Online Appendices for:

The Health Impacts of Hospital Delivery Practices

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Appendix A: An Overview of the Literature on the Health Effects of Cesarean Delivery

Infant Outcomes. Table A-I summarizes a selection of recent studies on the short and medium-run health effects of cesarean delivery for infants. We review studies on injury or death of the baby; lung function and respiratory problems; asthma; immune system; and breastfeeding. Not included in the table are several other active areas of research that study impacts of cesarean delivery on longer-term outcomes such as the probability of adult obesity (see the recent review by Darmasseelane et al., 2014).

Across the board a general finding is that babies delivered by c-section fare worse: higher neonatal and post-neonatal death; elevated risks of respiratory system problems including asthma; evidence of digestive system disorders, and lower rates of breastfeeding. An unusually detailed prospective study by Villar et al. (2007) of births in eight Latin American countries illustrates the general nature of these findings and the difficulty in interpreting the results as causal.[1] The authors show that neonatal death rates for cephalic fetuses delivered by c-section after trial of labor are substantially higher than rates for those delivered vaginally (0.65% versus 0.38%). Eliminating the roughly 30% of intrapartum c-sections performed after indications of fetal distress, the neonatal death rate of the remaining c-section group falls to 0.51% -- not statistically different from the rate for the vaginal births (but still higher), and indicative of a potentially large endogeneity bias in the overall comparison.

[1] This study is unusual in collecting detailed data on reasons for c-section, gathered immediately after the birth by trained survey staff.

Our reading of the literature is that the most widely documented correlation is between c-section delivery and respiratory problems. Such a pattern has been documented in large-scale cohort studies in several Nordic countries (e.g., Hansen et al., 2008; Tollanes et al., 2008) and in meta analyses of the literature (e.g., Thavagnanam et al., 2008). As discussed in a recent review by Hyde et al. (2012), there is clinical evidence that babies born by c-section have worse lung function immediately after birth -- possibly attributable to a therapeutic effect of the labor process (including release of hormones and clearance of lung liquid). A number of researchers also hypothesize that there is a transfer of microbes from mother to infant during labor that aid in the development of the immune and digestive systems (e.g., Neu and Rushing, 2012).

Maternal Outcomes. Table A-II presents a parallel summary of the literature on the health effects of cesarean delivery on mothers. Here the literature is less numerous: our reading is that the major health risks include complications at birth and maternal death; reduction in future fertility; abnormal placentation in subsequent pregnancies; and risk of future stillbirths. Most studies find that mothers who deliver by c-section have higher risk of birth-related complications (such as need of a blood transfusion), higher risk of severe morbidity and mortality in the period after the birth, reduced future fertility, higher risk for placenta previa (placenta near or covering the cervix) and placenta accreta/increta/percreta (abnormal placental attachment). Evidence on future stillbirths is less clear.

As with the literature on infant health effects, most of these studies are based on observational designs, making it difficult or impossible to assert causality, though some of the potential effects are grounded in clinic evidence (see for example the review of studies on abnormal placentation by Clark and Silver, 2011). An interesting exception is the study by Halla et al. (2019) on future fertility, which uses day of the week of the birth as an instrument for c-section. We find that there appear to be more pre-scheduled c-sections on weekdays, leading to concerns over this instrument in our setting.

Table A1: Summary of Literature on Infant Health Effects of C-Section Delivery

Health Issue	Study authors; design; main findings
1. Delivery injuries and death	a. Rouse and Owen (1999): prophylactic CS for large fetuses (>4000g) has small impact on permanent brachial plexus injury
	b. Alexander et al. (2006): 1.1% of CS babies have some birth injury - mostly cuts from the incision
	c. Villar et al. (2007): CS might decrease death for cephalic pregnancies, definitely for breech; increased NICU, but rupturing of membranes may be protective
	d. MacDorman et al (2008): CS has 1.7-2.4 higher risk of infant neonatal mortality for primary, low-risk births. Intention to treat analysis combines CS after TOL with vaginal births as intended vaginal
	e. Molina et al. (2015): cross-national analysis of CS and infant morality; neonatal mortality rates decline until CS rate of 20%, then stable across countries
2. Lung Function and Repiratory Problems	a. Hansen et al. (2008): Danish cohort study (cov-adj); scheduled CS increases risk of respiratory illness 200-400%
	b. Moore et al. (2012): Australian register study (cov-adj); elective CS increases risk of hospitalization for bronchiolitis by 10% in first year of life
	c. Hyde et al. (2012): review of clinical literature; CS without TOL associated with reduced lung function after birth
	d. Kristensen and Hendriksen (2016): Danish register study (cov-adj); elective CS associated with 20% higher risk of pneumonia and other mucosal system disorders
3. Asthma	e. Salam et al (2006): retrospective study of California youth; CS raises incidence of allergy by 26% (cov-adj)
	b. Roduit et al. (2008): Dutch cohort study (cov-adj). CS associated with 20% increase in risk of childhood asthma, higher effect for allergic parents
	c. Thavagnanam et al. (2008): meta analysis of 23 studies of CS and asthma; CS associated with 45% increase in risk at age 8
	d. Tollanes et al. (2008): Norwegian register study (cov-adj); CS raises risk of asthma by age 18 by 50%
	e. Jachetta (2014): IV study using MSA-level malpractice premiums instrument; CS associated with higher rate of hospitalization for asthma and lung disease
4. Immune System	a. Neu and Rushing (2011): review of clinical literature; CS without TOL affects micobial colonization/immune response
	b. Sevelsted et al. (2016): Danish register study (cov-adj); CS associated with higher risk of immune deficiency, inflammatory bowel disorders
	c. Stokholm et al. (2016): prospective study of Copenhagen births; CS associated with different gut microbes in first year
5. Breastfeeding	Prior et al (2012): meta-analysis of 48 studies; CS without TOL associated with lower rate of early initiation of breastfeeding; CS after TOL same as vaginal births

Notes: CS = c-section delivery; OR = odds ratio; TOL=trial of labor; cov-adj = covariate adjustment; IV=instrumental variables

