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ABSTRACT

This paper examines whether loss of locally available hospital-based obstetric services affects racial/ethnic disparities in intrapartum care access and birth outcomes in rural areas of the US. To conduct causal inference, we combine difference-in-difference and propensity score matching methods to control for observable and time-invariant unobservable heterogeneity across counties. Using data from Vital Statistics birth certificate records from 2005-2018 from rural counties in the mainland US, our empirical analysis reaches several findings. Women in counties that lost obstetric services are more likely to receive intrapartum care outside their counties of residence and to deliver in an urban county compared to women in matched counties. Nonetheless, there are no consistent effects of obstetric unit closure on maternal and infant health in the full sample. Among Black mothers, however, obstetric unit closure is not associated with delivering in an urban county, and there is a more consistent pattern of negative effects of closure on infant health. Importantly, the adoption of scope-of-practice laws for certified nurse midwives, the adoption of telehealth payment parity laws and the ACA Medicaid expansions have implications for narrowing racial/ethnic disparities in health in response to obstetric unit closures.

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1. Introduction

Access to high-quality maternal health services, including hospital-based obstetric care, is critical to health outcomes before, during, and after pregnancy (CMS 2022). Rates of severe maternal morbidity (SMM) and mortality are rising in the US, with Black and American Indian/Alaska Native (AIAN) women, as well as rural women, having elevated risk of adverse outcomes (Creanga et al. 2014; Petersen et al. 2019; Kozhimannil et al. 2019). However, many rural hospitals do not provide obstetric care (Kozhimannil et al. 2020). There have been 180 rural hospital closures since 2005 leaving a significant fraction of rural counties without hospital-based obstetric units (Hung et al. 2017).

An important implication of obstetric unit closures in rural areas is that women may need to travel farther for intrapartum care, which may lead to changes in the location and types of services received, possibly affecting health outcomes (Grzybowski, Stoll, and Kornelsen 2011). Racial/ethnic minority women may be affected disproportionately since they face structural barriers to accessing intrapartum care, and, in some cases, have maternal health outcomes that are far worse than those of other groups. For example, based on 2011-2016 data, the CDC reports that the rate of pregnancy-related mortality for Black women living in the most rural areas of the U.S. was 59.3 deaths per 100,000 live births; this rate was 19.7 deaths per 100,000 live births for white women residing in the same areas (GAO April 2021).

In this paper, we estimate the effects of losing hospital-based obstetric care in rural US counties on location and type of intrapartum care as well as maternal/infant health at the time of delivery, with a focus on shedding light on rural racial/ethnic health disparities. Our empirical analysis is based on individual-level data from Vital Statistics birth certificate records for the period 2005–2018 merged with county-level data on obstetric unit closures and socioeconomic characteristics. Using propensity score methods (PSM) and a difference-in-difference (DiD) setting, we compare outcomes before and after obstetric unit closure among women residing in counties that lost obstetric services vs. women residing in matched counties that did not lose services.

We are particularly interested in two effects. First, we test for heterogeneous effects of obstetric unit closure by maternal race/ethnicity. Second, we explore whether three specific policies may have remediated any racial/ethnic disparities in health generated by obstetric unit closures. The first policy is the scope-of-practice (SOP) law of certified nurse midwives (CNMs), which increases the supply of obstetric care providers potentially from the local area. The second policy is the telehealth payment parity law, which increases the supply of obstetric care providers potentially from distant urban areas. The third policy is the 2010 Affordable Care Act (ACA) Medicaid expansions, which potentially bolstered community health resources.

Our paper reaches several principal findings. We find that obstetric unit closure affects location and nature of delivery but has mixed and small adverse effects on infant health. Interestingly, our results reveal significant racial/ethnic heterogeneity, with closures having more detrimental effects on Black women compared to white and Hispanic women. Importantly, it appears that the SOP law adoption enhances the birth outcomes of Black women disproportionally, whereas the TPP law adoption and ACA Medicaid expansion have a more uniform impact on the birth outcomes between white and Black women.

Our study relates to two strands of literature. The first examines travel behaviors of rural women seeking obstetric care. Kozhimannil et al. (2016) find that rural women with preterm births and clinical complications, as well as those without local access to higher-acuity neonatal care, are more likely to give birth in non-local hospitals (Kozhimannil et al. 2016). Hung et al. (2016) report that 7.2% of their sample of 263 rural U.S. hospitals closed their obstetric units between 2010-14, increasing travel distance for intrapartum care.

The second strand of literature focuses on how loss of locally-available obstetric services affects birth outcomes. Lorch et al. (2013) find that obstetric unit closures in Philadelphia increase delivery volume of remaining hospitals and decrease access to prenatal care, detracting from health outcomes. Avdic, Lundborg, and Vikström (2018) find that while maternity ward closures in Sweden increase distance travelled for delivery, closures do not affect the health of women directly affected.[4]

In a closer relationship to our work, Sontheimer et al. (2008) study rural counties in Missouri, and Kozhimannil et al. (2018) and Fischer, Royer, and White (2022) focus on rural U.S. counties. The first work finds that rural counties that lose hospital-based obstetric care (1990-2002) experience a rise in low birthweight births. The second work finds that rural counties that lose hospital-based obstetric units (2004-14) experience increases in out-of-hospital births; births in hospitals without obstetric units; and preterm births. The third work finds that rural counties that lose hospital-based obstetric units (1989-2019) experience negligible or slightly beneficial impacts on maternal and birth outcomes. They argue that such results are driven by women receiving higher quality care by traveling outside their residing counties.

Our study contributes to the literature in two ways. First, the previous studies examine average outcomes at the county-year level, while we study a large set of outcomes at the individual level. As a result, we can provide novel evidence regarding whether obstetric unit

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[4] There were some negative health effects caused by over-crowding on women not directly targeted by closures.

closures affect racial/ethnic minority women disproportionately. Second, our work is the first study exploring the role of policy in remediating the effects of obstetric unit closure on maternal care for women of different races/ethnicities. In particular, our work has implications for which policies can narrow racial/ethnic disparities in maternal birth outcomes generated by loss of hospital-based obstetric units in rural areas.

2. Empirical Strategy

A. Data

We use the restricted-access 2005-2018 U.S. Vital Statistics Natality files (birth certificates) with county identifiers from the National Center for Health Statistics. We obtain information about obstetric unit closures from the American Hospital Association (AHA) and the Area Health Resource File (AHRF). We use the county of maternal residence to merge the natality files with the information about obstetric unit closures at the county-level. The unit of analysis is the birth record, which contains both maternal and infant variables.

The sample is limited to women whose counties of residence are rural, defined as counties having a USDA ERS Rural-Urban Continuum Code (RUCC) between 4-10. Further, we limit our sample to singleton births and exclude births with implausible birth weights (>= 6,803 grams), births with the distance between residing and birth occurrence counties over 1,000 miles, and births from Alaska and Hawaii.

B. Outcome and Treatment Variables

We begin with a set of outcomes capturing travel behaviors, including whether the mother received intrapartum care in a county other than her residence county; the distance traveled to receive intrapartum care; and whether the birth is delivered in an urban county

(Kozhimannil et al. 2018; Fischer, Royer, and White 2022). Distance information comes from the NBER county distance database, which includes the great circle distance between counties, and urban county is defined as a county having a RUCC code of 1-3.

Then, we examine type of intrapartum care, including whether the birth is out-of-hospital; whether the birth is assisted by certified nurse-midwife (CNM); and whether the birth is a cesarean section. Also, we examine two childbirth complications, namely whether the infant used assisted ventilation and whether the infant was admitted to the NICU. These latter two outcomes capture both the health of the child and the services available at the hospital where the child is delivered.

Finally, we measure maternal morbidity with an indicator which is set to one if at least one of the following is recorded on the birth certificate: 1) maternal transfusion; 2) third or fourth-degree perineal laceration; 3) ruptured uterus; 4) unplanned hysterectomy; 5) admission to intensive care unit; and 6) eclampsia. We interpret this maternal morbidity measure with caution since there is evidence that SMM is under-reported on birth certificates relative to hospital discharge data (Luke et al. 2018). We also examine three birth outcomes based on the information recorded on the birth certificate: 1) whether the birth is preterm (<37 weeks gestation), 2) logarithm of birth weight and 3) logarithm of Apgar score[5].

For the treatment variable, we construct a binary indicator of obstetric unit closure. We obtain the number of short-term general (STG) hospitals with obstetric units from the AHA and AHRF data. We start with a sample of 900 rural counties that have at least one hospital with an obstetric unit in 2005. We then construct a measure of obstetric unit closure (*OB*

[5] Apgar score is computed by adding points (2, 1, or 0) for heart rate, respiratory effort, muscle tone, response to stimulation, and skin coloration; a score of 10 represents the best possible condition. We replaced zeros with ones so that we could log this variable.

Closure) that takes a value 0 when a county has at least one obstetric unit operated by a hospital, and a value 1 when the county has lost all hospital-based obstetric units.

[Insert Exhibit 1 about here]

Exhibit 1A depicts the 416 counties colored in red, in which complete obstetric unit closure occurred between 2005 and 2018. The 200 counties colored in blue have at least one obstetric unit that remained open throughout the study period.[6] In our sample, about 62% of observations have *OB Closure* = 1. Further, among those counties with *OB Closure* = 1, Exhibit 1B depicts that most of them lost all their obstetric units in or before 2013.

C. Propensity Score Matching (PSM) Model

We use the PSM approach to control for possible selection issues driven by unmeasured county characteristics affecting both obstetric unit closure and outcomes. Following Kozhimannil et al. (2019) and Hung et al. (2017), we postulate that demographic and market characteristics are useful in modeling obstetric unit closure. To estimate the propensity score, we assume whether a county experiences complete loss of obstetric care is governed by a Probit model:

$$OB\ Closure_c^* = z_c\alpha + \eta_c, \qquad Closure_c = 1\{Closure_c^* \geq 0\}$$

where $\eta_c \sim N(0,1)\ and\ OB\ Closure_c = 1$ if county c experiences complete loss of hospital-based obstetric care during our sample period, and $Closure_c = 0$ otherwise. The set of explanatory variables z_c are measured in 2005, the first year of our analysis period (see

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6 These 200 counties serve as the control group for the 416 treated counties based on our PSM model, described in the next section.

Supplemental Material, Section A for details).

In Supplemental Material, Section B we report the descriptive statistics of our matched sample, which we limit to first births. The matched sample includes 662,759 first births. About 40% of women in our analytic sample receive intrapartum care outside of their residing counties, traveling about 17 miles, and 26% of the sample delivers in an urban county. Conditional on traveling outside their residing counties, they travel about 42.5 miles (= 17/0.4), or 32 minutes of driving time if the speed is at 80 miles/hour (typical speed limits on rural interstates range from 65 to 80 mile/hour). About 1.1% of the sample are out-of-hospital births, 8.1% are assisted by a CNM and 28.7% are cesarian deliveries. About 5-6% of infants use assisted ventilation and are admitted to the NICU. Maternal morbidity is a rare event with an occurrence rate of 2.8%. For birth outcomes, 10% are preterm, the average birth weight is 3,194 grams, and average Apgar score is about 9.

D. Difference-in-Difference (DiD) Model

To estimate the effect of obstetric unit closure on outcomes, we use the following DiD model using the matched sample:

$$Outcome_{ict} = a \cdot 1_{\{0 \leq \Delta t l\}} \times OB\ Closure_c + X_{it}\beta + \gamma_c + \gamma_t + \varepsilon_{ict} \quad (1)$$

The dependent variable $Outcome_{ict}$ represents an outcome variable for woman i residing in county c in year t. In Equation 1, $OB\ Closure_c$ is an indicator for county c experiencing loss of hospital-based obstetric care our sample period. Let $\Delta t(c) \equiv t - t_{Closure(c)}$ so the event time indicator $1_{\{\Delta t(c)=r\}}$ represents r years before ($r < 0$) or after ($r \geq 0$) the year of complete loss of obstetric units ($t_{Closure(c)}$) in county c. The parameter a is the coefficient of the interaction between the event time indicators and $OB\ Closure_c$, that is, $1_{\{0 \leq \Delta t(c)\}} \times OB\ Closure_c$. Since we choose the years before the obstetric unit closure, that is, $r \leq -1$, as the baseline years in the analysis, the parameter a measures the difference in outcome variables for rural women residing in treated and matched counties at year $r \geq 0$ relative to the baseline year.

The maternal characteristics X_{it} include: (1) dummy variables for maternal age groups; (2) dummy variables for Black and Hispanic, with white non-Hispanic as the baseline (we drop mothers from other racial/ethnic groups from the sample); (3) dummy variables for maternal education - less than high school, high school graduate, some college, college graduate and more than college graduate; (4) dummy variables for maternal chronic conditions - pre-pregnancy diabetes, gestational diabetes, pre-pregnancy hypertension, and gestational hypertension; (5) an indicator of whether the woman smoked in the first trimester; and (6) an indicator that the mother is married. We also include a set of county-specific fixed effects γ_c and year-specific fixed effects γ_t. The random variable ε_{ict} is an error term. More details are available in Supplemental Material, Section C.

3. Results

A. Main Results

Exhibit 2 depicts the parameters α of Equation (1) for various outcome variables (listed on the vertical axis). The bars cover the 90% confidence level of the estimates. Our discussion focuses on first-born infants. The results from first-born children and higher-born children are qualitatively consistent with each other (see Supplemental Material, Section D).

[Insert Exhibit 2 about here]

Travel Behaviors and Type of Delivery: Our results show that women in treated counties are about 4 percentage points more likely than women in matched counties to receive intrapartum care outside their counties of residence; this effect represents about an 8 percent increase evaluated at the mean for treated counties. Consistently, the average number of miles travelled for intrapartum care also increases. Women in treated counties travel a longer distance to receive intrapartum care and are about 2 percentage points more likely than women in matched counties to deliver in an urban county (about an 8 percent increase at mean for treated counties). Obstetric unit closure is associated with about a 10 percent increase in the likelihood that the infant is delivered by a certified nurse-midwife (evaluated at mean for treated counties), but there is no association between obstetric unit closure and the probability that the delivery is by C-section.

These findings suggest that obstetric unit closure may lead to rural women finding alternatives (possibly of higher quality) located in urban counties (Fischer, Royer, and White 2022). Further, conditional on receiving intrapartum care outside the residing county, the travel distance is about 42 miles (or about 30-minutes of driving time).

Maternal Morbidity and Birth Outcomes: In Exhibit 2, the findings suggest that losing obstetric care in the residing county does not affect maternal morbidity. The effects on birth outcomes, however, are mixed. Infants whose mothers reside in treated counties have lower APGAR scores and are more likely to use assisted ventilation at birth compared to infants whose mothers reside in matched counties, but there are no effects on pre-term birth, birthweight, and admission to NICU. Use of assisted ventilation may reflect poor infant health, but also captures the availability of this technology and hospital practices, making it difficult to evaluate the effects on this outcome in isolation. We find positive effects of obstetric unit closure on dichotomous indicators of "low Apgar," "low birthweight," and "very low birthweight", but these effects are only statistically significant for "low Apgar" and "very low birthweight" among Black infants (see Supplemental Material, Section E).

