1.25	-0.19	-0.22**	-1.95***	-0.12***
	(1.07)	(0.18)	(0.10)	(0.59)	(0.03)
Payer = Private health	-1.09**	-0.23**	-0.21***	-1.75***	-0.25***

insurance					
	(0.48)	(0.09)	(0.08)	(0.52)	(0.07)
Payer = Medicaid	0.30	0.02	0.09	-1.97**	-0.20***
	(0.78)	(0.13)	(0.09)	(0.82)	(0.07)
Interpregnancy Interval between Delivery of Pregnancy 1 and Pregnancy 2 (months)	0.13***	0.02***	0.01***		
	(0.02)	(0.00)	(0.002)		
Constant	5.79	46.64***	12.26***	30.015***	1.04***
	(4.75)	(1.18)	(1.07)	(2.90)	(0.10)
R2/Pseudo R2	0.81	0.76	0.54	0.01	
N	29,463	29,463	29,463	29,463	96,258

Notes: Columns 1, 2, and 4 were estimated using OLS regression. Column 3 was estimated using a logistic regression and column 5 was estimated using a Poisson regression. Robust standard errors are in parentheses (clustered at the hospital level).

* p<0.1; ** p<0.05; *** p<0.01

Appendix Table 3. Coefficients from Multinomial Logistic Regression for Categorical Number of Births (No subsequent births is reference category)

	Has one additional birth	Has 2+ additional births
Breech Cesarean	-0.03	-0.48***
	(0.08)	(0.15)
Maternal Age	-0.07***	-0.12***
	(0.004)	(0.01)
Maternal Age > 35	-0.44***	-0.42***
	(0.05)	(0.09)
Maternal weight prior to pregnancy 1	-0.004**	-0.001
	(0.00)	(0.001)
Maternal weight at delivery of pregnancy 1	0.003**	0.001
	(0.001)	(0.002)
Weeks of gestation	-0.0004	-0.02***
	(0.01)	(0.01)
Any uterine or placental anomalies	-0.13**	-0.19
	(0.06)	(0.13)
Any fetal or congenital anomaly or infant death	-0.09	-0.03
	(0.08)	(0.12)
5 Minute APGAR	-0.03**	-0.02
	(0.01)	(0.03)
Maternal height (inches)	0.01	0.00
	(0.003)	(0.01)
Mother married	0.26***	0.33***
	(0.06)	(0.08)
Tobacco use during pregnancy	-0.22***	-0.09
	(0.05)	(0.13)
Alcohol use during pregnancy	-0.13	-0.15
	(0.19)	(0.23)
Maternal Education = College or more	0.36***	0.47***
	(0.05)	(0.08)
Maternal race = White	-0.09	-0.48***
	(0.08)	(0.14)
Mother Hispanic/Latino	-0.07	-0.24**
	(0.07)	(0.12)
Received WIC during pregnancy	-0.63***	-0.75***
	(0.16)	(0.22)
Payer = Private health insurance	-1.25***	-1.61***
	(0.37)	(0.43)
Payer = Medicaid	-1.06***	-1.13***
	(0.35)	(0.41)
Constant	1.87***	3.29***
	(0.53)	(0.71)
n	96,258	

Notes: Coefficients from a multinomial logistic regression model estimating equation [2] are presented with robust standard errors are in parentheses (clustered at the hospital level). The dependent variable equals 0 if the mother had no additional births (reference category), 1 if the mother had one additional birth and 2 if the mother had 2 or more additional births. * p<0.1; ** p<0.05; *** p<0.01

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