Table A2: Summary of Literature on Maternal Health Effects of C-Section Delivery

Health Outcome	Study authors; design; main findings
1. Complications at birth; mortality	a. Lydon-Rochell et al. (2000): cohort of primiparous women in Washington State; 80% higher rate of rehospitalization in 60 days following CS b. Deneux-Tharaux et al. (2006): 3.5 times more likely for mom to die in CS c. Villar et al (2007): WHO-supported study of Latin American births; incidence of mother injury/death increases in CS d. Kuklina et al (2009): rise in CS explains rise in maternal morbidity at birth e. Curtin et al. (2015): US births in 2013; (no cov-adj); higher rates of tranfusion, ICU admission f. Molina et al. (2015): cross-national analysis of CS and maternal morality; mortality rates decline until CS rate of 20%, then stable across countries
2. Fertility	a. Hall et al. (1989): U.K. cohort study (cov-adj); 23% lower fertility b. Kjerulff et al. (2013): U.S. cohort study (covariate adustment); 16% lower fertility c. Gurol-Urganci et al. (2013): meta analysis of 18 cohort studies; mean effect = 9% reduction in fertility following CS d. Halla et al. (2018): IV based on day of delivery; lower fertility
3. Abnormal Placentation (previa, accreta, etc.)	a. Hemminki et al. (2005): Finish register (cov-adj); 90% higher risk b. Getahun et al. (2006): U.S. linked cohorts (cov-adj); 30-100% higher risks c. Gurol-Urganci et al. (2011): U.K. cohort study and meta analysis of 37 studies; CS at first birth raises risk of placenta previa in second by 50-60% d. Clark and Silver (2011): review of previous studies; increased risks uterine rupture, hysterectomy, abnormally invasive placenta and multiple blood transfusions
4. Future Stillbirth	a. Bahtiyar et al. (2006): large U.S. cross-section study (cov-adj); no effect b. O'Neill et al (2013): A review of previous studies; CS increases the risk of stillbirth by 23%

Note: see Table A-I

Additional References for Appendix A

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Appendix B: Interpretation of First Stage, Reduced Form and IV Estimates

Consider the case where individuals (indexed by i) belong to mututally exclusive subgroups. Let X_i represent a vector of indicators for membership in each of J subgroups, let y_i represent an outcome of interest, let D_i represent an endogenous treatment indicator, and let Z_i represent an instrumental variable.

Suppose we estimate a pooled first stage model for D_i that includes Z_i and the vector X_i:

$$D_i = \pi_0 + \pi_1 Z_i + \pi_X X_i + v_i.$$

By standard Frisch-Waugh arguments the OLS estimate of π_1 is:

$$\widehat{\pi}_1 = \frac{\sum_i (D_i - \overline{D}_{j(i)})(Z_i - \overline{Z}_{j(i)})}{\sum_i (Z_i - \overline{Z}_{j(i)})^2}$$

where $j(i)$ is $i's$ subgroup, and $\overline{D}_j$ and $\overline{Z}_j$ represent the means of D and Z within subgroup j. Let N represent the combined sample size and N_j the sample size for group j. Then

$$\begin{aligned}
\widehat{\pi}_1 &= \frac{\sum_j \sum_{i \in j} (D_i - \overline{D}_{j(i)})(Z_i - \overline{Z}_{j(i)})}{\sum_j \sum_{i \in j} (Z_i - \overline{Z}_{j(i)})^2} \\
&= \sum_j \left(\frac{N_j}{N} \right) \left(\frac{\frac{1}{N_j} \sum_{i \in j} (Z_i - \overline{Z}_j)^2}{\frac{1}{N} \sum_j \sum_{i \in j} (Z_i - \overline{Z}_{j(i)})^2} \right) \frac{\sum_{i \in j} (D_i - \overline{D}_{j(i)})(Z_i - \overline{Z}_{j(i)})}{\sum_{i \in j} (Z_i - \overline{Z}_{j(i)})^2} \\
&= \sum_j \left(\frac{N_j}{N} \right) \frac{V_{Zj}}{V_Z} \widehat{\pi}_{1j}
\end{aligned}$$

where V_{Zj} is the variance of Z within group j, V_Z is the overall variance of Z and $\widehat{\pi}_{1j}$ is the first stage regression coefficient for group j.

By the same argument if we estimate a pooled reduced form model for y_i that includes Z_i and the vector X_i:

$$y_i = \delta_0 + \delta_1 Z_i + \delta_X X_i + u_i.$$

the OLS estimate of δ_1 is

$$\widehat{\delta}_1 = \sum_j \left(\frac{N_j}{N}\right) \frac{V_{Zj}}{V_Z} \widehat{\delta}_{1j}$$

where $\widehat{\delta}_{1j}$ is the reduced form coefficient for group j. Finally, the pooled IV estimate of the effect of D on y using Z as an instrument and controlling for X is:

$$\begin{aligned}
\widehat{\beta}_1 &= \frac{\widehat{\delta}_1}{\widehat{\pi}_1} \\
&= \sum_j \left(\frac{N_j}{N}\right) \left(\frac{V_{Zj}}{V_Z}\right) \left(\frac{\widehat{\pi}_{1j}}{\widehat{\pi}_1}\right) \frac{\widehat{\delta}_{1j}}{\widehat{\pi}_{1j}} \\
&= \sum_j \left(\frac{N_j}{N}\right) \left(\frac{V_{Zj}}{V_Z}\right) \left(\frac{\widehat{\pi}_{1j}}{\widehat{\pi}_1}\right) \widehat{\beta}_{1j}
\end{aligned}$$

where $\widehat{\beta}_{1j} = \widehat{\delta}_{1j}/\widehat{\pi}_{1j}$ is the IV estimate within subgroup j.

Appendix C: Data

a. Overview of PDD/ED/AS/Linked Birth Cohort Data

California OSHPD has created a linked file that combines in-patient discharge records for delivering mothers and newborns with Vital Statistics (VS) data (i.e., information collected from birth certificates and death records) and information on in-patient, Emergency Department (ED), and Ambulatory Surgery Center (ASC) records for each mother in the period from one year before to one year after the birth, and for each infant in the period up to one year after the birth. We use a version of this file that has information on live hospital delivered births for the period from 2007 to 2011.

Appendix D of the data base gives the name, address, zip code, and Hospital Service Areas (HSA) for each hospital, ED, and ASC in the state. We also use external information from the Dartmouth Atlas website to assign HSA's and Health Referral Regions (HRR's). We add data from the US Census Bureau on average income in each zip code.

b. Construction of relative distance instruments

The procedure for constructing a mother's relative distance to high and low c-section hospitalsconsists of 3 steps:

1. We estimate each hospital's risk-adjusted c-section rate among low-risk first births;

2. We classify hospitals as low (L) or high (H) c-section hospitals based on their risk-adjusted c-section rates from (1);

3. We calculate each mother's distances to the nearest L and H hospitals, from which we calculate our main relative distance measure.