Thus, we conclude that while obstetric unit closures may have increased travel distance and changed the location/type of delivery for rural women, closure does not appear to affect maternal health (based on our limited SMM measure) and has modest, if any, negative effects on infant health in the full sample.

B. Robustness Checks

B.1. Parallel Trend Assumption

The identifying assumption underlying the DiD model is that rural women residing in treated and matched counties would have similar trends in outcome variables in the absence of the obstetric unit closure. To test the reasonableness of this assumption of parallel trends, we apply an event study approach and estimate the following equation:

$$Outcome_{ict} = (\Sigma_{r=\ldots,-2}\, a_r \cdot 1_{\{\Delta t(c)=r\}} + \Sigma_{r=0,\ldots}\, a_r \cdot 1_{\{\Delta t(c)=r\}}) \times OB\ Closure_c + X_{it}\beta + \gamma_c + \gamma_t + \varepsilon_{ict} \quad (2)$$

The set of a_r includes the coefficients on the interactions between the event time indicators and $OB\ Closure_c$, that is, $1_{\{\Delta t(c)=r\}} \times OB\ Closure_c$. Since we choose the year before closure, that is, $r = -1$, as the baseline year in the analysis, a_r measures the difference in outcome variables for rural women residing in treated and control counties in year r relative to the omitted a_{-1}, which is the difference relative to the year before closure.

[Insert Exhibit 3 about here]

Exhibit 3 plots the results of the event studies for our main sample of first-born children. The confidence intervals for the estimates before t-1 mostly cover zero. Further, in Section F of Supplemental Material, we restrict our sample to counties that had closures between 2009 and 2014, so that there are at least four years of data before and after each closure. The results are consistent with those depicted in Exhibit 3. These results suggest the parallel trends assumption is reasonable.

B.2. Heterogeneity in Closure Timing

We address the potential issue of bias causes by staggered timing of obstetric unit closures and treatment effect heterogeneity. Following Goodman-Bacon (2021), we plot all the 2 × 2 pairwise DID estimates (on the vertical axis) against their weights (on the horizontal axis) (see Supplemental Material, Section G). The red line represents the weighted DID coefficient once accounting for the different weights associated with its components. First, we note that treated vs. never treated are the ones with the largest weights. The weight associated with this group is 50.5%. This suggests that the latter is the main source of identification in our setting. Second, although some 2 × 2 pairwise comparisons have the opposite sign compared to our DiD estimate, their weights are very close to zero. These results suggest that our results are robust to the heterogeneity in closure timing.

B.3. Alternative Matching Criteria

We explore two alternative matching criteria to illustrate the robustness of our results. First, in contrast to our main results based on a PSM using county characteristics from 2005, we employ county characteristics from two years before the closure for each county. Although this set of county characteristic is less exogenous, it has the advantage that it should have more predictive power for closures happening in the latter part of our sample period. Second, we perform the PSM without using neighboring counties to mitigate the potential spillover effects of obstetric unit closure on the control group. Section H of Supplemental Material reports the results of these two checks; results are consistent with our main results.

C. Racial/Ethnic Disparities

C.1. Average Effects

We extend our model to incorporate heterogeneous effects for women of different race/ethnicities as follows:

$$Outcome_{ict} = \boldsymbol{a_0}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c) + \boldsymbol{a_1}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Black_i) + \boldsymbol{a_2}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Hispanic_i) + X_{it}\beta + \gamma_c + \gamma_t + \varepsilon_{ict} \quad (3)$$

where $Black_i$ denotes Black, $Hispanic_i$ denotes Hispanic, and the base group is white women. Exhibit 3 shows the total effect of obstetric unit closure on outcomes of white women ($\boldsymbol{a_0}$); outcomes of Black women ($\boldsymbol{a_0} + \boldsymbol{a_1}$); and outcomes of Hispanic women ($\boldsymbol{a_0} + \boldsymbol{a_2}$).

[Insert Exhibit 4 about here]

The parameter estimates $\boldsymbol{a_0}$ (presented in the top panel of Exhibit 4) are close to those of the main results because white women comprise most of our sample. The bottom panel shows the total effects of obstetric closure on Black and Hispanic women ($\boldsymbol{a_0} + \boldsymbol{a_1}$ and $\boldsymbol{a_0} + \boldsymbol{a_2}$, respectively). Two findings are notable. First, for all racial/ethnic groups, obstetric unit closures increase the likelihood that women leave their counties of residence for intrapartum care; closure increases the likelihood than a CNM is the birth attendant for white and Black women. However, obstetric unit closure is not associated with Black women being more likely to deliver in urban (and presumably better-resourced) counties, which was the case for white and Hispanic women. This may be related to the geographical distribution of Black women, who are concentrated in the South where obstetric units are the scarcest (see Supplemental Material, Section I).

Also, for Hispanic women only, obstetric unit closure is associated with increased risk of delivering outside a hospital and increased risk of cesarean delivery; these effects are small in percentage point terms, but the increased risk of out-of-hospital birth reflects a change of 21 percent evaluated at the sample mean for women living in treated counties. Thus, our first conclusion from Exhibit 4 is that the main results in Exhibit 2 mask racial/ethnic disparities in how obstetric unit closures affect location of birth and type of delivery.

Our second conclusion from Exhibit 4 is while the effects of obstetric unit closure on maternal and infant health appear small overall, any negative effects are concentrated among Black infants. For Black infants, obstetric unit closure is positively associated with use of assisted ventilation at birth, and negatively associated with both birthweight and APGAR score (closure also increases the likelihood of Black infants having very low birthweight and low Apgar score, see Supplemental Material, Section E). We find no effects of obstetric unit closure on infant outcomes for Hispanic women, and for white women there are only effects on assisted ventilation. Thus, our results suggest that for Black women, obstetric unit closures lead women to leave their counties of residence for care, but they do not deliver in a more urban area, thus possibly leading to adverse outcomes for their infants. We do not see this pattern for white and Hispanic women, whose outcomes may be buffered by being able to access urban counties for delivery.

C.2. Mitigating Policies

We examine several policies that potentially mitigate the racial/ethnic disparities of OB closure on maternal and birth outcomes. Specifically, we consider SOP laws for CNMs, TPP laws and the ACA Medicaid expansions. To test whether these policies affect the racial/ethnic disparities of obstetric unit closure on maternal and birth outcomes, we extend Equation (3) as follows:

$$Outcome_{ict} = \boldsymbol{a_0}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c) + \boldsymbol{a_1}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Black_i) + \boldsymbol{a_2}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Hispanic_i) + \boldsymbol{a_{01}}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Post_{ct}) + \boldsymbol{a_{11}}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Black_i \times Post_{ct}) + \boldsymbol{a_{21}}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Hispanic_i \times Post_{ct}) + X_{it}\beta + \gamma_c + \gamma_t + \varepsilon_{ict} \quad (4)$$

Since the three polices all have state-year variation, we construct an indicator $Post_{ct}$ to take the value one for county c in the years after the policy is implemented. The vector X_{it} also includes $Post_{ct}$, $Black_i \times Post_{ct}$, and $Hispanic_i \times Post_{ct}$.

SOP Law for CNMs. CNMs are the most common non-physician providers, attending fewer than 10 percent of all US births in 2018. However, there is heterogeneity across states in part because of their SOP laws for CNMs. In some states, the SOP law requires births to be supervised or attended by a physician. For instance, in Missouri all births must be supervised by a physician, whereas in Nevada mothers can choose to use only a CNM. Thus, states with a more flexible SOP law for CNMs may affect maternal and birth outcomes by increasing the supply of providers in the treated counties (Markowitz & Adams, 2022; Markowitz et al., 2017).

To test whether the adoption of SOP law affects the racial/ethnic disparities of obstetric unit closure on maternal and birth outcomes, we estimate Equation 4 with $Post_{ct} = 1$ if a state adopts the SOP law to allow CNMs practice independently, i.e. they have full practice and prescription authority, and 0 otherwise (including states with the SOP law allowing a reduced or restricted practice).

The upper panel of Exhibit 5 presents the parameter estimates of $\boldsymbol{a_0}$ (left) and $\boldsymbol{a_0}+\boldsymbol{a_{01}}$ (right) for white women. The upper left panel suggests that, before the adoption of SOP law, white women travel outside their residence counties and to urban counties for intrapartum care in response to obstetric unit closure. However, there are no significant effects on maternal morbidity and birth outcomes. Interestingly, the upper right panel suggests that, after the adoption of SOP law, white women are less likely to travel to outside counties and urban counties for intrapartum care in response to obstetric unit closure. They are less likely to have cesarean delivery, which potentially driven by the lack of physicians in their residing counties after obstetric unit closure. Such adjustments in travel behaviors and delivery method do not seem to affect maternal and birth outcomes substantially.

[Insert Exhibit 5 about here]

The lower panel of Exhibit 5 presents the parameter estimates of $\{a_0+a_1, a_0+a_2\}$ (left: the total effect of OB closure on outcomes for Black and Hispanic women, respectively, before the SOP law adoption) and $\{a_0+a_1+a_{01}+a_{11}, a_0+a_2+a_{01}+a_{21}\}$ (right: the total effect of OB closure on outcomes for Black and Hispanic women, respectively, after the SOP law adoption). The lower left panel suggests that, before the SOP law adoption, Black and Hispanic women are more likely to travel to outside and urban counties for intrapartum care in response to obstetric unit closure, which is similar to the responses of white women. However, the birth outcomes for Black women deteriorate after obstetric unit closure.

The lower right panel suggests that, after SOP law adoption, Black women do not change their travel behaviors for intrapartum care in response to obstetric unit closure. Interestingly, they are less like to have out-of-hospital births and are more likely to have CNMs to perform the intrapartum care. As a result, perhaps, their infants are more likely to utilize assisted ventilation. Encouragingly, obstetric unit closure does not have adverse effect on birth outcomes for Black women, which is an improvement over the pre-adoption period. These results suggest that the SOP law adoption alters how Black women seek intrapartum care and improves their birth outcomes. After the SOP law adoption, Hispanic women's responses to obstetric unit closures do not change substantially, except that they are less likely to have maternal morbidity, which is an improvement over the pre-adoption period.

Overall, these results suggest that the SOP law adoption does not benefit white women, except altering their travel behaviors. However, the SOP law adoptions benefit Black and Hispanic women in different ways. On the one hand, Hispanic women have better maternal health at delivery. On the other hand, Black women seem to benefit from having hospital care for intrapartum care from within-county providers. Thus, racial/ethnic disparities in the effect of obstetric unit closure on maternal and infant health are narrower after SOP law adoption.

TPP Law. According to AHA (2019), 76% of U.S. hospitals had fully or partially implemented a computerized telehealth system by 2017. Starting with only one state had private parity law for telemedicine, there were 37 states having some forms of private parity law for telemedicine. Telemedicine parity laws are particularly relevant for our setting because a range of obstetrical care, such as prenatal care through videoconference and at-home monitoring, can be performed using telemedicine (KFF 2020). As a result, telemedicine likely increases care access for rural populations, who are previously underserved by in-person methods.

To test whether the adoption of TPP law affects the racial/ethnic disparities of obstetric unit closure on maternal and birth outcomes, we estimate Equation 4 with $Post_{ct}$ = 1 if a state adopts the TPP law, and 0 otherwise.

The upper panel of Exhibit 6 presents the parameter estimates of a_0 (left) and a_0+a_{01} (right) for white women. The upper left panel suggests that, before the adoption of TPP law, white women travel outside their residence counties and to urban counties for intrapartum care in response to obstetric unit closure. However, there are no significant effects on maternal morbidity and birth outcomes. Interestingly, the upper right panel suggests that, after the adoption of TPP law, white women travel even further outside counties and to urban counties for intrapartum care in response to obstetric unit closure. They are less likely to have out-of-hospital birth, more likely to have CNM for delivery and more likely to utilize NICU. However, such adjustments accompany adverse effects on pre-term birth, birth weight and Apgar score. Nonetheless, it is consistent with the idea that telehealth supports white women to find providers outside their residing counties. Given the long distance to reach their providers, they possibly may schedule pre-term delivery, which can be a safe option for them. Other explanations for our findings are possible as well.

[Insert Exhibit 6 about here]

The lower panel of Exhibit 6 presents the parameter estimates of $\{a_0+a_1, a_0+a_2\}$ (left: the total effect of OB closure on outcomes for Black and Hispanic women, respectively, before the TPP law adoption) and $\{a_0+a_1+a_{01}+a_{11}, a_0+a_2+a_{01}+a_{21}\}$ (right: the total effect of OB closure on outcomes for Black and Hispanic women, respectively, after the TPP law adoption). The lower left panel suggests that, before the TPP law adoption, Black and Hispanic women do not respond to obstetric unit closure in a systematic way, and their birth outcomes are not affected after obstetric unit closure.

Further, the lower right panel suggests that, after the TPP law adoption, Black women travel further for intrapartum care in response to obstetric unit closure. They are more likely to have CNM for delivery, less likely to have cesarean delivery and more likely to utilize NICU. However, such adjustments accompany adverse effects on birth weight and Apgar score. One interpretation of these findings is that Black women have a similar arrangement as white women, i.e. schedule pre-term delivery. Further, after the SOP law adoption, Hispanic women's responses to obstetric unit closures by traveling further. However, there are no substantial changes in their birth outcomes.

Overall, these results suggest that the TPP law adoption affects white and Black women in a similar way, i.e. it possibly helps them to overcome the lack of local obstetric providers by scheduling pre-term delivery with a distant provider. However, the TPP law adoption does not affect the birth outcomes of Hispanic women significantly. The TTP law adoption may support women of different race/ethnicities to deal with obstetric unit closure.

ACA Medicaid Expansion. The ACA Medicaid expansions potentially can improve birth outcomes by helping obstetric units become more viable (by serving fewer uninsured patients) and survive in rural areas, but Carroll et al. (2022) finds little evidence for this idea. Nevertheless, the ACA Medicaid expansion may improve outcomes indirectly, by strengthening the surviving health care facilities serving women in the treated counties in states that expanded Medicaid.

To test whether the ACA Medicaid expansions affect the racial/ethnic disparities of obstetric unit closure on maternal and birth outcomes, we estimate Equation 4 with $Post_{ct}$ = 1 if a state expanded Medicaid, and 0 otherwise. Medicaid expansions mostly took place in 2014 in most states, but two states in our sample expanded in 2015 and two in 2016, respectively.

The upper panel of Exhibit 7 presents the parameter estimates of a_0 (left) and a_0+a_{01} (right) for white women. The upper left panel suggests that, before the Medicaid expansion, white women travel outside their residence counties and to urban counties for intrapartum care in response to obstetric unit closure. However, there are no significant effects on maternal morbidity and birth outcomes. Interestingly, the upper right panel suggests that, after the Medicaid expansion, white women travel farther to outside counties and urban counties for intrapartum care in response to obstetric unit closure. Such travel decisions accompany a lower out-of-hospital birth rate, and higher use of assisted ventilation and NICU. We interpret such results as being consistent with a more intensive use of intrapartum care after the Medicaid expansion. However, there are adverse effects on pre-term birth and birth weight. We interpret these results are similar to those derived from the TPP law adoption, although we acknowledge that other explanations are possible.