In step 1 we fit a logistic regression model to our sample of low-risk first births that includes a baseline set of case risk factors $X_i$and indicators for the hospital $h(i)$ at which mother i delivered.

Specifically, using our LRFB sample, we estimate the model:

$$P(C_i = 1|X_i) = \Lambda(\alpha + \mathbf{X}_i'\beta + \gamma_{h(i)})$$

where Λ is the logistic CDF.

In step 2 we compare hospital h's estimated logit coefficient $\hat{\gamma}_h$ to the birth-weighted average hospital coefficient in each Hospital Referral Region (HRR) $\bar{\gamma}_{HRR} = \left[\sum_{j \in HRR} N_j\right]^{-1} \sum_{j \in HRR} N_j \hat{\gamma}_j$ (where N_h is the number of low risk first births delivered at hospital h in our analysis sample). We define a hospital to be a "high c-section hospital" (or H hospital) if $\hat{\gamma}_h \geq \bar{\gamma}_{HRR}$ and otherwise a "low c-section hospital."

In step 3 we use information on the centroid of each mother's home zip code and on the centroids of the zip codes for each hospital to define the distance from each mother to each hospital. We then define the distance to the nearest H hospital and the nearest L hospital.

Appendix D: Heterogeneity in the Health Effects of Delivery at High C-Section Hospital

One issue for the interpretation and extrapolation of our findings is the extent of heterogeneity in the treatment effects associated with delivery at a high c-section hospital.[1] To address this, we extend our instrumental variables setup using a simple control function approach that allows for a random effect in the impact of H delivery (Garen 1984; Heckman and Vytlacil 1998; Wooldridge 2015). Specifically suppose that the causal model relating health outcome y_i to patient characteristics X_i and type of hospital H_i is:

$$y_i = \beta_0 + \beta_{1i} H_i + \beta_x X_i + \epsilon_i \,,$$

where β_{1i} is a random coefficient and ϵ_i is a structural error incorporating the unobserved determinants of health. We assume that:

$$E[\beta_{1i}|H_i, X_i, Z_i] = \beta_1 + \lambda_u u_i + \lambda_x (X_i - \bar{X})$$
$$E[\epsilon_i|H_i, X_i, Z_i] = \theta_u u_i$$

where u_i is the error in the first stage equation (1) for H_i. Here β_1 represents the average treatment effect (ATE) of delivery at an H hospital and $\lambda_u u_i$ represents a self-selection effect that arises if mothers with a stronger preference for H hospitals have larger or smaller treatment effects from delivering there. A pattern in which λ_u has the same sign as β_1 represents positive Roy sorting. Similarly, the term $\lambda_x (X_i - \bar{X})$ represents potential heterogeneity in the treatment effect with respect to (predetermined) maternal and infant characteristics. Finally, the term $\theta_u u_i$ captures any correlation between latent health and the unobserved component of preferences for an H hospital.

As shown by Heckman and Vytlacil (1998) and Wooldridge (2015) this model can be estimated in two steps by first estimating the first stage model for hospital type, obtaining the residual $\hat{u}_i$, and then estimating a second-step model:

$$y_i = \beta_0 + \beta_1 H_i + \beta_x X_i + \lambda_u H_i \hat{u}_i + \lambda_x H_i (X_i - \bar{X}) + \theta_u \, \hat{u}_i + \epsilon_i'$$

This model includes the estimated first stage residual $\hat{u}_i$, an interaction between $\hat{u}_i$ and H_i, and interactions between H_i and the other covariates. Excluding the interaction terms leads to an estimate for β_1 that is numerically equivalent to the standard IV estimate. Adding the interaction terms allows for heterogeneity in the effect of H delivery that can be correlated with either observed characteristics or unobserved preferences. To account for the fact that the first-stage residual is a generated regressor,

[1] There is a large and growing literature on heterogeneous treatment effects: see Imbens and Wooldridge (2009) for a general discussion and Cornelissen et al. (2016) for a recent survey emphasizing heterogeneity in marginal treatment effects.

we conduct inference on the second-step parameters via a block bootstrap, clustered as usual by mother's zip code.

Appendix Table VII presents estimated control function models for 7 infant health outcomes including the incidence of a low 5-minute Apgar score and the main outcomes from Table VI. For each outcome we present a benchmark model with no interactions (yielding the IV coefficients already shown in Tables V and VI), and a second model that adds four interactions with H_i: one with the estimated first stage residual, two with observable indicators of infant health – birthweight and gestation – and a fourth interaction with the average c-section rate in the HRR (hospital referral region). For ease of interpretation we standardize the three observable interaction factors.

Looking across the models in Appendix Table VII we see three interesting patterns. Most importantly, estimates of the ATEs of H-delivery from models that allow for self-selection and heterogeneous treatment effects are very close to the LATEs from our baseline IV procedure. Second, there is almost no evidence of heterogeneity in the effects of H delivery across infants of different birth weights or gestations. There is more evidence of heterogeneity with respect to local c-section rates: in HRR's with higher cesarean rates the effects of H delivery on inpatient stays are lower. Third, there is mixed evidence on the question of whether the unobserved determinants of hospital selection are positively or negatively correlated with the treatment effect of an H hospital. For inpatient stays and adverse events in the neonatal period we see *larger* (more negative) impacts for infants whose mothers have a stronger preference for H hospitals – i.e., Roy sorting. For ED visits and death however, we see the opposite pattern – evidence of negative Roy sorting.[2] This conflicting pattern of evidence may not be too surprising given that the effect of H delivery varies across outcome measures.

[2] Chandra and Staiger (2020) also find negative Roy sorting in hospital's policies over use of more intensive AMI treatments.

Appendix E Results excluding hospital-level controls

To address concerns related to "correlated beneficial care" in our main analysis, we included control variables for a set of delivery-hospital characteristics that are thought to independently influence quality and health outcomes. Specifically, we control for: the observed log volume of births, both in total and in our low-risk first-births (LRFB) sample; the presence of 6 different levels of neonatal intensive care units (generously provided by Ciaran Phibbs); hospital ownership (7 types); and measures of the hospital's breastfeeding initiation rates (separate rates of *any* and *exclusive* breastfeeding, provided separtely by the California Department of Public Health).

In this Appendix, we repeat our key analyses excluding all of these hospital-level controls. We find that our results are virtually unaffected by their exclusion, reflecting the fact that these characteristics are very weakly correlated with our instrument, and that within hospital markets, there is limited systematic relationship between hospital c-section rates and this important set of hospital characteristics.