[Insert Exhibit 7 about here]

The lower panel of Exhibit 7 presents the parameter estimates of $\{a_0+a_1, a_0+a_2\}$ (left: the total effect of OB closure on outcomes for Black and Hispanic women , respectively, before Medicaid expansion) and $\{a_0+a_1+a_{01}+a_{11}, a_0+a_2+a_{01}+a_{21}\}$ (right: the total effect of OB closure on outcomes for Black and Hispanic women , respectively, after Medicaid expansion). The lower left panel suggests that, before Medicaid expansion, Black and Hispanic women are more likely to travel to outside and urban counties for intrapartum care in response to obstetric unit closure, which is similar to the responses of white women. However, the birth outcomes for Black women deteriorate after obstetric unit closure.

The lower right panel suggests that, after Medicaid expansion, Black women are less likely to travel for intrapartum care in response to obstetric unit closure. They stay in their residing counties and use CNMs for delivery. Interestingly, there are no significant effects on birth outcomes for Black women, which is an improvement over the pre-expansion period.

After Medicaid expansion, Hispanic women's responses to obstetric unit closures are similar to those of white women. They travel longer distances outside their residing counties and their infants are more likely to use assisted ventilation and the NICU. Further, birth outcomes for Hispanic women are not responsive to obstetric unit closure after Medicaid expansion.

Overall, these results suggest that ACA Medicaid expansions benefit those white women who travel outside their residing counties for intrapartum care. However, ACA Medicaid expansions benefit Black and Hispanic women in different ways. On the one hand, Hispanic women's responses after Medicaid expansion are similar to those of white women. On the other hand, Black women seem to face barriers to traveling outside their counties for intrapartum care, but their birth outcomes improve, presumably by using services from within-county providers. Racial/ethnic disparities in the effect of obstetric unit closure on infant health are slightly narrower after ACA Medicaid expansion.

4. Conclusion

There is growing policy concern over "maternity care deserts" in the U.S., geographic areas, often rural areas, where access to hospital-based obstetric care and obstetric providers is limited or non-existent (March of Dimes 2020). These areas tend to be affected by confounding, hard-to-measure trends that are associated with adverse health outcomes and health disparities, making it challenging to disentangle correlations between obstetric unit closures and adverse outcomes from causal relationships. In this paper, we used DiD-PSM methods to address this empirical problem, focusing on estimating not only the main effects of closures on outcomes, but also on the impact of obstetric unit closures on racial/ethnic disparities in outcomes and the role of various policies in possibly buffering any negative effects.

The findings in this paper are consistent with other recent papers (Kozhimannil et al. 2018; Fischer, Royer, and White 2022) in that we find obstetric unit closure affects location and nature of delivery but has mixed and small adverse effects on infant health. Our results reveal, however, significant racial/ethnic heterogeneity, with closures having more detrimental effects on Black women compared to white and Hispanic women. Importantly, it appears that SOP law adoption improves birth outcomes of Black women by increasing their access to hospital care for intrapartum care. The TPP law adoption affects birth outcomes of white and Black women possibly by increasing their use of scheduled pre-term deliveries with distant providers. The ACA Medicaid expansion may have bolstered rural health care systems. White women possibly increase their use of schedule pre-term delivery with distant providers, whereas Black women access care within their residing counties. Overall, among these mitigating policies, the SOP law adoption enhances the birth outcomes of Black women disproportionally, whereas TPP law adoption and ACA Medicaid expansions have a more uniform impact on the birth outcomes of white and Black women.

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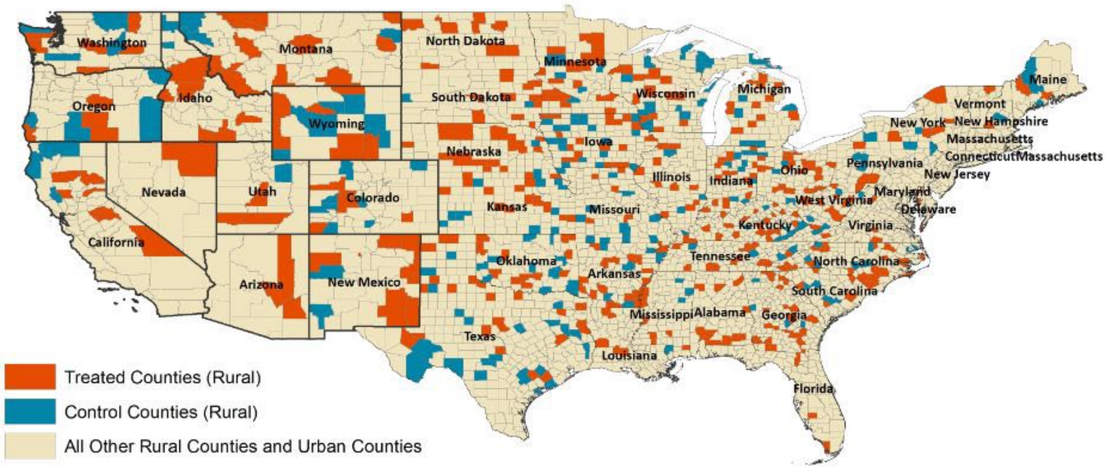


Exhibit 1a. Rural counties in mainland US that lost all hospital-based obstetric services between 2005-18.

Notes: Treated=416, Control=200.

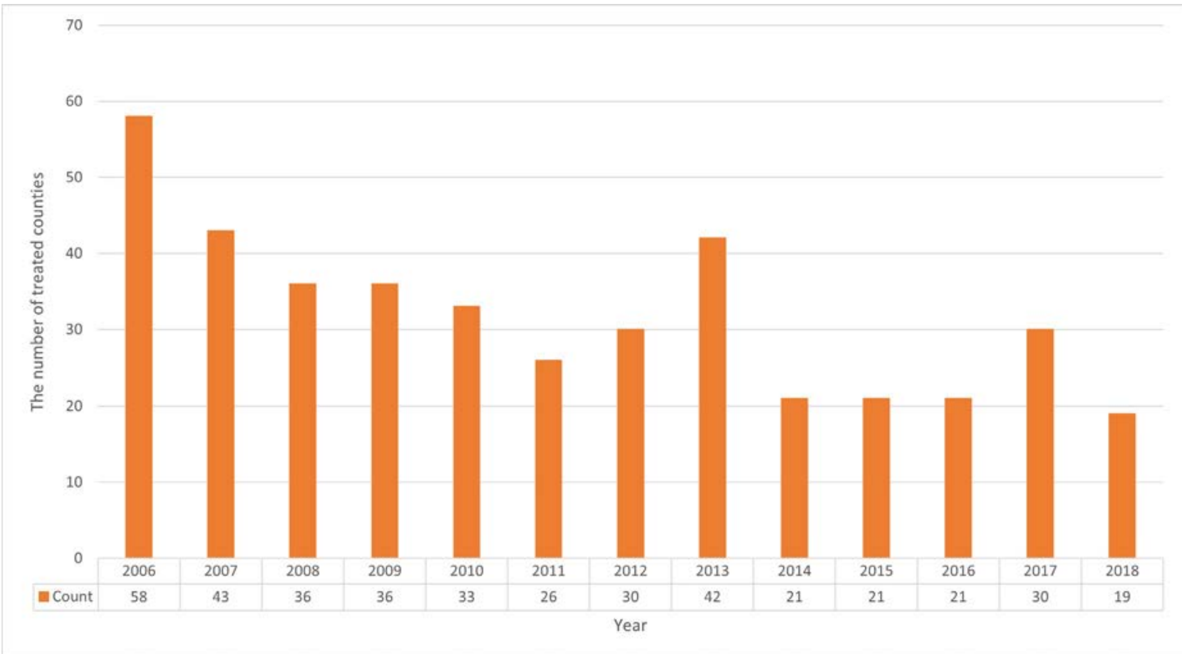


Exhibit 1b. Timing of rural counties in mainland US losing all hospital-based obstetric services

Notes: Data come from American Hospital Association (AHA) Annual Survey Database and Area Health Resource File (AHRF). Treated counties are those that had hospital-based obstetric services in 2005 and lost all services between 2005 and 2018. Control counties in Exhibit 1a are those identified as matched counties using propensity score methods applied to the pool of rural counites that had services in 2005 and did not lose all services between 2005-2018.

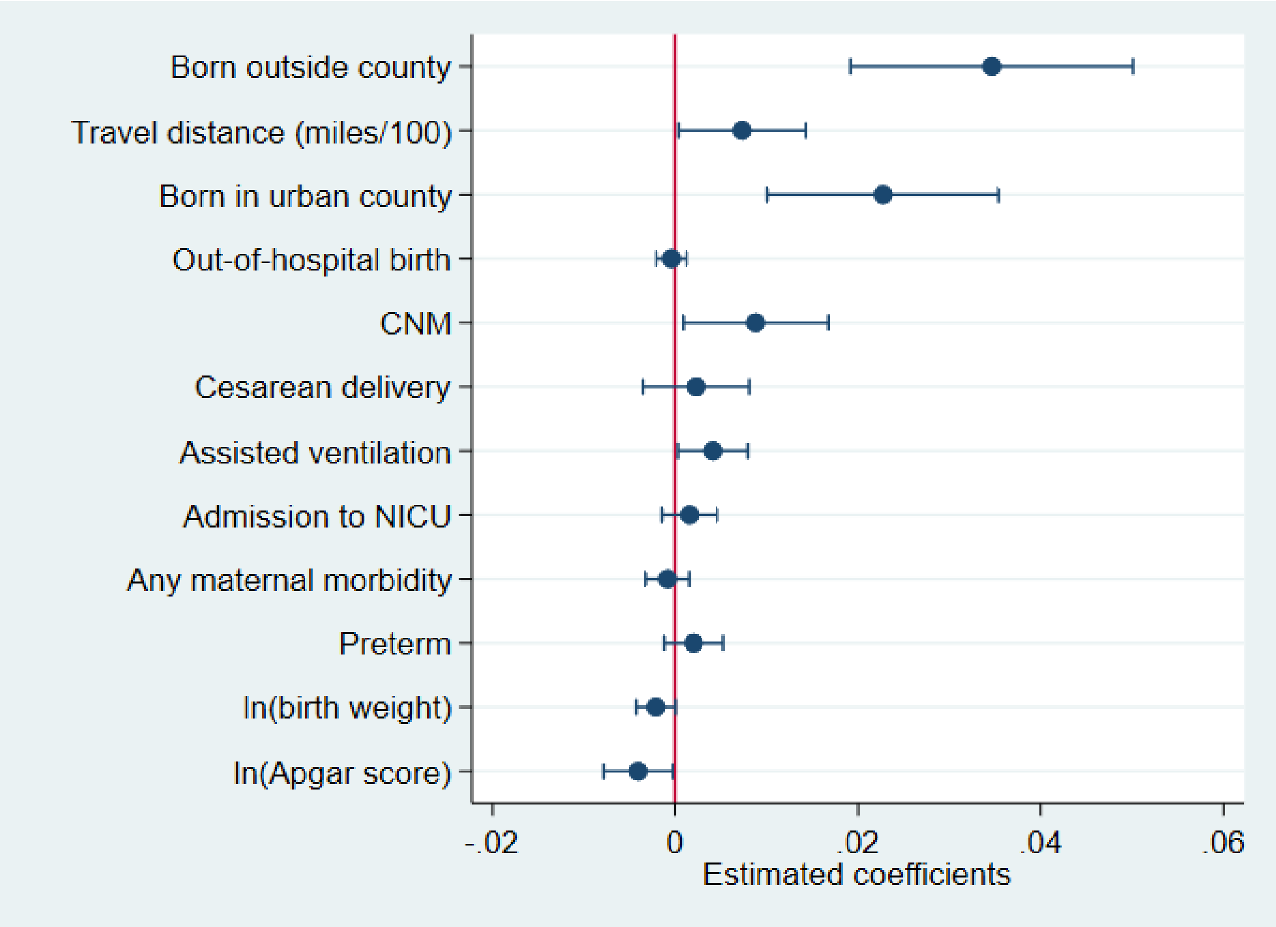


Exhibit 2: Effects of losing hospital-based obstetric services on delivery outcomes

Notes: Figure presents the estimated parameter **α** from Equation (1) in text (other estimates not shown), which is reproduced below:

$$Outcome_{ict} = \boldsymbol{\alpha} \cdot 1_{\{0 \leq \Delta t(c)\}} \times \text{OB Closure}_c + X_{it}\beta + \gamma_c + \gamma_t + \varepsilon_{ict}$$

Equation (1) is estimated using PSM-DID model. The dependent variable in Equation 1 is an outcome variable for woman i residing in county c in year t having her first-born child. The variable OB Closure_c is an indicator for county experiencing obstetric unit closure during our sample period. The variable $1_{\{0 \leq \Delta t(c)\}}$ is the event time indicator denoting the year of and all years after obstetric unit closure in county c. County fixed effects and year fixed effects are included. The control variables are listed in Table B1 in Supplemental Material, Section B. Standard errors clustered at county-level. The bars cover the 90% confidence level of estimates.

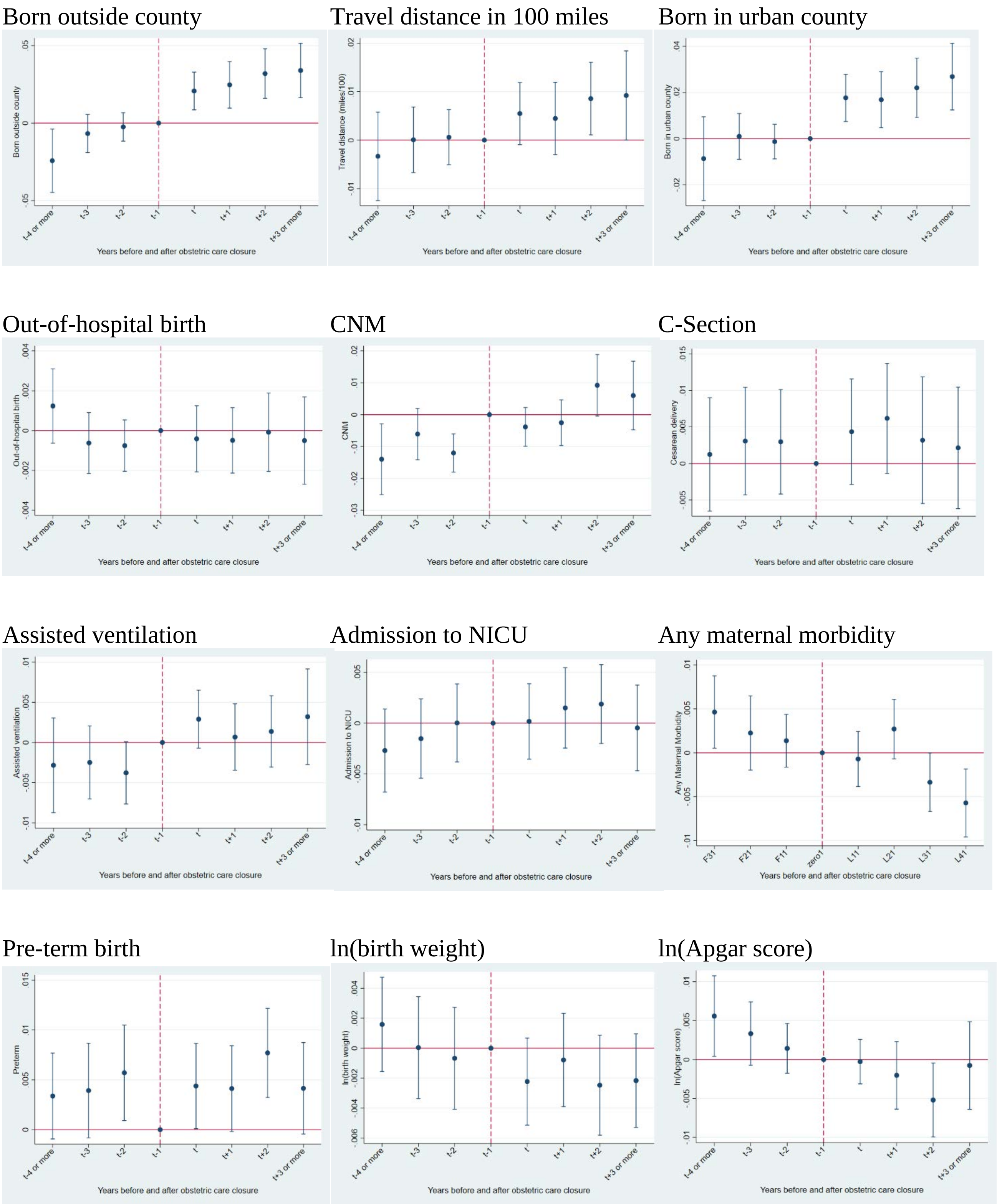
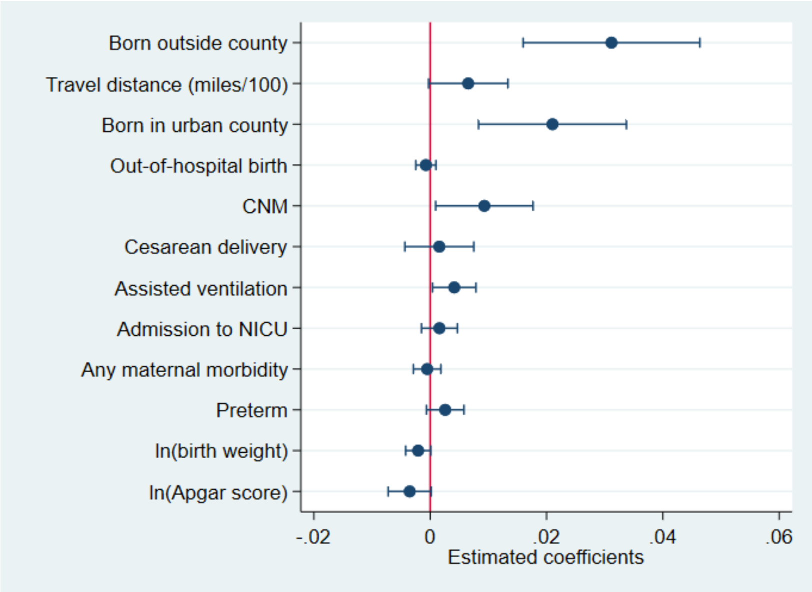


Exhibit 3: Event Study for all outcome variables

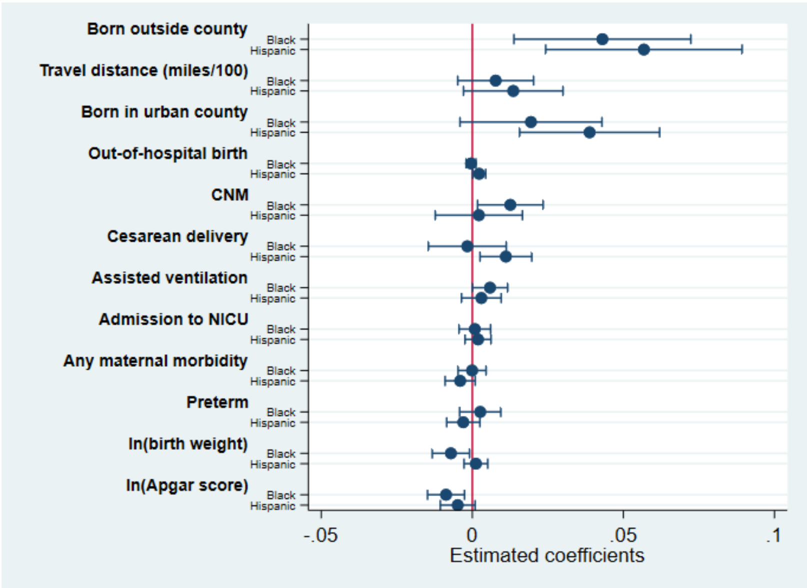
Notes: This figure presents the parameter a_r of Equation (2), which is reproduced as follows:

$$Outcome_{ict} = (\Sigma_{r=\ldots,-2}\, a_r \cdot 1_{\{\Delta t(c)=r\}} + \Sigma_{r=0,\ldots}\, a_r \cdot 1_{\{\Delta t(c)=r\}}) \times OB\ Closure_c + X_{it}\beta + \gamma_c + \gamma_t + \varepsilon_{ict}$$

The set of a_r includes the coefficients of the interactions between the event time indicators and *OB Closure*$_c$, that is, $1_{\{\Delta t(c)=r\}} \times$ *OB Closure*$_c$. The control variables are listed in Panel C and D of Table B1 above. Standard errors clustered at county-level in parentheses. The bars cover the 90% confidence level of estimates.



(A) White mothers



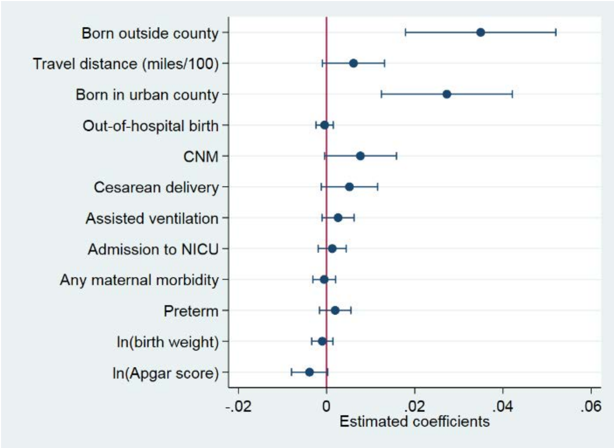
(B) Black and Hispanic mothers

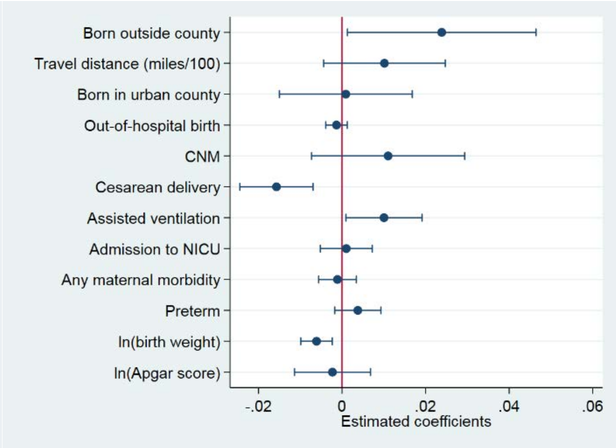
Exhibit 4: Racial/ethnic differences in effects losing hospital-based obstetric services

Notes: Figure presents the estimated parameters $\boldsymbol{a_0}$ (top panel), $\boldsymbol{a_0} + \boldsymbol{a_1}$ (the upper bar in bottom panel) and $\boldsymbol{a_0} + \boldsymbol{a_2}$ (the lower bar in bottom panel) from Equation (3), which is reproduced below:

$$Outcome_{ict} = \boldsymbol{a_0}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c) + \boldsymbol{a_1}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Black_i) + \boldsymbol{a_2}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Hispanic_i) + X_{it}\beta + \gamma_c + \gamma_t + \varepsilon_{ict}$$

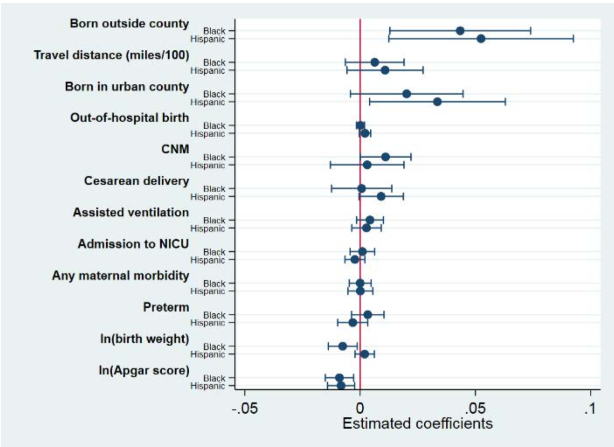
All notes from Exhibit 2 apply. In addition, $Black_i$ denotes the mother is African American, $Hispanic_i$ denotes the mother is Hispanic, and the base group is white mothers.

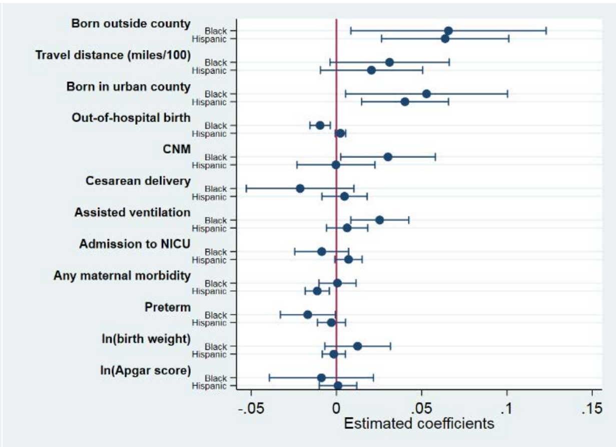




(A1) White mothers before adoption

(A2) White mothers after adoption





(B1) Black and Hispanic mothers before adoption

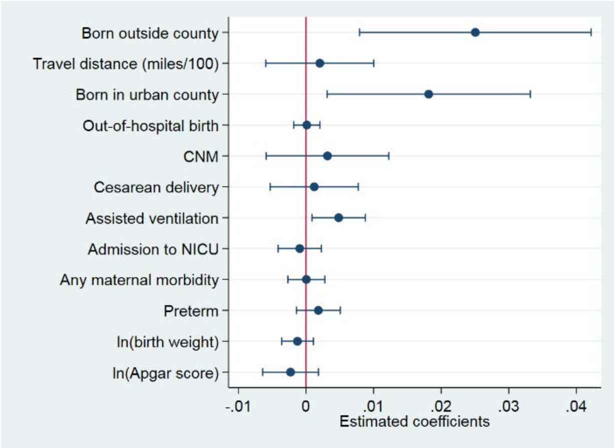
(B2) Black and Hispanic mothers after adoption

Exhibit 5: Effects of losing hospital-based obstetric services before and after SOP Law adoption

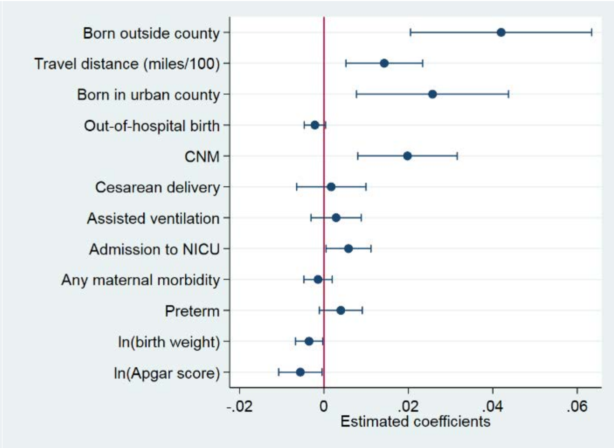
Notes: Figure presents the parameter estimates from Equation (4), which is reproduced below:

$$Outcome_{ict} = \boldsymbol{a_0}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c) + \boldsymbol{a_1}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Black_i) + \boldsymbol{a_2}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Hispanic_i) + \boldsymbol{a_{01}}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Post_{ct}) + \boldsymbol{a_{11}}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Black_i \times Post_{ct}) + \boldsymbol{a_{21}}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Hispanic_i \times Post_{ct}) + X_{it}\beta + \gamma_c + \gamma_t + \varepsilon_{ict}$$

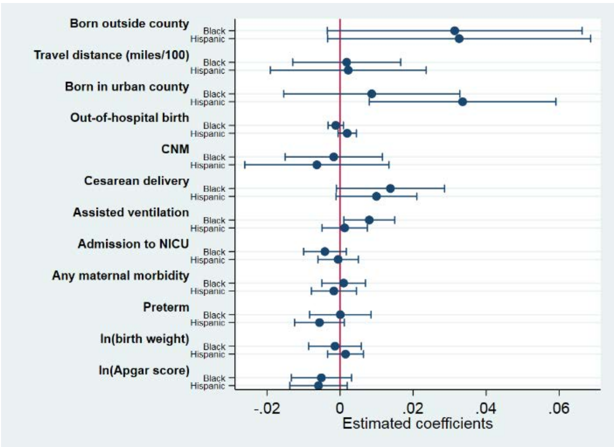
All notes from Exhibit 2 apply. In addition, 1) $Post_{ct}$ is an indicator for post-adoption year in a county located in a state that adopt the SOP law; 2) $Post_{ct}$, $Black$ x $Post_{ct}$, $Hispanic$ x $Post_{ct}$ are also included in X_{it}. *Panel A1 depicts* a_0 *(the total effect of OB closure on outcomes for white mothers in adoption states in years before adoption occurred, and in all years for states that did not adopt). Panel A2 depicts* $a_0 + a_{01}$ *(the total effect of OB closure on outcomes for white mothers in adoption states in post-adoption years). Panel B1 depicts* $\{a_0+a_1,\ a_0+a_2\}$ *(the total effect of OB closure on outcomes for Black and Hispanic mothers in adoption in years before adoption occurred, and in all years for states that did not adopt), and Panel B2 depicts* $\{a_0+a_1+a_{01}+a_{11},\ a_0+a_2+a_{01}+a_{21}\}$ *(the total effect of OB closure on outcomes for Black and Hispanic mothers in adoption states in post-adoption years).*