Appendix Table E1: Orthogonality of Relative Distance to Maternal Characteristics and Risk Factors (No Hosp. Controls)

	Effect of moving 10 miles closer to H hospital on row variable (s.e. in parentheses)		Effect of delivering at H hospital on row variable (s.e. in parentheses)	
	(1)		(2)	
Maternal Characteristics				
Mother's Age	0.021	(0.068)	-0.098	(0.055)
Mother's Education	-0.040	(0.048)	-0.035	(0.040)
White (non-Hispanic)	0.016	(0.013)	0.005	(0.004)
Black	-0.003	(0.007)	-0.010	(0.002)
Asian	-0.008	(0.012)	0.009	(0.006)
Hispanic	-0.006	(0.014)	-0.002	(0.007)
Father Present	-0.001	(0.002)	-0.003	(0.001)
Gov't Insurance	-0.001	(0.004)	0.067	(0.011)
Private Insurance	0.002	(0.005)	-0.087	(0.011)
Mother's Height (inches)	0.023	(0.043)	0.000	(0.022)
Mother's Weight (pounds)	0.039	(0.302)	-0.270	(0.170)
BMI Pre-pregnancy	-0.011	(0.041)	-0.047	(0.027)
Mother's Use of Hospital in Year Before Birth				
Any ED Visit	0.006	(0.004)	0.007	(0.003)
Number ED Visits	0.010	(0.007)	0.010	(0.004)
Inpatient Stay	-0.001	(0.001)	0.003	(0.001)
Prenatal Care:				
Prenatal Visits (#)	0.046	(0.055)	0.251	(0.048)
Month Started Pre. Care	0.021	(0.021)	-0.060	(0.018)
Late Prenatal Care (>4th mo)	0.003	(0.002)	-0.002	(0.002)
Other Risk Characteristics				
Diabetes	-0.001	(0.001)	-0.003	(0.001)
Herpes	-0.001	(0.001)	-0.001	(0.000)
Asthma	0.001	(0.001)	-0.004	(0.001)
Smoked When Pregnant	0.002	(0.001)	-0.001	(0.001)
Cigs/Day Pre-pregnancy	0.024	(0.025)	0.006	(0.013)
Infant Characteristics				
Gestation (days)	0.044	(0.076)	-0.711	(0.052)
Birth Weight (grams)	1.129	(4.023)	-13.981	(1.993)
Low Birth Weight (<2500 g)	0.000	(0.001)	0.002	(0.001)
Characteristics of Mother's Home Zip Code				
Mean Income (1000 US $)	1.349	(1.059)	-0.296	(0.259)
Zip Mean Mother Educ.	0.010	(0.045)	0.004	(0.008)
Zip Mean Dropout	0.005	(0.008)	0.000	(0.001)
Zip Mean Black	-0.004	(0.006)	-0.003	(0.001)
Zip Mean Hispanic	-0.006	(0.014)	0.001	(0.002)
Logit predictions based on above 31 covariates				
Predicted Pr(Infant ED visit)	0.001	(0.003)	0.006	(0.002)
Predicted Pr(Infant readmission)	0.000	(0.001)	0.002	(0.000)
Predicted Pr(Infant death) x 100	-0.001	(0.002)	0.004	(0.001)
F-tests based on above 31 covariates				
Joint F-statistic: F(31,1249)	1.041		17.714	
Joint F-test *p* -value	0.406		0.000	

Notes: Table shows estimated coefficients and standard errors from regression of row variable on relative distance in 10s of miles to a high c-section (H) hospital (column 1) or delivery at an H hospital (column 2). All models include HSA and year effects, distance from home to nearest hospital, and fraction of mothers in zip code with government insurance. Logit predictions from logit model of respective outcome on all demographic and risk factors listed above. Bottom two rows present F-statistics and p-values from the joint F-test for all 31 row variables in reverse regression with relative distance or delivery hospital type as dependent variable. Standard errors clustered by zip code.

Appendix Table E2: Estimated Effects of Relative Distance on Place, Mode, and Timing of Delivery (No Hosp. Controls)

		Instrument=Relative Distance to H Hospital Coefficients × 100		Instrument= Indicator for Closer to H Hospital Coefficients × 10	
Outcome Variable	Mean	Baseline controls only	All controls	Baseline controls only	All controls
	(1)	(2)	(3)	(4)	(5)
Deliver at H Hospital	0.515	1.586	1.600	1.014	1.014
		(0.154)	(0.153)	(0.122)	(0.119)
C-section Delivery	0.256	0.186	0.183	0.109	0.118
		(0.030)	(0.030)	(0.023)	(0.022)
Scheduled C-section	0.092	0.056	0.053	0.026	0.023
		(0.021)	(0.019)	(0.014)	(0.013)
Unscheduled C-section	0.163	0.130	0.130	0.082	0.095
		(0.029)	(0.023)	(0.019)	(0.018)
Delivered 1+ Days After Arrival	0.479	-0.054	-0.052	-0.044	-0.049
		(0.036)	(0.037)	(0.025)	(0.025)
Delivered 2+ Days After Arrival	0.046	-0.041	-0.041	-0.022	-0.022
		(0.014)	(0.014)	(0.010)	(0.010)
C-section on Day of Arrival	0.125	0.126	0.120	0.084	0.088
		(0.022)	(0.025)	(0.016)	(0.016)
C-section 1+ Days After Arrival	0.132	0.061	0.067	0.024	0.029
		(0.021)	(0.020)	(0.016)	(0.015)
Vaginal Del. on Day of Arrival	0.396	-0.072	-0.068	-0.040	-0.039
		(0.032)	(0.031)	(0.024)	(0.023)
Vaginal Del. 1+ Days After Arrival	0.347	-0.114	-0.119	-0.068	-0.078
		(0.031)	(0.033)	(0.022)	(0.022)
Breakdown of C-Section Deliveries:					
C-Section at H Hospital	0.149	0.491	0.494	0.314	0.320
		(0.048)	(0.050)	(0.039)	(0.039)
C-Section at L Hospital	0.106	-0.305	-0.312	-0.205	-0.202
		(0.036)	(0.032)	(0.030)	(0.028)
Fractions of Complier Groups -- Moving 7 mi. closer to H hospital (col. 2-3) or closer to H hospital (col. 4-5)					
P(H Complier)		0.111	0.112	0.101	0.101
P(C&H Complier)		0.013	0.013	0.011	0.012
P(H Complier & C Always-Taker)		0.021	0.022	0.021	0.020
P(H Complier & V Always-Taker)		0.077	0.077	0.070	0.069
P(C Complier|H Complier)		0.117	0.114	0.107	0.116
P(C Always-Taker|H Complier)		0.192	0.195	0.203	0.200

Notes: Analysis Sample=491,604 low-risk first births. Standard errors in parentheses clustered at 5-digit ZIP code level. "Baseline controls" are dummies for Hospital Service Area and year of birth, controls for distance to closest hospital, and fraction of new mothers in ZIP code covered by Medi-Cal or other public insurance. "All controls" include 59 additional controls: mother's age (17 dummies), mother's education (8 dummies), race (4 dummies), father present, insurance type (3 dummies), cubic in mother's height, cubic in mother's weight, pre-pregnancy BMI, mother's pre-birth hospital use (3 variables), prenatal care (3 variables), mother's diseases and smoking (5 variables), birthweight and gestation (3 variables) and ZIP code characteristics (5 variables).

Appendix Table E3: Effects of Delivery at High C-Section Hospital on Infant and Maternal Outcomes At Birth (No Hosp. Controls)

Outcome Variable	Mean (1)	OLS Coefficients (2)	Reduced-Form Coefficients (x100) (3)	2SLS coefficients (5)
First-Stage Models:				
Deliver at H hospital	0.515	--	1.600	--
			(0.153)	
Infant Outcomes:				
Low (<7) 5-minute Apgar (x100)	0.700	-0.212	-1.310	-0.819
		(0.030)	(0.476)	(0.307)
NICU admission, including transfers	0.040	-0.014	-0.019	-0.011
		(0.001)	(0.013)	(0.008)
Ventilation	0.015	-0.002	0.044	0.027
		(0.001)	(0.018)	(0.011)
Length of stay (days)	2.354	0.065	-0.120	-0.074
		(0.012)	(0.140)	(0.085)
Maternal Outcomes:				
Trauma to perineum and vulva during labor	0.461	-0.122	-0.159	-0.099
		(0.004)	(0.051)	(0.028)
Perineal laceration (2nd degree or higher)	0.290	-0.074	-0.145	-0.090
		(0.003)	(0.037)	(0.020)
Length of labor (days) (birth - admission)	0.530	-0.056	-0.106	-0.065
		(0.003)	(0.047)	(0.028)
Post-birth stay (days) (discharge-birth)	2.105	0.142	0.085	0.052
		(0.007)	(0.073)	(0.045)

Notes: Analysis Sample=491,604 low-risk first births, except models for 5-minute Apgar, which includes 487,643 observations, and models for length of stay, length of labor and length of post-birth stay, which have 482,187 observations. Length of labor is measured by number of days from mother's admission to birth, top-coded at maximum of 3 days. Mother's length of stay is top-coded at 5 days. Post birth stay is length of stay minus length of labor. Standard errors in parentheses clustered at 5-digit ZIP code level. All models include the full set of controls described in note to Table 2 with the exception of hospital controls. OLS coefficients from regression of outcome on an indicator of delivery at a high c-section hospital and controls. Instrumental variable in all cases is relative distance to high c-section hospital, and endogenous variable in 2SLS models is delivery at high c-section hospital.

Appendix Table E4: Effects of Delivery at High C-Section Hospital on Subsequent Hospital Visits and Post-Birth Outcomes (No Hosp. Controls)

Outcome Variable	Mean (1)	OLS Coefficients (2)	Reduced-Form Coefficients (x100) (3)	2SLS coefficients (4)
Infant Outcomes:				
Any ED visit in year after birth	0.338	0.008	0.128	0.080
		(0.004)	(0.050)	(0.031)
ED visit for acute respiratory condition	0.126	0.010	0.074	0.046
		(0.002)	(0.028)	(0.018)
Inpatient stay in neonatal period	0.041	0.001	-0.038	-0.024
		(0.001)	(0.011)	(0.007)
Inpatient stay in year after birth	0.085	0.002	-0.038	-0.024
		(0.001)	(0.019)	(0.012)
6+ days in hospital or death in neonatal period (x100)	6.746	-0.371	-4.497	-2.771
		(0.119)	(1.435)	(0.882)
Death in year after birth (x100)	0.121	-0.005	-0.364	-0.228
		(0.013)	(0.159)	(0.098)
Maternal Outcomes:				
Any inpatient stay or ED/ASC visit	0.149	0.002	0.025	0.016
		(0.001)	(0.025)	(0.015)
Any ED visit in year after birth	0.129	0.001	0.025	0.015
		(0.001)	(0.025)	(0.015)
Inpatient stay in year after birth	0.022	0.000	0.006	0.004
		(0.000)	(0.007)	(0.005)

Notes: Analysis Sample=491,604 low-risk first births. Standard errors in parentheses clustered at 5-digit ZIP code level. All models include the full set of controls described in note to Table 2 with the exception of hospital controls. OLS coefficients from regression of outcome on an indicator of delivery at a high c-section hospital and controls. Instrumental variable in all cases is relative distance to high c-section hospital, and endogenous variable in 2SLS models is delivery at high c-section hospital.

Appendix F: Additional Appendi Tables and Figures

Appendix Table 1: Characteristics of High and Low C-section Hospitals

	Hospital Type:	
	High CS	Low CS
C-section rate (LRFBs):		
All	0.289	0.220
With no sign of labor	0.104	0.081
With sign of labor	0.186	0.139
Ownership:		
For profit	0.180	0.086
Private non-profit	0.746	0.723
Government	0.068	0.140
Academic	0.006	0.051
Other Characteristics:		
Has NICU	0.741	0.858
NICU admit rate	0.027	0.042
Volume	3,696	3,635
Weekend admit rate	0.240	0.262

Notes: see text for procedure to define H and L hospitals. Statistics are weighted by births.