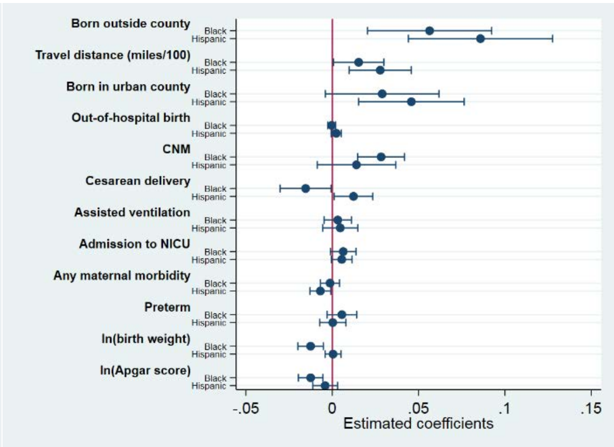
(A1) White mothers before adoption



(A2) White mothers after adoption



(B1) Black and Hispanic mothers before adoption



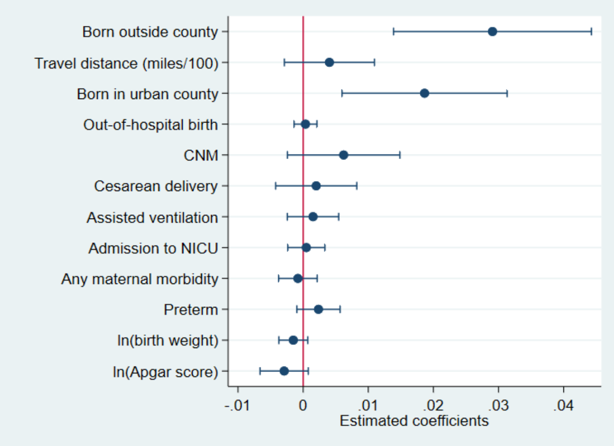
(B2) Black and Hispanic mothers after adoption

Exhibit 6: Effects of losing hospital-based obstetric services before and after TPP Law adoption

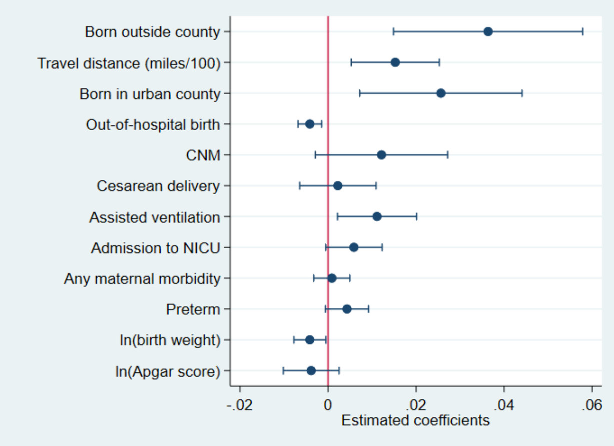
Notes: Figure presents the parameter estimates from Equation (4), which is reproduced below:

$$Outcome_{ict} = \boldsymbol{a_0}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c) + \boldsymbol{a_1}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Black_i) + \boldsymbol{a_2}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Hispanic_i) + \boldsymbol{a_{01}}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Post_{ct}) + \boldsymbol{a_{11}}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Black_i \times Post_{ct}) + \boldsymbol{a_{21}}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Hispanic_i \times Post_{ct}) + X_{it}\beta + \gamma_c + \gamma_t + \varepsilon_{ict}$$

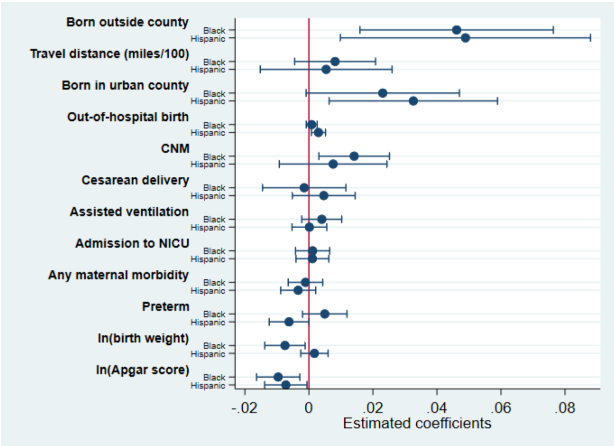
All notes from Exhibit 2 apply. In addition, 1) $Post_{ct}$ is an indicator for post-adoptio n year in a county located in a state that adopt the SOP law; 2) $Post_{ct}$, $Black \times Post_{ct}$, $Hispanic \times Post_{ct}$ are also included in X_{it}. *Panel A1 depicts* a_0 *(the total effect of OB cl osure on outcomes for white mothers in adoption states in years before adoption occurred, an d in all years for states that did not adopt). Panel A2 depicts* $a_0 + a_{01}$ *(the total effect of OB closure on outcomes for white mothers in adoption states in post-adoption years). Panel B1 depicts* $\{a_0+a_1,\ a_0+a_2\}$ *(the total effect of OB closure on outcomes for Black and Hispanic mothers in adoption in years before adoption occurred, and in all years for states that did n ot adopt), and Panel B2 depicts* $\{a_0+a_1+a_{01}+a_{11},\ a_0+a_2+a_{01}+a_{21}\}$ *(the total effect of OB closure on outcomes for Black and Hispanic mothers in adoption states in post-adoption years).*



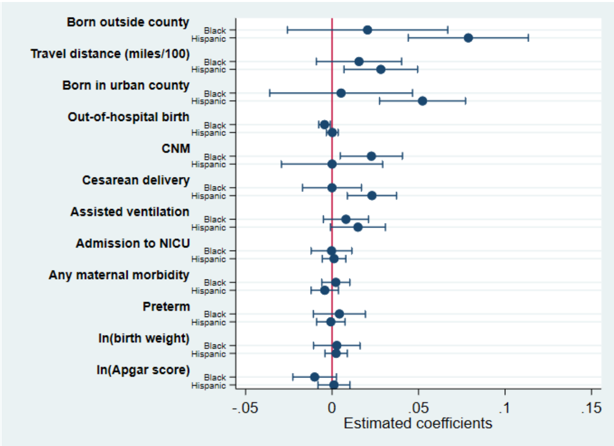
(A1) White mothers before expansion



(A2) White mothers after expansion



(B1) Black and Hispanic mothers before expansion



(B2) Black and Hispanic mothers after expansion

Exhibit 7: Effects of losing hospital-based obstetric services before and after ACA Medicaid expansion

Notes: Figure presents the parameter estimates from Equation (4), which is reproduced below:

$$Outcome_{ict} = \boldsymbol{a_0}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c) + \boldsymbol{a_1}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Black_i) + \boldsymbol{a_2}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Hispanic_i) + \boldsymbol{a_{01}}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Post_{ct}) + \boldsymbol{a_{11}}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Black_i \times Post_{ct}) + \boldsymbol{a_{21}}\cdot(1_{\{0\leq\Delta t(c)\}} \times OB\ Closure_c \times Hispanic_i \times Post_{ct}) + X_{it}\beta + \gamma_c + \gamma_t + \varepsilon_{ict}$$

All notes from Exhibit 2 apply. In addition, 1) $Post_{ct}$ is an indicator for post-expansion year in a county located in a state that expanded Medicaid; 2) $Post_{ct}$, $Black \times Post_{ct}$, $Hispanic \times Post_{ct}$ are also included in X_{it}. *Panel A1 depicts a_0 (the total effect of OB closure on outcomes for white mothers in expansion states in years before expansion occurred, and in all years for states that did not expand). Panel A2 depicts $a_0 + a_{01}$ (the total effect of OB closure on outcomes for white mothers in expansion states in post-expansion years). Panel B1 depicts $\{a_0+a_1, a_0+a_2\}$ (the total effect of OB closure on outcomes for Black and Hispanic mothers in expansion states in years before expansion occurred, and in all years for states that did not expand), and Panel B2 depicts $\{a_0+a_1+a_{01}+a_{11}, a_0+a_2+a_{01}+a_{21}\}$ (the total effect of OB closure on outcomes for Black and Hispanic mothers in expansion states in post-expansion years).*

Supplemental Material – List of Items

Section:	Item:	Referenced in text, Section:
A	Figure A1, Table A1: Propensity score model, common support and balancing tests	2C
B	Table B1: Descriptive statistics for matched sample	2C
C	Table C1-C2: Full DD specifications	2D
D	Figure D1: Replicating main results with higher-born children	3A
E	Figure E1: Results for low birthweight, very low birthweight, and low Apgar	3A
F	Figure F1: Event studies for all outcomes for 2009-14	3B
G	Figure G1: 2 x 2 DiD Estimates	3B
H	Figure H1-H2: Alternative matching criteria	3B
I	Table I1: Geographic distribution of (1) sample women by race/ethnicity; and (2) obstetric unit availability	3C

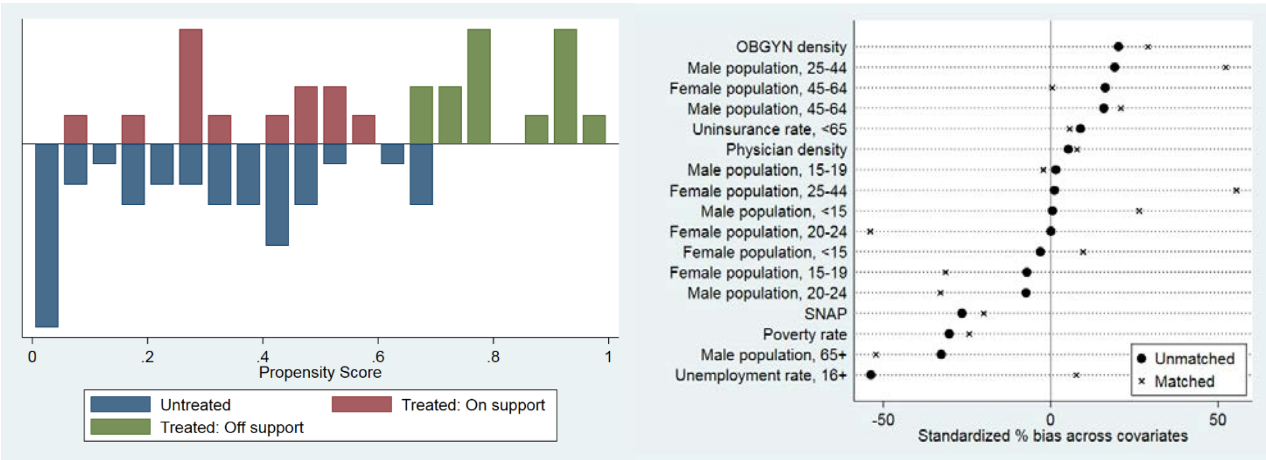
Section A: Propensity Score Matching

Table A1 reports the results of Probit estimation where the dependent variable $OB\ Closure_i = 1$ if county i experiences a complete loss of hospital-based obstetric services during our sample period, and $OB\ Closure_i = 0$ otherwise. Figure A1 (Left) depicts the propensity scores computed with the Probit estimation. On support means that we are able to find a matched county. Conversely, off support means that we are not able to find a matched county. Overall, the assumption of common support is mostly verified. Further, to ensure the matched counties are useful and appropriate, we only keep the on-support treated counties in our empirical analysis.

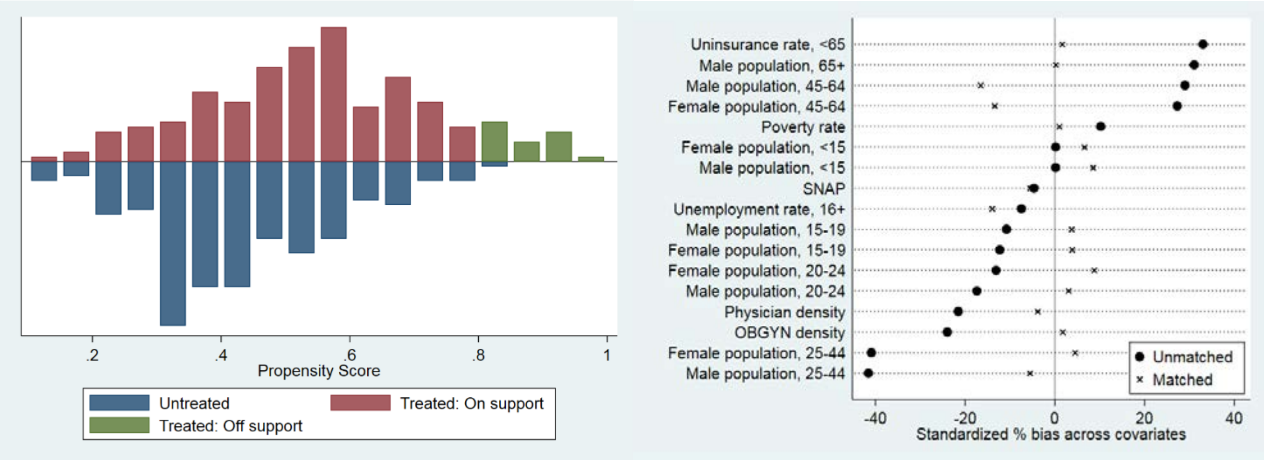
Figure A1 (Right) depicts the characteristics of treated and control counties. The unmatched sample shows that there are differences across a range of characteristics. Notably, the biases are reduced after the matching, and there is no statistically significant difference between treatment and control counties on their covariates used in the Probit estimation.

Figure A1. Common Support (Left) and Balancing Tests (Right)

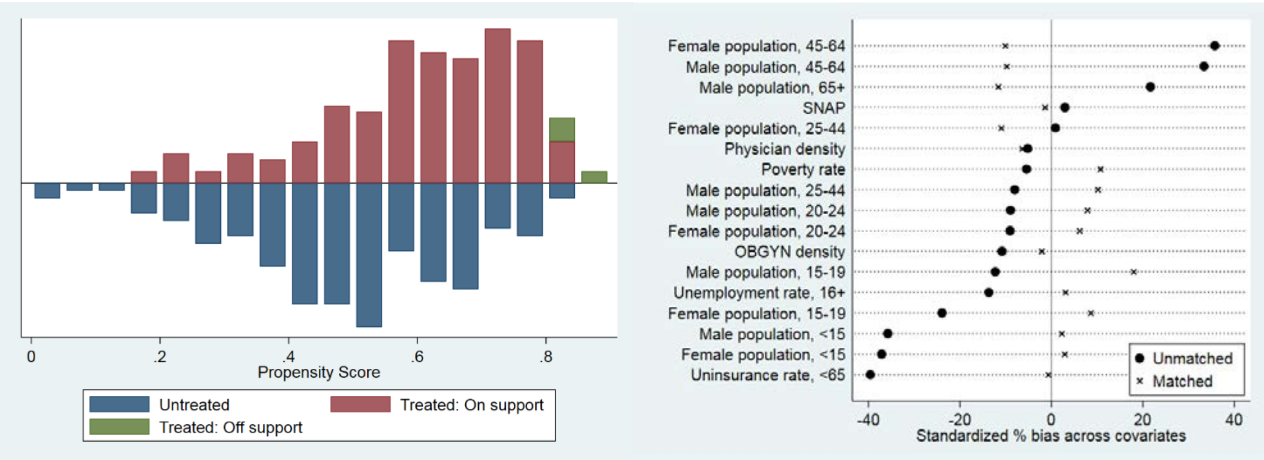
Northeast region:



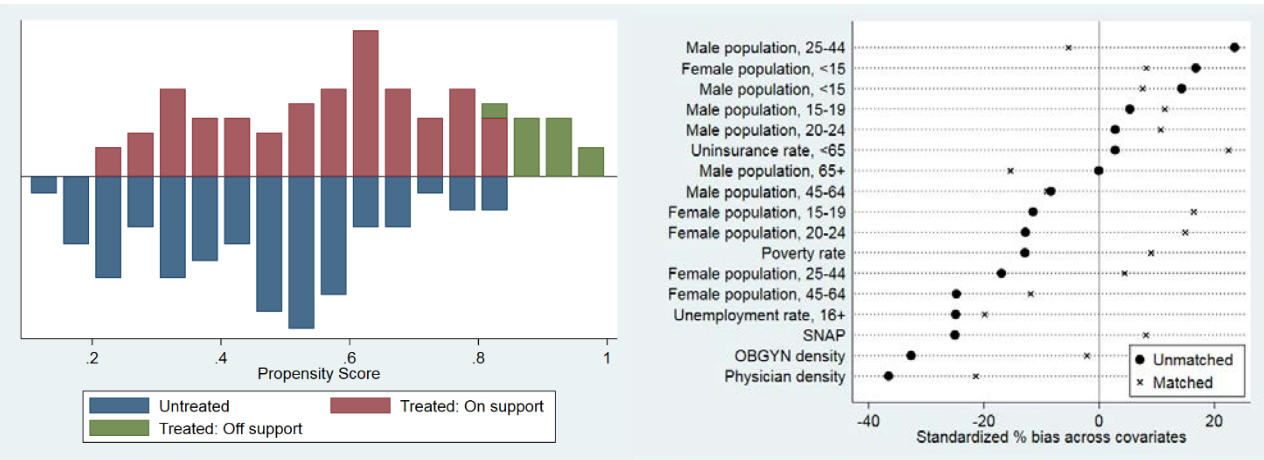
Midwest region:



South region:



West region:



Note: This figure depicts the propensity scores for treated and control observations. It based on Column 1 of Table A1.

Table A1. Propensity Score Estimation

	Northeast	Midwest	South	West
Unemployment	-1.007*	0.030	-0.227**	-0.284*
	(0.537)	(0.116)	(0.094)	(0.150)
Uninsured	0.204	0.039	-0.144***	-0.011
	(0.173)	(0.040)	(0.043)	(0.046)
Poverty	0.570	0.127*	0.053	0.108
	(0.366)	(0.066)	(0.051)	(0.100)
SNAP	-24.429	-7.964	-3.577	-10.349
	(26.525)	(5.260)	(5.079)	(8.188)
Physician density	-0.010	-0.003	-0.002	-0.001
	(0.007)	(0.002)	(0.002)	(0.004)
OBGYN density	0.120	0.011	-0.027	-0.040
	(0.109)	(0.027)	(0.026)	(0.035)
Male15	-283.073	34.932	2.500	-22.870
	(207.207)	(34.467)	(41.823)	(58.167)
Male1519	125.142	-52.585	15.286	45.037
	(206.402)	(39.323)	(39.514)	(62.943)
Male2024	-434.951**	8.197	13.138	-11.755
	(196.719)	(27.140)	(28.144)	(52.458)
Male2544	118.062	-11.899	-7.650	30.728
	(93.608)	(22.709)	(21.986)	(33.610)
Male4564	-240.671	25.731	22.821	40.116
	(155.501)	(30.190)	(30.380)	(48.602)
Male65	-208.297	-5.486	18.208	40.684
	(166.919)	(39.999)	(43.318)	(69.498)
Female15	329.142	15.625	4.453	74.729
	(210.452)	(39.550)	(44.824)	(63.436)
Female1519	-79.017	-61.328	-63.669	-48.626
	(187.443)	(44.371)	(47.028)	(52.039)

Female2024	245.362	40.503	26.290	22.493
	(159.538)	(27.817)	(32.324)	(53.783)
Female2544	-264.032**	-36.752*	2.780	-18.824
	(105.424)	(22.128)	(22.589)	(41.308)
Female4564	321.355*	34.196	-1.475	-26.754
	(192.882)	(37.606)	(39.342)	(47.452)
Constant	20.72473	-5.041	1.037	-9.425
	(68.115)	(17.026)	(19.275)	(29.109)
Observations	65	376	321	138

Note: This table reports the coefficients from Probit estimation. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Section B: Descriptive Statistics

Table B1: Descriptive Statistics (Matched Sample)

	Sample	Treated counties Closure=1	Matched counties Closure=0
Panel A: Outcome Variables			
Travel Behaviors:			
Born outside residence county	0.395	0.438	0.323
Travel distance (miles/100)	0.167	0.181	0.145
Born in urban county	0.264	0.285	0.229
Intrapartum Care:			
Out-of-hospital birth	0.011	0.011	0.011
CNM	0.081	0.082	0.079
Cesarean delivery	0.287	0.289	0.284
Assisted ventilation	0.052	0.050	0.056
Admission to NICU	0.060	0.060	0.059
Maternal Morbidity and Birth Outcomes:			
Any maternal morbidity	0.028	0.030	0.031
Preterm	0.102	0.103	0.101
ln(birth weight)	8.069	8.070	8.069
ln(Apgar score)	2.152	2.152	2.151
Panel B: Treatment Variable			
Closure	0.624	1	0
Panel C: Mother Characteristics			
Age dummy, <15	0.003	0.003	0.003
Age dummy, 15-19	0.239	0.234	0.247
Age dummy, 20-24	0.386	0.390	0.380
Age dummy, 25-44	0.372	0.373	0.370
Age dummy, 45+	0.0002	0.0002	0.0002
White	0.807	0.815	0.792
Black	0.074	0.079	0.066

Hispanic	0.119	0.105	0.143
Education dummy, less than high school	0.182	0.190	0.177
Education dummy, high school graduate	0.309	0.307	0.311
Education dummy, some college/college	0.455	0.452	0.457
Education dummy, graduate degree/above	0.054	0.052	0.055
Pre-pregnancy diabetes	0.008	0.008	0.007
Gestational diabetes	0.041	0.042	0.040
Pre-pregnancy hypertension	0.015	0.015	0.014
Gestational hypertension	0.080	0.081	0.079
Smoking in the first trimester	0.150	0.151	0.147
Marital status	0.469	0.474	0.460
Panel D: County Characteristics			
Unemployment Rate, 16+	6.450	6.380	6.567
Uninsurance Rate, <65	15.187	14.755	15.904
Poverty Rate	17.038	17.033	17.048
SNAP (recipient rate)	0.150	0.148	0.153
Physicians per 100,000 population	117.972	112.652	126.807
OB/GYNs per 100,000 population	6.121	6.079	6.192
Male population proportion, <15	0.098	0.098	0.097
Male population proportion, 15-19	0.035	0.035	0.035
Male population proportion, 20-24	0.036	0.037	0.035
Male population proportion, 25-44	0.122	0.123	0.121
Male population proportion, 45-64	0.132	0.131	0.132
Male population proportion, 65+	0.074	0.073	0.075
Female population proportion, <15	0.093	0.093	0.093
Female population proportion, 15-19	0.033	0.033	0.033
Female population proportion, 20-24	0.033	0.034	0.033
Female population proportion, 25-44	0.117	0.117	0.117
Female population proportion, 45-64	0.134	0.134	0.135
Observations	662,759	413,664	249,095

Note: This sample includes all first-born observations from women residing in the treated counties and in the matched control counties.

Section C: Full DD specifications

Table C1. Full specification for model 1

VARIABLES	(1) Born outside county	(2) Travel distance (miles/100)	(3) Born in urban county	(4) Out-of-hospital birth	(5) CNM	(6) Cesarean delivery
Obstetric unit closure	0.0347***	0.00734*	0.0227***	-0.000410	0.00882*	0.00231
	(0.00937)	(0.00422)	(0.00769)	(0.00100)	(0.00482)	(0.00353)
Pre-pregnancy diabetes	0.127***	0.0961***	0.152***	-0.00608***	-0.0492***	0.268***
	(0.00818)	(0.00615)	(0.00832)	(0.00113)	(0.00397)	(0.00704)
Gestational diabetes	0.00852	0.000803	0.0110**	-0.00944***	-0.0185***	0.109***
	(0.00529)	(0.00256)	(0.00490)	(0.000836)	(0.00210)	(0.00339)
Pre-pregnancy hypertension	0.0663***	0.0513***	0.0781***	-0.00848***	-0.0306***	0.194***
	(0.00763)	(0.00494)	(0.00758)	(0.000750)	(0.00273)	(0.00544)
Gestational hypertension	0.0479***	0.0359***	0.0541***	-0.0105***	-0.0232***	0.160***
	(0.00551)	(0.00323)	(0.00493)	(0.000939)	(0.00186)	(0.00283)
Black	-0.0930***	-0.0324***	-0.0653***	-0.000503	-0.00664**	0.0339***
	(0.00755)	(0.00402)	(0.00720)	(0.000388)	(0.00304)	(0.00398)
Hispanic	-0.0418***	-0.0215***	-0.0352***	-0.0121***	0.00467	0.0107***
	(0.00967)	(0.00500)	(0.00641)	(0.00155)	(0.00575)	(0.00269)
High school	0.0350***	0.0130***	0.0324***	-0.0301***	-0.0114***	0.0173***
	(0.00467)	(0.00198)	(0.00332)	(0.00508)	(0.00274)	(0.00227)
Some college/college	0.0899***	0.0367***	0.0808***	-0.0367***	-0.0143***	-8.69e-05
	(0.00636)	(0.00256)	(0.00501)	(0.00629)	(0.00351)	(0.00259)
Graduate degree/above	0.112***	0.0530***	0.110***	-0.0390***	-0.0126***	-0.0118***
	(0.00861)	(0.00404)	(0.00765)	(0.00670)	(0.00430)	(0.00386)
Age dummy, 15-19	-0.0319***	-0.0183**	-0.0363***	0.0143***	0.00334	0.0174**
	(0.00848)	(0.00723)	(0.00716)	(0.00250)	(0.00500)	(0.00844)
Age dummy, 20-24	-0.0126	-0.00469	-0.0232***	0.0315***	0.00266	0.0723***
	(0.00925)	(0.00755)	(0.00766)	(0.00502)	(0.00542)	(0.00872)
Age dummy, 25-44	0.0264***	0.0143*	0.0232***	0.0250***	-0.0130**	0.161***

	(0.00937)	(0.00771)	(0.00789)	(0.00361)	(0.00574)	(0.00882)
Age dummy, 45+	0.122***	0.163***	0.151***	0.0210***	-0.0651***	0.374***
	(0.0388)	(0.0510)	(0.0384)	(0.00767)	(0.0182)	(0.0381)
Unemployment Rate, 16+	-0.00242	-0.000882	-0.00324**	-0.000223	-0.000925	0.00131
	(0.00232)	(0.00129)	(0.00140)	(0.000186)	(0.00121)	(0.00101)
Uninsurance Rate, <65	0.000140	0.000611	-0.000860	1.34e-05	0.000966	-0.000185
	(0.00127)	(0.000673)	(0.00100)	(0.000154)	(0.00102)	(0.000566)
Poverty Rate	0.000188	0.000442	-0.000648	3.49e-05	-0.000224	-0.000305
	(0.000813)	(0.000508)	(0.000650)	(0.000109)	(0.000513)	(0.000518)
Physicians per 100,000 pop	-9.87e-05	-4.28e-05	-6.95e-05	6.52e-06	1.03e-05	-2.36e-05
	(6.57e-05)	(3.50e-05)	(4.99e-05)	(6.98e-06)	(5.43e-05)	(4.35e-05)
OB/GYNs per 100,000 pop	-0.00263***	-0.000834**	-0.00187***	3.25e-05	-0.000171	0.000297
	(0.000908)	(0.000408)	(0.000603)	(8.83e-05)	(0.000584)	(0.000440)
SNAP (recipient rate)	0.142	0.116	0.0420	0.0388**	-0.0132	0.0428
	(0.194)	(0.108)	(0.147)	(0.0154)	(0.123)	(0.0720)
Male pop proportion, <15	1.934	0.929	-0.297	0.0594	1.619**	-0.0792
	(1.454)	(0.765)	(1.228)	(0.177)	(0.800)	(0.671)
Male pop proportion, 15-19	1.264	1.095	-1.013	0.0161	2.690**	-0.110
	(1.792)	(1.026)	(1.494)	(0.196)	(1.208)	(0.785)
Male pop proportion, 20-24	0.795	0.770	-0.0546	-0.0378	0.911	-0.157
	(1.259)	(0.798)	(1.126)	(0.134)	(0.909)	(0.572)
Male pop proportion, 25-44	-0.317	0.0735	-1.823*	0.0432	0.131	-0.293
	(1.112)	(0.633)	(0.960)	(0.128)	(0.767)	(0.496)
Male pop proportion, 45-64	2.019	0.312	0.579	-0.0572	0.824	-0.0734
	(1.607)	(0.818)	(1.457)	(0.173)	(0.881)	(0.633)
Male pop proportion, 65+	1.190	0.625	-0.774	0.276	1.478	-0.169
	(2.167)	(1.173)	(1.825)	(0.221)	(1.415)	(0.923)
Female pop proportion, <15	-0.0659	0.336	-0.834	0.261	0.740	0.0325
	(1.333)	(0.809)	(1.060)	(0.204)	(0.977)	(0.674)
Female pop proportion, 15-19	-0.450	-0.255	-1.137	0.173	0.248	-0.644
	(1.658)	(0.872)	(1.377)	(0.213)	(1.200)	(0.829)
Female pop proportion, 20-24	-0.192	-0.514	-1.270	0.0772	0.841	-0.0306

	(1.187)	(0.676)	(0.959)	(0.179)	(0.855)	(0.644)
Female pop proportion, 25-44	-0.206	0.0864	-0.404	0.0406	0.771	-0.0616
	(1.278)	(0.761)	(1.087)	(0.154)	(0.822)	(0.545)
Female pop proportion, 45-64	-0.644	0.00357	-1.187	0.158	0.714	-0.282
	(1.231)	(0.719)	(1.074)	(0.158)	(1.032)	(0.590)
Smoking in the first trimester	-0.0447***	-0.0202***	-0.0369***	-0.0110***	-0.00764***	0.0222***
	(0.00327)	(0.00162)	(0.00301)	(0.00129)	(0.00135)	(0.00180)
Marital status	0.0327***	0.0154***	0.0265***	0.0178***	0.00555***	-0.0149***
	(0.00308)	(0.00153)	(0.00265)	(0.00232)	(0.00159)	(0.00180)
Observations	662,759	662,759	662,759	662,759	662,759	662,759
R-squared	0.285	0.094	0.259	0.064	0.119	0.045

Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; The model also includes county and year fixed effects, which are not shown in table.

Table C2. Full specification for model 1-conti.