Appendix Table 2: Effect of Delivery at High C-Section Hospital on the Joint Distribution of Timing of Birth, Mode, and Low Apgar Score

	Mean Rate in L Hospitals (%) (1)	IV Estimate of Effect of Delivery at H Hospital (%) (2)
Delivery 1st Day (Any Mode)		
with 5-minute Apgar <7	0.31	-0.11
		(0.24)
with 5-minute Apgar ≥ 7	49.98	1.75
		(2.33)
Delivery 2nd Day or Later (Any Mode)		
with 5-minute Apgar <7	0.47	-0.65
		(0.27)
with 5-minute Apgar ≥ 7	49.25	-0.99
		(2.34)
Vaginal Delivery 1st Day		
with 5-minute Apgar <7	0.20	-0.11
		(0.17)
with 5-minute Apgar ≥ 7	40.26	-5.07
		(1.96)
Vaginal Delivery 2nd Day or Later		
with 5-minute Apgar <7	0.31	-0.31
		(0.21)
with 5-minute Apgar ≥ 7	37.20	-5.83
		(1.93)
Cesarean Delivery 1st Day		
with 5-minute Apgar <7	0.11	0.00
		(0.13)
with 5-minute Apgar ≥ 7	9.72	6.82
		(1.33)
Cesarean Delivery 2nd Day or Later		
with 5-minute Apgar <7	0.16	-0.33
		(0.15)
with 5-minute Apgar ≥ 7	12.04	4.84
		(1.35)

Notes: Sample= 487,643 (timing of birth has some missing values). See notes to Table 5. Estimates in second column are from same specification as used in Table 5. Standard errors, clustered at 5 digit zip code level, in parentheses.

Appendix Table 3: Estimated Effects of Reative Distance on Infant Death
Logistic and Probit Regressions

Specification	Coefficient on relative distance	Avg. marginal effect of rel. dist. (percentage points)
Logistic	-2.604	-0.338
	(1.301)	(0.169)
Probit	-0.824	-0.337
	(0.399)	(0.164)

Notes: Analysis sample, low-risk first births. Outcome is infant death in first year. Standard errors in parentheses clustered at 5-digit ZIP code level. All models include the full set of controls described in note to Table 2.

Appendix Table 4: Comparison to Effects on Otherwise-Low-Risk Breech First Births

	Analysis Sample	Low-risk breech first births
Outcome Variable	(1)	(2)
First-Stage Models:		
Deliver at high c-section (H) hospital	1.328	1.706
	(0.134)	(0.204)
Reduced-Form Models:		
Delivered by c-section	0.149	-0.064
	(0.027)	(0.041)
Low 5-minute Apgar score (x100)	-1.084	-1.368
	(0.471)	(2.138)
Any ED visit in year after birth	0.117	-0.108
	(0.049)	(0.135)
ED visit for acute respiratory condition	0.070	-0.002
	(0.028)	(0.097)
Inpatient stay in neonatal period	-0.042	0.133
	(0.012)	(0.066)
Inpatient stay in year after birth	-0.034	0.210
	(0.021)	(0.083)
6+ days in hospital or death in neonatal period (x100)	-2.803	18.842
	(1.526)	(7.640)
Death in year after birth (x100)	-0.344	1.213
	(0.161)	(1.692)
Births	491,604	12,749

Notes: Column (1) presents estimates from main of LRFB analysis sample in text. Column (2) presents estimates from sample of breech births that otherwise meet the definition for low-risk first births.

Appendix Table 5: Multi-Channel Estimates of Effects of Delivery at High C-Section Hospital
First-Stage and Reduced-Form Model Estimates

	First stage models *Deliver at:*					Reduced-form estimates, 5-channel model						
	High c-section hosp.	Low (<7) 5-min. Apgar score hosp.	High infant ED use hosp.	High infant inpatient use hosp.	High infant death hosp.	Low (<7) 5-min. Apgar score (×100)	Any ED visit	Acute respiratory ED visit	Neonatal inpatient visit	Inpatient visit in first year	6+ days in hosp. or neo. death (×100)	Death (×100)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Rel. dist. to high c-section hosp.	1.308	-0.184	-0.092	0.180	0.011	-0.780	0.142	0.084	-0.036	-0.024	-1.739	-0.339
	(0.136)	(0.124)	(0.088)	(0.122)	(0.140)	(0.512)	(0.055)	(0.031)	(0.013)	(0.021)	(1.593)	(0.188)
Rel. dist. to low 5-min. Apgar score hosp.	0.211	1.170	-0.203	0.071	0.036	1.023	0.006	-0.008	-0.011	-0.018	2.233	-0.083
	(0.125)	(0.125)	(0.083)	(0.123)	(0.140)	(0.534)	(0.053)	(0.030)	(0.015)	(0.022)	(1.699)	(0.183)
Rel. dist. to high infant ED use hosp.	-0.346	0.292	0.717	-0.196	0.110	-0.223	0.081	0.053	0.014	0.016	-2.551	-0.064
	(0.115)	(0.120)	(0.072)	(0.105)	(0.128)	(0.496)	(0.051)	(0.027)	(0.012)	(0.018)	(1.421)	(0.172)
Rel. dist. to high infant inpatient use hosp.	0.256	-0.285	0.301	1.843	0.342	0.420	-0.006	0.057	0.046	0.068	2.950	-0.138
	(0.149)	(0.122)	(0.081)	(0.125)	(0.148)	(0.560)	(0.062)	(0.031)	(0.013)	(0.020)	(1.742)	(0.203)
Rel. dist. to high infant death hosp.	-0.409	0.012	-0.026	-0.047	1.415	-0.339	0.081	0.035	0.020	0.039	0.363	0.200
	(0.138)	(0.141)	(0.086)	(0.131)	(0.153)	(0.512)	(0.057)	(0.032)	(0.012)	(0.022)	(1.675)	(0.201)

Notes: Analysis Sample=491,604 low-risk first births. All models include the full set of controls described in note to Table 2. Standard errors in parentheses clustered by mother's zip code. All models include controls for hospital confounds as discussed in the text.

Appendix Table 6: Single- and Two-Channel Instrumental Variables Estimates of Effects of Delivery at High C-Section Hospital

	Low 5-minute Apgar (x100)		Any ED visit		Acute resp. ED visit		Neonatal inpatient visit		Inpat. visit in first year		6+ days in hosp. or neonatal death (× 100)		Death (× 100)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Deliver at high c-section hospital	-0.816	-0.519	0.088	0.094	0.053	0.058	-0.032	-0.032	-0.026	-0.026	-2.063	-2.049	-0.259	-0.227
	(0.362)	(0.389)	(0.037)	(0.039)	(0.021)	(0.021)	(0.009)	(0.008)	(0.016)	(0.014)	(1.115)	(1.081)	(0.120)	(0.142)
Deliver at high outcome hospital		0.937		0.106		0.089		0.030		0.041		1.311		0.116
		(0.416)		(0.067)		(0.036)		(0.007)		(0.011)		(0.917)		(0.165)

Notes: Analysis Sample = 491,604 low-risk first births. All models (OLS and IV) include the full set of controls described in note to Table 2, as well as controls for hospital confounds, as discussed in the text. Instrumental variables are relative distance to high c-section hospital, relative distance to low 5-minute Apgar hospital (column 2), relative distance to high infant ED use hospital (columns 4 and 6), relative distance to high infant inpatient use hospital (columns 10 and 12), and relative distance to high infant death hospital (column 14). Standard errors in parentheses clustered by mother's zip code.

Appendix Table 7: Generalized Control Function Models for Apgar Scores, Adverse Event in Neonatal Period, and Death

	Low (<7) 5-minute Apgar score (x100)		Any ED visit in year after birth		ED visit for acute respiratory condition		Inpatient stay in neonatal period		Inpatient stay in year after birth		6+ days in hospital or death in neonatal period (×100)		Death in year after birth (×100)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Delivered at H Hospital	-0.816	-0.810	0.088	0.083	0.053	0.051	-0.032	-0.031	-0.026	-0.026	-2.121	-2.181	-0.259	-0.255
	(0.430)	(0.447)	(0.043)	(0.048)	(0.024)	(0.027)	(0.011)	(0.013)	(0.019)	(0.021)	(1.458)	(1.306)	(0.148)	(0.148)
Delivered at H Hospital	--	0.107	--	-0.139	--	-0.058	--	-0.009	--	-0.011	--	-1.687	--	0.138
× 1st stage residual		(0.147)		(0.013)		(0.008)		(0.004)		(0.005)		(0.533)		(0.053)
Delivered at H Hospital	--	-0.022	--	0.000	--	0.000	--	0.001	--	0.002	--	-0.004	--	0.014
× birthweight (standardized)		(0.026)		(0.001)		(0.001)		(0.001)		(0.001)		(0.093)		(0.016)
Delivered at H Hospital	--	0.005	--	0.003	--	0.002	--	-0.001	--	-0.001	--	-0.091	--	0.000
× gestation (standardized)		(0.027)		(0.001)		(0.001)		(0.001)		(0.001)		(0.087)		(0.012)
Delivered at H Hospital	--	0.046	--	0.000	--	0.001	--	0.003	--	0.007	--	0.094	--	0.005
× HRR c-section rate (standardized)		(0.041)		(0.004)		(0.003)		(0.001)		(0.001)		(0.116)		(0.014)
1st stage residual	0.757	0.695	-0.084	-0.011	-0.046	-0.016	0.034	0.038	0.032	0.037	2.576	3.454	0.269	0.197
	(0.432)	(0.471)	(0.043)	(0.049)	(0.023)	(0.027)	(0.011)	(0.012)	(0.019)	(0.021)	(1.443)	(1.285)	(0.150)	(0.155)

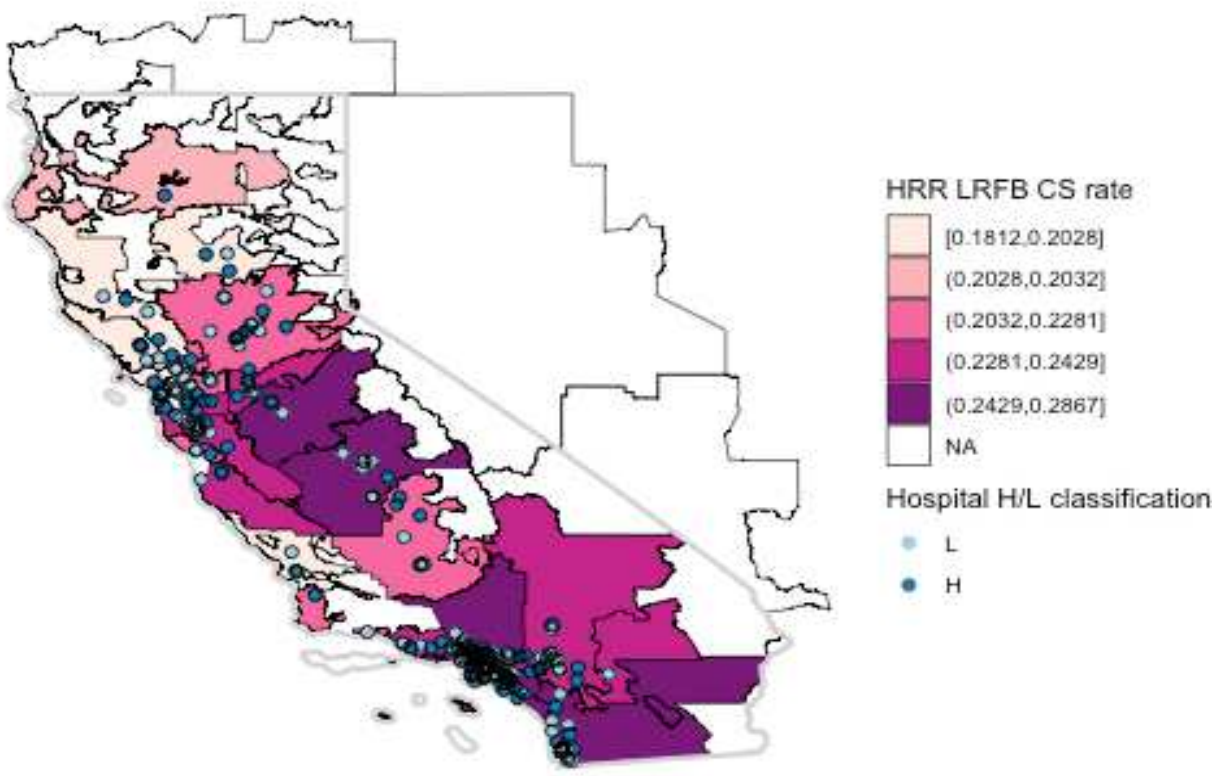
Notes: Analysis Sample=491,604 low-risk first births. All models include the full set of controls described in note to Table 2, as well as controls for hospital confounds as discussed in the text. Birthweight and gestation interaction terms are expressed in (demeaned) standard deviation units. Sample for Apgar scores is 487,643 births with non-missing 5-minute Apgar scores. Standard errors are bootstrapped (200 repetitions) and clustered at the mother's zip code.