VARIABLES	(7) Assisted ventilation	(8) Admission to NICU	(9) Any maternal morbidity	(10) preterm	(11) ln(birth weight)	(12) ln(Apgar score)
Obstetric unit closure	0.00414*	0.00157	-0.000815	0.00202	-0.00210	-0.00403*
	(0.00233)	(0.00182)	(0.00145)	(0.00195)	(0.00132)	(0.00229)
Pre-pregnancy diabetes	0.0756***	0.158***	0.00459	0.132***	0.0219***	-0.0399***
	(0.00497)	(0.00694)	(0.00397)	(0.00607)	(0.00418)	(0.00376)
Gestational diabetes	0.0146***	0.0231***	0.00514***	0.0219***	0.0166***	-0.00413***
	(0.00163)	(0.00194)	(0.00194)	(0.00216)	(0.00153)	(0.00116)
Pre-pregnancy hypertension	0.0480***	0.0858***	0.00751**	0.104***	-0.0982***	-0.0309***
	(0.00331)	(0.00410)	(0.00369)	(0.00425)	(0.00348)	(0.00257)
Gestational hypertension	0.0476***	0.0759***	0.00831***	0.109***	-0.0889***	-0.0223***
	(0.00164)	(0.00224)	(0.00181)	(0.00242)	(0.00186)	(0.00104)
Black	0.00943***	0.0135***	0.00128	0.0451***	-0.0809***	-0.0183***
	(0.00144)	(0.00141)	(0.00139)	(0.00219)	(0.00174)	(0.00160)
Hispanic	-0.00541***	-0.00265**	0.00251*	0.0107***	-0.0186***	0.00416***
	(0.00148)	(0.00109)	(0.00148)	(0.00144)	(0.00115)	(0.00112)
High school	-0.00115	-0.00206**	-0.00538***	-0.0178***	0.0112***	0.00232***
	(0.000871)	(0.000979)	(0.00139)	(0.00138)	(0.000980)	(0.000783)
Some college/college	-0.00509***	-0.00606***	-0.00318**	-0.0258***	0.0267***	0.00766***
	(0.000973)	(0.00108)	(0.00146)	(0.00146)	(0.00114)	(0.000884)
Graduate degree/above	-0.0100***	-0.00918***	0.00109	-0.0322***	0.0338***	0.0111***
	(0.00151)	(0.00161)	(0.00217)	(0.00214)	(0.00166)	(0.00139)
Age dummy, 15-19	-0.00536	-0.0182***	-0.0155**	-0.0862***	0.0241***	0.00798*
	(0.00490)	(0.00569)	(0.00670)	(0.00907)	(0.00552)	(0.00455)
Age dummy, 20-24	-0.00468	-0.0155***	-0.0145**	-0.0945***	0.0233***	0.00634
	(0.00499)	(0.00574)	(0.00669)	(0.00918)	(0.00566)	(0.00457)
Age dummy, 25-44	0.000314	-0.00466	-0.0121*	-0.0812***	0.0148***	0.000615
	(0.00506)	(0.00580)	(0.00675)	(0.00924)	(0.00567)	(0.00460)
Age dummy, 45+	0.0591**	0.0894***	-0.0168	-0.000664	-0.0601***	-0.00209

	(0.0254)	(0.0305)	(0.0180)	(0.0312)	(0.0201)	(0.0132)
Unemployment Rate, 16+	9.96e-05	0.000269	-0.000252	-0.000120	0.000284	8.57e-05
	(0.000848)	(0.000488)	(0.000556)	(0.000497)	(0.000338)	(0.000676)
Uninsurance Rate, <65	0.00112**	0.000226	0.000358	-3.20e-05	2.55e-05	-2.02e-05
	(0.000510)	(0.000251)	(0.000339)	(0.000317)	(0.000226)	(0.000374)
Poverty Rate	0.000694	-0.000299	2.50e-06	-0.000389	9.18e-05	0.000392
	(0.000534)	(0.000290)	(0.000214)	(0.000312)	(0.000225)	(0.000380)
Physicians per 100,000 pop	3.85e-05	5.31e-05**	1.17e-05	4.42e-05*	-4.47e-05***	-4.72e-05*
	(3.94e-05)	(2.20e-05)	(2.36e-05)	(2.37e-05)	(1.59e-05)	(2.80e-05)
OB/GYNs per 100,000 pop	-0.000155	-0.000374*	0.000120	-0.000400*	0.000133	0.000392
	(0.000265)	(0.000225)	(0.000230)	(0.000234)	(0.000162)	(0.000284)
SNAP (recipient rate)	-0.0642	0.0316	0.0177	0.0146	0.00487	0.122***
	(0.0568)	(0.0323)	(0.0371)	(0.0388)	(0.0286)	(0.0426)
Male pop proportion, <15	-0.656	-0.251	-0.0200	-0.251	0.383*	-0.509
	(0.627)	(0.290)	(0.388)	(0.325)	(0.225)	(0.383)
Male pop proportion, 15-19	-0.338	-0.997***	-0.269	-0.257	0.678**	0.732
	(0.684)	(0.374)	(0.478)	(0.415)	(0.295)	(0.487)
Male pop proportion, 20-24	0.244	-0.0614	0.165	0.271	0.137	-0.729**
	(0.516)	(0.262)	(0.380)	(0.366)	(0.217)	(0.350)
Male pop proportion, 25-44	-0.297	-0.593**	0.115	-0.216	0.550***	-0.451
	(0.398)	(0.245)	(0.295)	(0.285)	(0.204)	(0.318)
Male pop proportion, 45-64	-0.201	-0.256	-0.00773	-0.542	0.778***	-0.331
	(0.490)	(0.326)	(0.369)	(0.331)	(0.245)	(0.367)
Male pop proportion, 65+	-0.538	-0.566	0.443	-0.134	0.654*	-1.073*
	(0.740)	(0.452)	(0.556)	(0.473)	(0.362)	(0.561)
Female pop proportion, <15	-0.214	-0.290	0.199	0.223	0.214	-0.209
	(0.446)	(0.323)	(0.350)	(0.366)	(0.279)	(0.391)
Female pop proportion, 15-19	-0.951	0.206	-0.0524	-0.324	0.357	0.0142
	(0.675)	(0.483)	(0.476)	(0.497)	(0.350)	(0.520)
Female pop proportion, 20-24	-0.818	-0.461	-0.347	-0.220	0.741***	0.00802
	(0.497)	(0.300)	(0.368)	(0.357)	(0.250)	(0.358)
Female pop proportion, 25-44	-0.297	0.0722	-0.225	0.0657	0.103	0.190

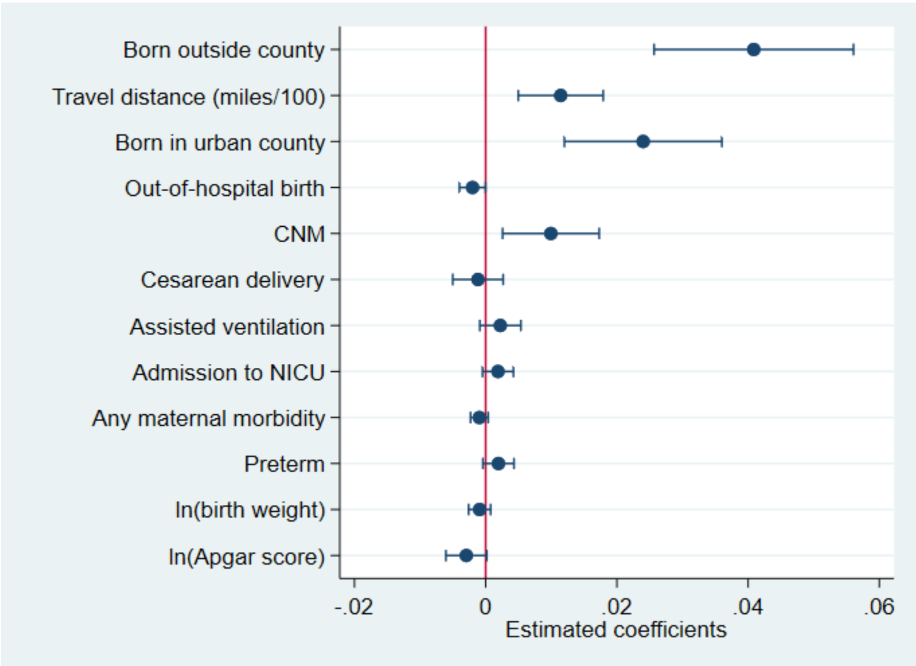
	(0.361)	(0.271)	(0.317)	(0.284)	(0.203)	(0.322)
Female pop proportion, 45-64	-0.634	-0.302	-0.152	0.525	0.0269	-0.484
	(0.419)	(0.303)	(0.409)	(0.344)	(0.245)	(0.337)
Smoking in the first trimester	0.00374***	0.00666***	-0.00791***	0.00770***	-0.0503***	0.000328
	(0.000859)	(0.000961)	(0.000813)	(0.00124)	(0.00104)	(0.000717)
Marital status	-0.00418***	-0.00648***	0.00631***	-0.0174***	0.0143***	0.00386***
	(0.000726)	(0.000748)	(0.000867)	(0.000964)	(0.000715)	(0.000604)
Observations	662,759	662,759	292,910	662,759	662,759	662,759
R-squared	0.021	0.026	0.011	0.022	0.046	0.027

Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; The model also includes county and year fixed effects, which are not shown in table.

Section D: Results for higher-born children

Figure D1 depicts that the results of Equation (1) from second or higher-born children are qualitatively consistent with those from first-born children. We prefer to use the sample of first-born children because our sample women may adjust their behaviors after they give birth to the first-born child.

Figure D1. Replicating Main Results with Second or Higher-born Children



Notes: This figure presents the parameter **α** of Equation (1), which is reproduced as follows:

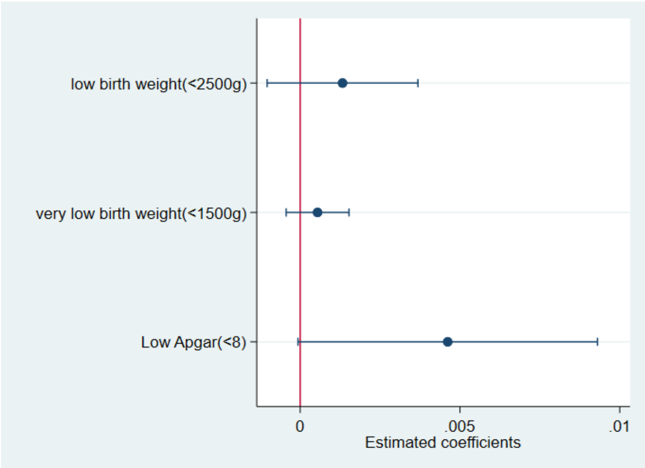
$$Outcome_{ict} = \boldsymbol{\alpha} \cdot 1_{\{0 \leq \Delta t(c)\}} \times OB\ Closure_c + X_{it}\beta + \gamma_c + \gamma_t + \varepsilon_{ict} \quad (1)$$

Equation (1) is estimated with PSM-DID model. The y-axis presents the outcome variables for women i residing in county c in year t. The variable $OB\ Closure_c$ is an indicator for counties experiencing complete obstetric unit closure during our sample period. The control variables are listed in Panel C and D of Table B1 above. County fixed effects and year fixed effects are included. Standard errors clustered at county-level in parentheses. The bars cover the 90% confidence level of estimates. N = 1,449,988.

Section E: Results for low birthweight, very low birthweight, and low Apgar

Figure E1 depicts that the results of Equation (1) for three additional outcomes, dichotomous indicators of low birthweight, very low birthweight, and low Apgar.

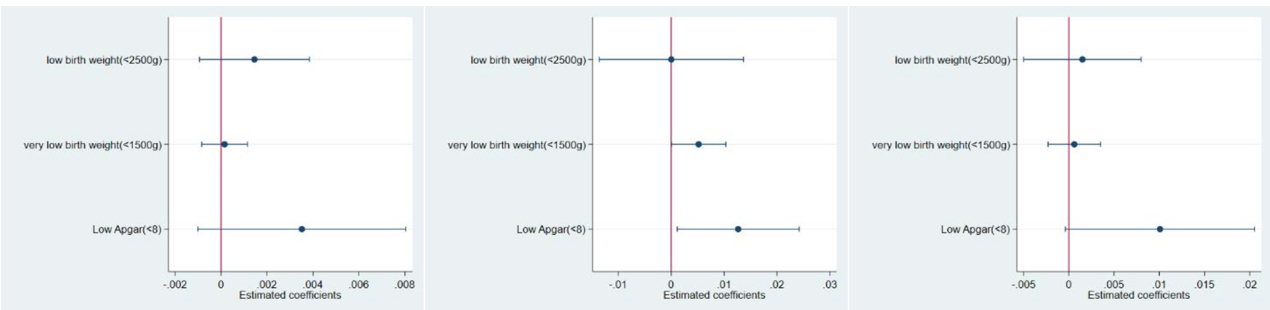
Figure E1. Main Results – Additional outcomes



Notes: This figure presents the parameter **α** of Equation (1), which is reproduced as follows:

$$Outcome_{ict} = \alpha \cdot 1_{\{0 \leq \Delta t(c)\}} \times OB\ Closure_c + X_{it}\beta + \gamma_c + \gamma_t + \varepsilon_{ict} \quad (1)$$

Equation (1) is estimated with PSM-DID model. The y-axis presents the outcome variables for women *i* residing in county *c* in year *t*. The variable *OB Closure*$_c$ is an indicator for counties experiencing complete obstetric unit closure during our sample period. The control variables are listed in Panel C and D of Table B1 above. County fixed effects and year fixed effects are included. Standard errors clustered at county-level in parentheses. The bars cover the 90% confidence level of estimates.