Appendix Table 8: Effects of Delivery at High C-Section Hospital on Fertility and Second-Birth Outcomes

	LRFBs	Mean	OLS Coefficient (Deliver at H, 1st birth)	RF Coefficient (x 100)	2SLS Estimate (Scaled per 1st-birth delivery at H-hospital)
	(1)	(2)	(3)	(4)	(5)
Any 2nd birth in sample	491,307	0.197	0.008	-0.046	-0.035
			(0.002)	(0.029)	(0.022)
Days until 2nd birth	97,026	814.690	4.047	3.950	3.317
			(2.147)	(31.738)	(26.538)
C-section at 2nd birth	97,024	0.276	0.071	0.198	0.166
			(0.004)	(0.052)	(0.042)
Scheduled c-section at 2nd birth	97,024	0.249	0.072	0.195	0.164
			(0.004)	(0.049)	(0.039)
Gestation of 2nd birth (days)	94,674	275.521	-0.594	-2.737	-2.286
			(0.095)	(1.436)	(1.152)
Birthweight of 2nd birth (grams)	97,021	3385.342	-11.059	-72.440	-60.818
			(3.353)	(50.785)	(42.321)
Fetal or infant death at 2nd birth	97,026	0.005	0.000	0.007	0.006
			(0.001)	(0.008)	(0.007)
Maternal length of stay at 2nd birth	96,260	2.154	0.158	0.159	0.133
			(0.011)	(0.139)	(0.118)
Infant length of stay at 2nd birth	97,026	2.185	0.140	0.119	0.100
			(0.009)	(0.106)	(0.089)
Maternal ED, ASC, or inpatient stays in prenatal period of 2nd birth	97,026	0.454	0.008	0.147	0.123
			(0.007)	(0.097)	(0.083)
Maternal ED, ASC, or inpatient stays in year after 2nd birth	97,026	0.264	0.021	0.082	0.069
			(0.006)	(0.080)	(0.068)
Second infant ED, ASC, or inpatient stays in year after birth	97,026	0.585	0.008	0.083	0.070
			(0.009)	(0.147)	(0.123)

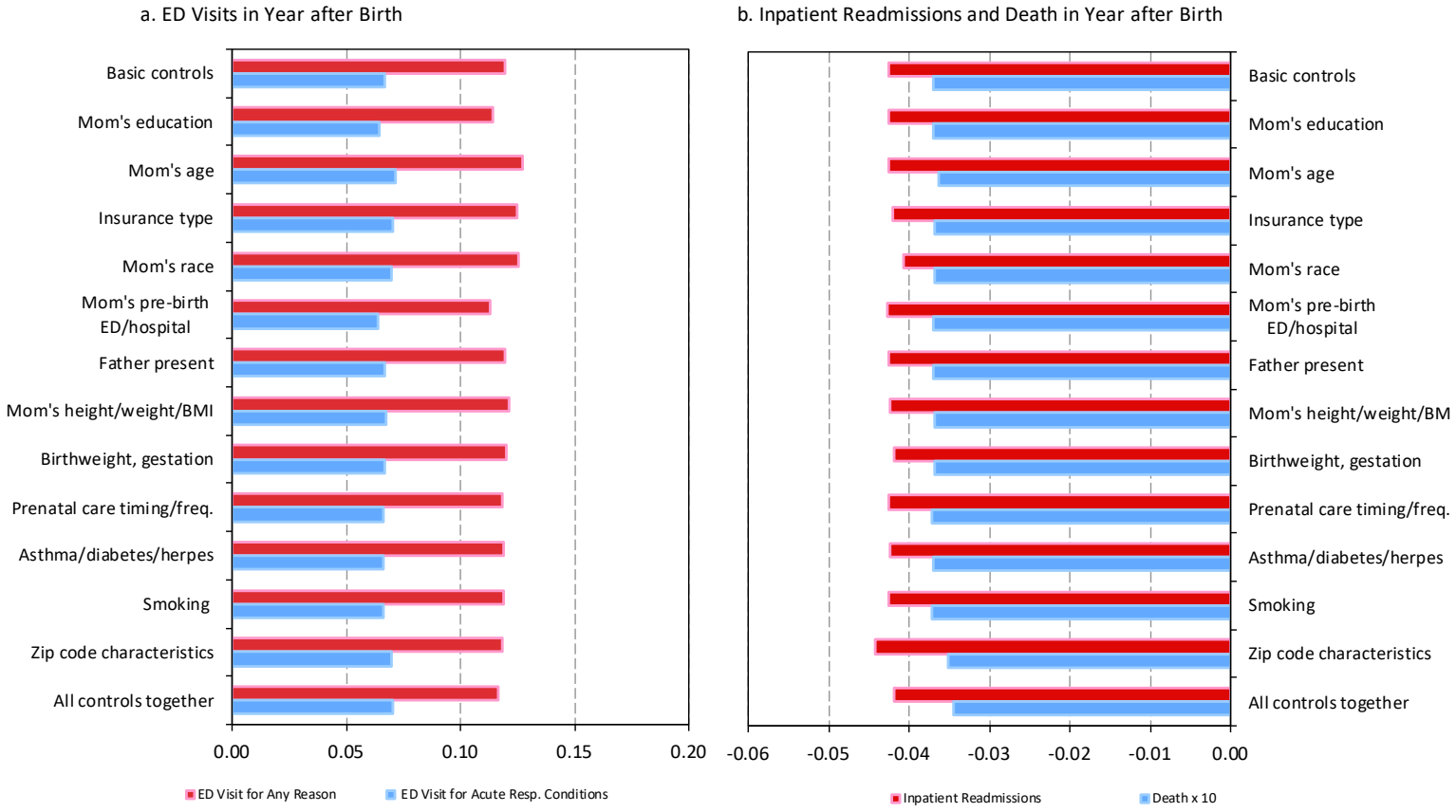
Notes: All models (OLS and IV) include the full set of controls described in note to Table 2, in addition to month (e.g. July 2008) indicators. Instrumental variable in all cases is relative distance to high-c-section hospital. Maternal and infant counts of stays topcoded at 5.

Appendix Figure 1: Hospital Classification



Notes: Figure reports the hospital classification (light blue and dark blue circles), the HRR boundaries, and the HRR average c-section rate for Low-Risk First Births (LRFB).

Appendix Figure 2: Sensitivity of Reduced-Form Effects of Relative Distance on Infant Health Outcomes



Notes: Figures report estimated reduced form effects on ED visits (panel a) or inpatient readmissions and death (panel b) from models that include basic set of controls described in Table 2 plus additional controls described on figure axes. "All controls together" estimate at bottom of figure include all control variables simultaneously.