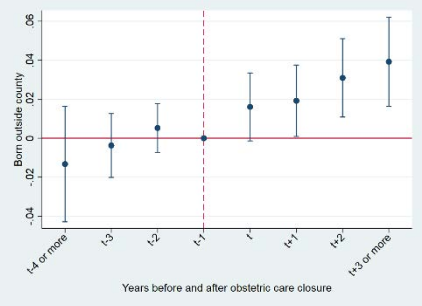


(a) White mothers (b) Black mothers

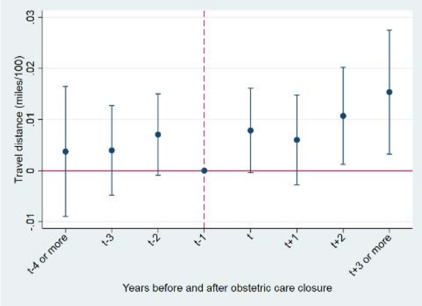
(c) Hispanic mothers

Section F: Event Study for the sample 2009-14

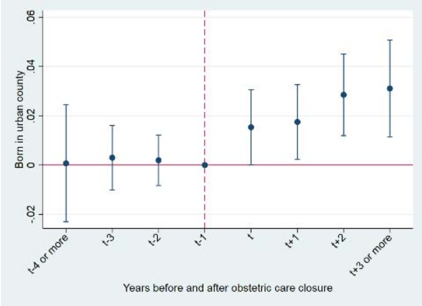
Born outside county



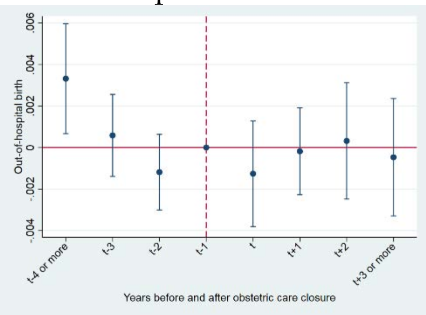
Travel distance in 100 miles



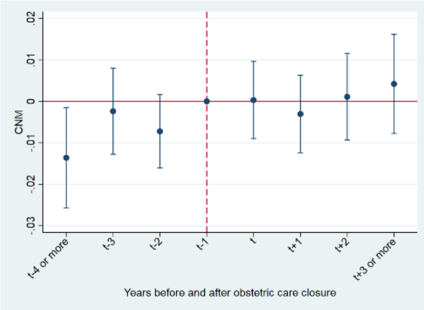
Born in urban county



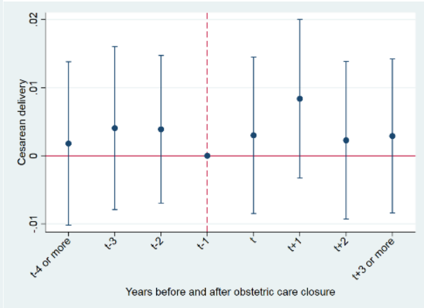
Out-of-hospital birth



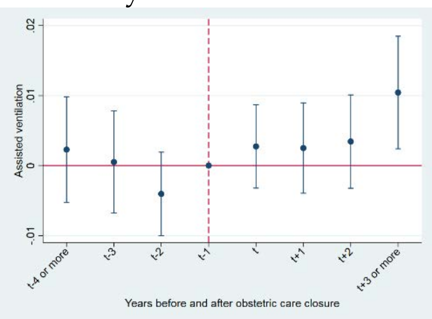
CNM



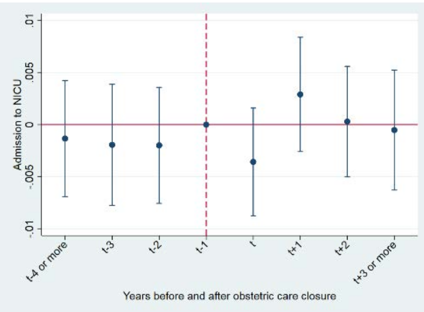
C-Section



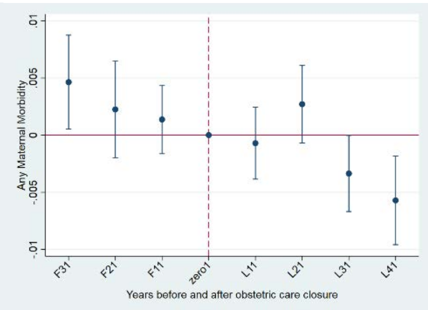
Assisted ventilation



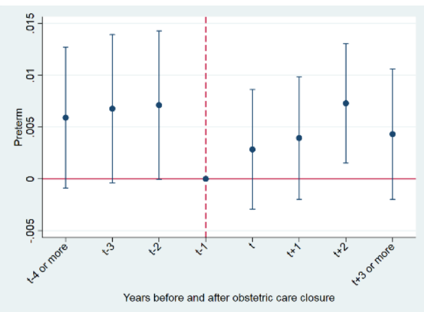
Admission to NICU



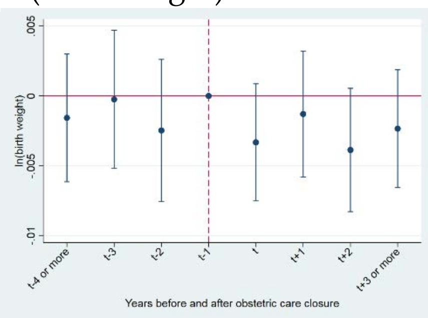
Any maternal morbidity



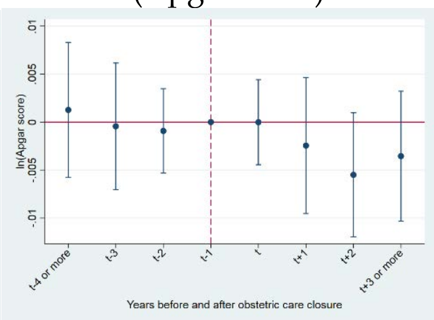
Pre-term birth



ln(birth weight)



ln(Apgar score)



Notes: This figure presents the parameter a_r of Equation (2), which is reproduced as follows:

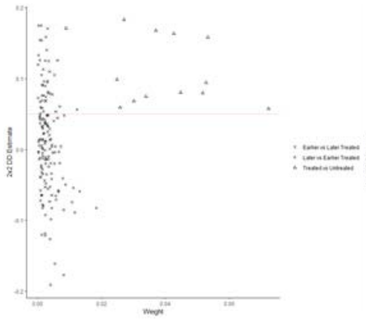
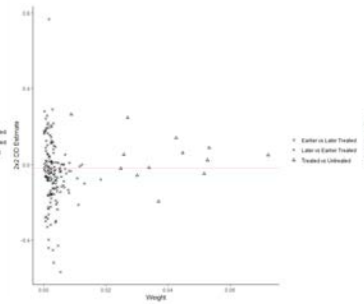
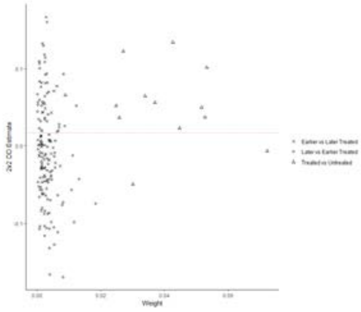
$$Outcome_{ict} = (\Sigma_{r=\ldots,-2}\, a_r \cdot 1_{\{\Delta t(c)=r\}} + \Sigma_{r=0,\ldots}\, a_r \cdot 1_{\{\Delta t(c)=r\}}) \times OB\ Closure_c + X_{it}\beta + \gamma_c + \gamma_t + \varepsilon_{ict}$$

The set of a_r includes the coefficients of the interactions between the event time indicators and *OB Closure*$_c$, that is, $1_{\{\Delta t(c)=r\}} \times$ *OB Closure*$_c$. The control variables are listed in Panel C and D of Table B1 above. Standard errors clustered at county-level in parentheses. The bars cover the 90% confidence level of estimates.

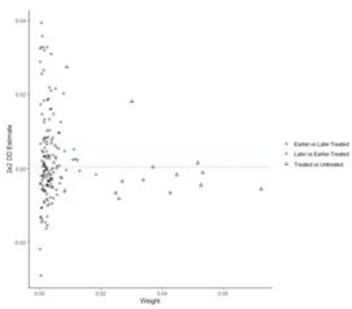
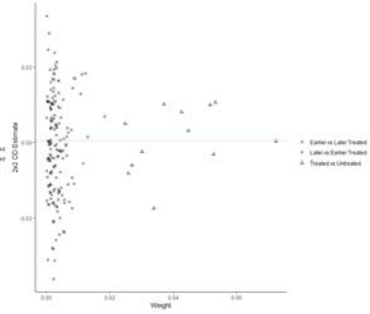
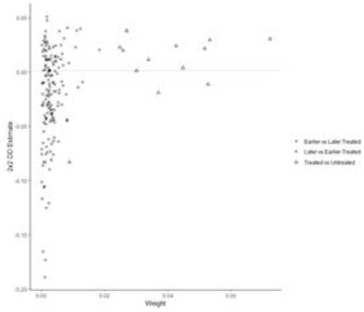
Section G: Goodman-Bacon approach, pairwise DiD estimates

Table G1: 2 x 2 DiD Estimates

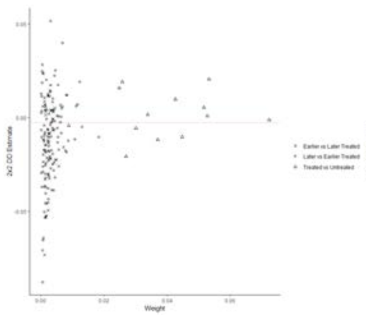
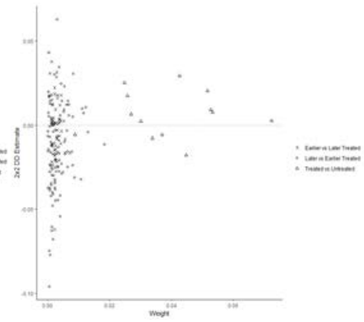
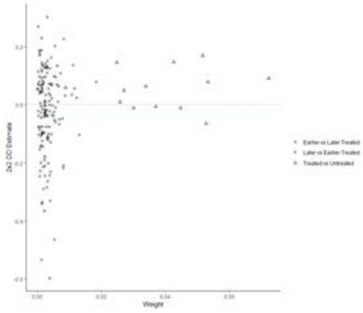
Born outside county | Travel distance in 100 miles | Born in urban county

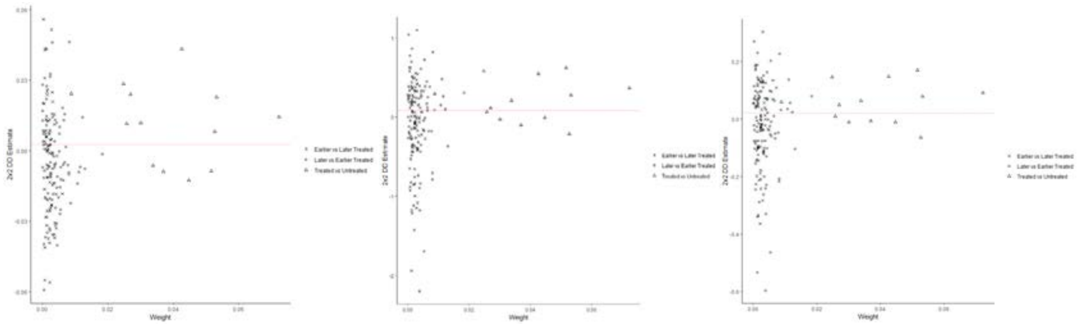
Out-of-hospital birth | CNM | C-Section

Assisted ventilation | Admission to NICU | Any maternal morbidity

Pre-term birth | ln(birth weight) | ln(Apgar score)



Notes: This plots each 2×2 DiD estimate against their weights calculated following the Goodman-Bacon (2018)'s decomposition for all outcome variables. The triangle refers to estimates where one timing group acts as treatment group and the never treated country as control group. The cross refers to timing-only estimates in which the early treated group acts as treatment group and the later treated group as control group. The circle refers to timing-only estimates in which the later treated group acts as treatment group and the earlier treated group as control group. The red horizontal line refers to the weighted average DiD coefficient resulting from the Goodman-Bacon's decomposition.

Section H: Alternative Matching Criteria

Figure H1: Replicating Main Results with PSM using County Characteristics in Year t-2

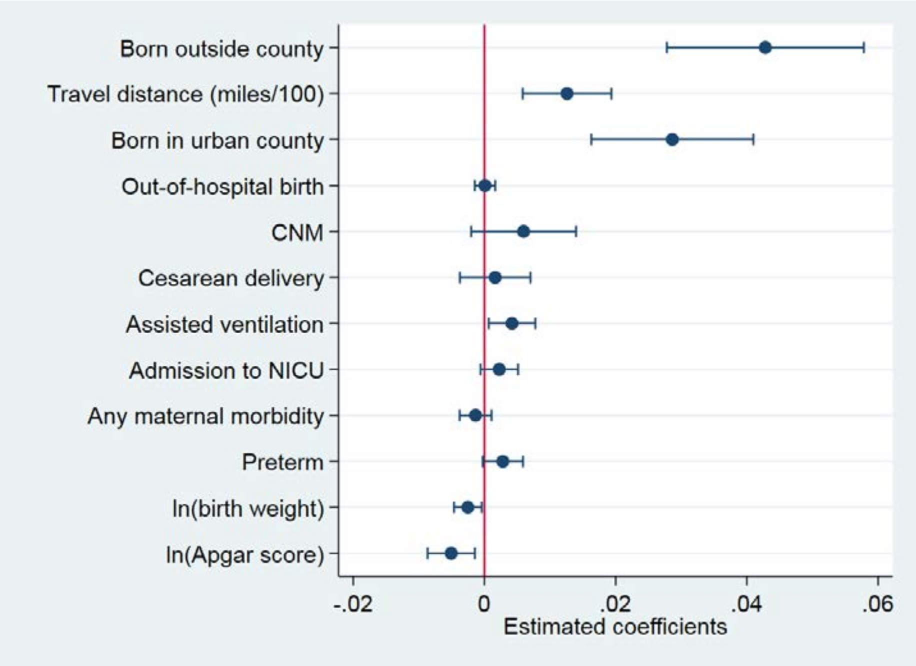
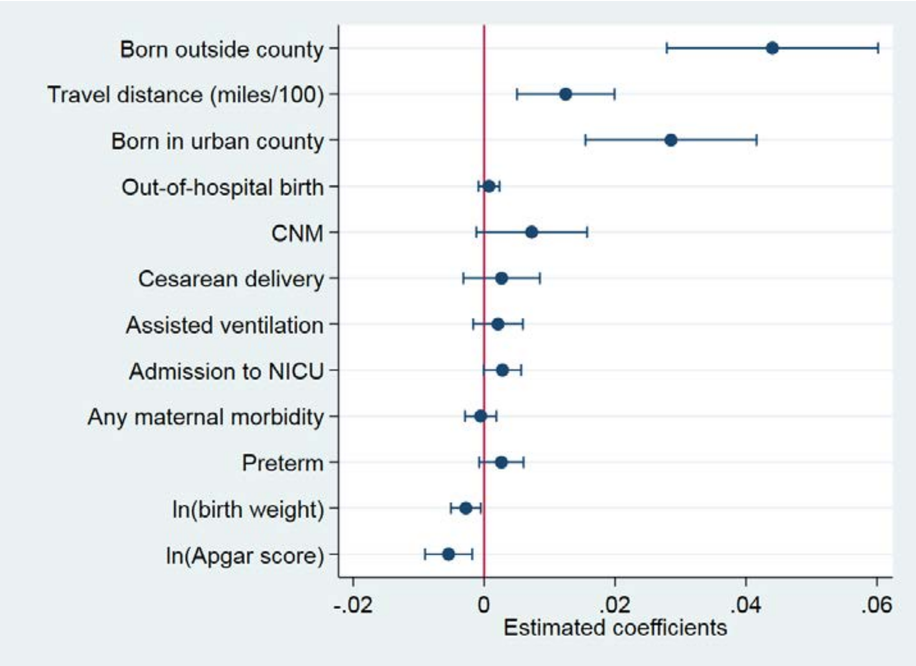


Figure H2: Replicating Main Results without Neighboring Counties



Section I: Geographic distribution of sample women and obstetric unit density

The geographical distribution of while, Black and Hispanic women in our sample is tabulated in Table G1. The geographical distribution of health care resources related to maternal and infant health is tabulated in Table G2.

Table I1: Geographic distribution of sample

	White	Black	Hispanic
Northeast	8.63%	0.82%	1.11%
Midwest	39.52%	10.30%	20.94%
South	38.19%	87.20%	44.34%
West	13.66%	1.68%	33.61%

Table I2: Geographic distribution of healthcare resources

	OB/GYN density	Hospital w/ OB unit	RUCC
Individual level (based on our sample)			
Northeast	6.882	1.218	4.929
Midwest	5.100	0.966	5.363
South	6.882	0.824	5.402
West	5.994	0.994	5.378

Note: OB/GYN density is OB/GYN per 100,000 population; Hospital w/ OB unit is count of this kind of hospital. All these numbers are mean value.